A STUDY ON THE MOBILITY OF RESEARCH AND DEVELOPMENT WORKERS

Project Report

Human Sciences Research Council
in partnership with the CSIR

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CSIR

Foreword

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Chapter 1 - Introduction

A metaphor from nature:
The flamingoes migrate only to return when the brackish waters are replenished

This introductory chapter briefly introduces the general framework within which the study occurred, the project terms of reference and objectives and the approach and layout of the report.

1.1 Problem statement

There has been much dramatisation of the "brain drain" from South Africa and the situation is often described as critical without any analysis of the international trends in this regard and the more subtle issues underlying the phenomena of "brain drain" and "brain gain". There has also been little regard for international trends in the flows of R&D workers and the benefits that can be drawn from the flows of skills between economies, that many countries, both developed and developing, are taking advantage of. There is appears to be some confusion over whether South Africa is in brain drain crisis or just affected by natural market flows with appropriate remedies required. The study aims to uncover these and other issues.

A worldwide problem is the difficulty of distinguishing the S&T workforce from the national workforce and the R&D workforce within the S&T workforce. Countries that manage to overcome these difficulties have had to develop and conduct specific surveys based on the OECD Canberra Manual approach. Given the paucity of relevant data on science and technology (S&T) and R&D human resources in South Africa it is difficult to obtain a clear picture of mobility of R&D workers. The study essentially draws on, and makes the best use of, available data on the S&T and R&D workforce and the mobility of R&D workers both within the South African S&T system and internationally.

There are concerns that, before and since 1994, South Africa has experienced a loss of key human resources from the country through emigration. The science and technology system has been undergoing ongoing restructuring and there are increasing pressures on research institutions to generate their own incomes as they seek to address broader and more equitable mandates. An apparent outcome of these and other pressures is that the more internationally mobile researchers have left institutions to seek more stimulating research environments elsewhere in the world. Other researchers have apparently been lured from research into management and other non-R&D environments where pay and other conditions of employment are more attractive. At the same time there are other concerns that South Africa's immigration policy has become very restrictive since 1994 and that this is exacerbating the skills shortage in the country. South Africa has a problem with the influx of illegal immigrants flowing into the country through neighbouring states and has difficulty in controlling and dealing with this. The flow of these illegal immigrants increases at times of economic and social crises in other countries as people seek possible opportunities in South Africa. The Immigration Act has to deal with both these potential immigrants and skilled workers from other developing and developed countries and achieving a balance in regulations has led to complex procedures being put into place.

The stark imbalances in gender and racial representivity in science and technology and research urgently need to be addressed but flow through from the higher education system which are dependent on the feed through from the schooling system are taking time to change. This is particularly true in the fields of science and technology. Hence the profile of the highly skilled workforce is only changing slowly over time. Worldwide, the choice of careers has grown as economies become more complex and global and the attraction of a career in research does not appear to be as strong as it used to be. Many other careers are far more lucrative and attractive.

Mobility studies are concerned with the relationships between all the forces in an economy that tend to attract or repel people and influence their career choices. In studying the mobility of R&D workers we are only looking at a very small sector of the population and one on which there is a scarcity of reliable historical data that avails itself to the study of flows into and out the system. There is more available data on the national human resources in science and technology (HRST) which is defined broadly as consisting of people with a minimum of a first diploma or degree. However, the type of data available on HRST is quite varied and conclusions are difficult to draw. The approach of this project was to therefore use as much available data and information as possible and also to draw on literature, international data, policy information and to conduct organisational interviews and personal case studies to elicit new and useful information from which to draw some better insight into the factors driving migration in the S&T and R&D workforce. Any conclusions drawn in this area need to be tempered with the realization that globalisation is an overwhelming factor and one over which developing countries have little control. If South Africa positions its science and technology and immigration systems unfavourably regarding the rest of the world it will lose ground to other countries which position themselves more favourably.

Over the last forty years the industrialized countries have seen dramatic shifts in the composition of their economies as the mines and smokestack industries have given way to service industries. By 1995, 48 percent of the Canadian population aged 25 to 64 had a post-secondary education (a proxy for knowledge workers) compared with an OECD average of 23 percent. In most OECD countries knowledge based industries account for 40-50% of business sector value added and about 30-40% of employment. This shift in the nature of production is occurring intimately with the unfolding information and communication technology revolution. In addition, the changing nature of work and new relationships between capital and labour have given rise to what is regarded as a new 'techno-economic paradigm' (Mansell and Wehn, 1998). This post-Fordist mode of production calls forth flexibility of labour and manifests across all spheres of value addition. The flexibility of labour is often narrowly understood as capital determining how, when and where human capital is to be deployed. The broader view would include that whereby knowledge workers are frequently themselves able to decide on where, when, how and for how much to work. Knowledge capital may indeed march to a different drum. This march is what R&D worker mobility is about. One might parody the Communist Manifesto thus: 'Knowledge workers have nothing to lose but their brains. They have a world to win.

What then of South Africa? The service sector of the economy, including financial services, was the most dynamic through the 1990s and now accounts for the majority

of the formally employed. It might be argued therefore that the country is moving toward that vague concept of the 'knowledge economy.' Maybe. Unlike many other developing countries, South Africa, with its first world-third world dichotomy joined the computer age alongside the OECD states, has a functioning national system of innovation, and displays many attributes associated with the advanced economies. Its challenge lies precisely in addressing the dichotomy lest it becomes submerged by its burden of history. Financial services, private medical care, insurance, minerals management, arms production, automotive components, agribusiness, to name but a few are world class industries where knowledge is managed for shareholder benefit. Extending such practices across society is the challenge for development, a challenge that critically rests upon the availability of high level skills.

1.2 Conceptual Terms of Reference

One of the most frequently mentioned vulnerabilities the National Advisory Council on Innovation (NACI) encountered during its annual site visits to SETIs in 2000 was the inadequate provision of appropriately skilled and experienced researchers and technical support staff. It took a range of forms, including:

- Significant numbers of experienced and productive professionals resigning, being retrenched, etc.
- The cost of capacity development of novice researchers
- The often low quality of research training offered by higher education institutions
- The revolving door phenomenon among middle and top black management staff It became clear that the inadequate provision and suspect sustainability of a senior R&D work force were already impacting negatively and was threatening to upset the achievements of the S&T system.

Subsequently NACI commissioned the HSRC to undertake a project that was to focus on the various dimensions of the mobility of the research and development (R&D) workers in South Africa in the domain of science and technology. In this investigation, R&D workers will refer to "researchers, technicians, and equivalent staff, and other supporting staff" (Canberra Manual, 1995:28) The construct mobility will be used to refer to "a flow not only between sectors, regions, and countries but also between occupations" (Canberra Manual, 1995:14) while the contract "brain drain [shall refer to the migration of highly qualified personnel" (Ibid). It was recognized that our knowledge of the extent, nature, dynamics, functions and the dysfunctions of the mobility of R&D are still very elementary and the projects terms of reference were to provide a better understanding of the dynamics surrounding mobility and to:

- assess the extent, nature, dynamics, functions, dysfunctions, etc. of R&D worker mobility.
- assess the implications of the mobility on the productivity of the NSI and programmes of research capacity development
- develop appropriate strategies

1.3 Objectives

The project was committed to producing a report covering selected aspects of the mobility of R&D workers in South Africa.

The main objectives of the project, as outlined in the terms of reference, were to:

- Quantify as reliably as possible the scale and nature of R&D personnel turnover and flows at a cross-section of HEIs, SEPIs and industry players
- Identify the causes (employers and employees) behind these flows
- Provide estimates of the R&D worker shortages in the key areas of technology expansion
- Assess the extent to which the R&D flows are productive or dysfunctional
- Provide seminal illustrative case studies over a five-year period of such mobility
- Conduct a workshop for the assessment of the findings and the drafting of an integrated report
- Formulate a range of appropriate policy options including appropriate implementation strategies
- Provide guidelines for measuring the impact of such strategic interventions
- Demarcate areas for further research

1.4 Components of the report

The report consists of six chapters, including this introductory chapter. Chapter 2 provides a framework for understanding the mobility of R&D workers through an overview of the theoretical issues involved in a study of mobility and provides an overview of South African policies and legislation concerning mobility. It concludes with an introduction to the various methodologies used in the project.

Chapter 3 uses various data sources and surveys to quantify the mobility of South Africa's research and development workers and human resources in science and technology. It attempts to map the flows in the system and integrate international movements of the highly skilled workforce.

Chapter 4 address mobility from the experiences of organisations. It deals with organisational issues and summarises issues arising from interviews with key people involved in priority fields of technology

Chapter 5 deals with mobility from the experiences of individuals and describes the subtler and more personal issues involved in mobility as gleaned from a series of interviews with individuals, discussing their experiences.

Chapter 6 concludes the report and provides a discussion on policy implications and lists recommendations arising from the project, arranging them in terms of short, medium and long-term frameworks.

An Appendix is provided which contains more detailed information on various aspects of the project.

Chapter 2 - A Framework for Understanding Mobility of Research and Development Workers

2.1 Introduction

A contextual and methodological overview of the project is presented in this chapter. After a brief overview of some primary issues surrounding mobility of South Africa's research and development (R&D) workers, three section review specific aspects of the project. The first provides a brief theoretical review and places the South African experience in a global context. The second is a critical review of relevant policies in South Africa. Finally, the third presents details on the methodologies used in the empirical components of the project.

Mobility of South Africa's R&D workers is not just about people crossing borders, but includes internal mobility. Looking at this project from a slightly different perspective, one can say that we are analysing the role mobility plays in the national system of innovation. In the modern global economy there is increased recognition that innovation does not follow a linear path from a lab to the market place. Both innovation by firms and advances in science depend more and more on interactions between business, national research organisations, and higher education institutions A basic way in which these interactions occur is through the mobility of individuals.

Investment in human capital is as important as investment in capital goods. In South Africa, skills are a strong resource constraint and are crucial determinants of innovation, productivity, and economic growth. Mobility of human capital is an important path for technology transfers between sectors, firms and internationally. Historically, many of South Africa's economic booms were accompanied by inflows of foreigners to develop and transfer foreign technologies.

In a recent article, Jeffrey Sachs identified the gap between science and technology in the North and South as being fundamental to the growing divide between the worlds rich and poor (2002). A dimension to bridging that gap and facilitating economic development is through the mobility of individuals. While innovation and knowledge transfers occur between individuals with diverse formal and informal qualifications, our project is concentrated upon formal R&D workers[1]. The importance of R&D worker mobility in other regions is reflected in a quote from a recent European Union seminar on the subject:

"It is essential, indeed, for Europe to be able to retain its own researchers and become an attractive pole for research talent from other parts of the world. It is necessary therefore to offer them good conditions that make it interesting for third-country researchers to come to Europe, starting from the conditions of entry" (Liberalli, 2002).

2.2 Theoretical

[1] Particularly considering South Africa's developing economy this limits the coverage of mobility in the national system of innovation since alot of innovation occurs in the informal adaption of foreign technologies. Nonetheless, this focus on the formal R&D worker provides a crucial initial benchmark to examine mobility.

This section describes the broad theoretical orientation of the project, which was developed through a review of local and international literature on mobility. A more comprehensive review of this literature and some prominent empirical research on the topic can by found in the literature survey, Appendix A2.1. Relationships between South African and international literature on mobility were investigated throughout the review. From this process three overarching themes emerged, these are labelled: globalisation, political and economic integration, and problemtisation of mobility.

Globalisation is a ubiquitous theme in the modern mobility literature. With free trade in goods, then services, free trade in human resources would appear the next logical step[2]. However, movement of people involves far more socio-economic interaction and disruption than goods or services. Following relatively closed economic policies between the World Wars; international markets became increasingly global after the Second World War. Today, therefore, most nations have fifty years of global transformation behind them. During the forty years after the Second World War up to the early 1990s, isolation severely limited South African participation in the global economy. Thus, South Africa in just ten years has faced a highly accelerated globalisation reality, while simultaneously trying to correct its legacy of domestic inequity. This has meant that South African R&D capacity has needed to be re-aligned within a global production structure and international competitiveness. The mobility of South African R&D workforce has obviously been influenced by this transformation and it will continue to be a major influence over the future employment structure of South Africa's R&D system.

Another pervasive theme around mobility has been political and economic integration. From Asia to Europe and the Americas, there have been a wide variety of political and economic integration initiatives. This diversity of nations is crucial to informing the South African experience where the New Partnership for Africa's Development (NEPAD) is providing a platform to advance African political and economic integration under the African Union (AU). South Africa's relatively advanced economic development gives it a unique position on the continent to advance the continent's and its own R&D capacity through co-ordinated management of highly skilled Africans across the AU. To these ends, the experience of the European Union with its heterogeneous nations and mobility of citizenry can be highly informative.

Mobility of South Africa's R&D workers plays several roles in the context of increased political and economic integration. First, mobility of researchers allows them to develop their individual potential as a researcher. This occurs through a variety of mechanisms, but its provision of a global reference and networking of similarly interested researchers is crucial. With increased integration it also can develop research scale that is crucial to attract others and building a virtuous circle of research development. Finally, integration and mobility of R&D workers can foster understanding of key regional problems and establish research networks that facilitate a more African focused research agenda.

[2] There appear to be some fundamental limitations to globalization, or at least trade-offs that must be decided when advancing globalization of one type over another. See Rodrik (2002).

Finally, in both the South African and international literature one is challenged by the complexity of mobility, which is made even more so in a study such as this inter-related to our understanding of the national (and international) system of innovation Data and analyses that presumably are investigating the same phenomenon can become incomparable because of nuances in definition. The literature therefore highlights the importance of clearly defining one's object of analysis. It is an area of research in which no one model clearly captures all of the major dimensions. Asking the right questions depends on the context and focus of analysis. This project has therefore tried to be as explicit as possible in defining what it is analysing and in placing its analysis within the local and international literature on mobility.

2.3 Policy

The main South African policy documents, legislation and government interventions with regard to skilled human resource development (HRD) and mobility are examined in terms of their original intended outcomes as envisaged by policy makers. Where possible, these documents and interventions are also briefly assessed in terms of their current perceived status and impacts, limitations and benefits regarding the stocks (development of high level human resources), movements (flows within the national S&T and R&D workforces) and international flows and forces (immigration and emigration).

It should be noted that since South Africa became a democracy in 1994, cabinet, ministries, parliament, government departments and stakeholders have been highly active in formulating and contributing to new and amended legislation and policy documents. For example, in 1998 and 1999, a total of 196 Acts were passed by parliament. More than 63 draft Bills and 226 Bills were also introduced in these years, as were six green papers and 21 white papers. Between 2000 and 2002, the rate of new legislation and policy introduction slowed somewhat to 156 Acts, 215 Bills, 90 draft Bills, two green papers and nine white papers. With this current rate of production of legislation and policy documents (the 1994–1997 years were even busier), the environment for implementing policy has been a complicated one, and much of the legislation and policy still has to be put into place in the spirit with which it was formulated. The integration of the numerous policies and policy instruments into coherent national strategies for equity, development and growth in a complex national and international environment presents government with difficult challenges.

The Development of High Level Human Resources (Stocks)

In view of the country's past racial divisiveness, policy makers are well aware that the equitable development of a skilled workforce at all levels is one of the most pressing problems facing South Africa. Policies and interventions have been developed to tackle these problems on three main fronts: the transformation of the public schooling system, the upgrading of worker skills and the restructuring of the higher education system.

The school system

The transformation of the public schooling system has the aim of providing a more equitable education system with access for all and the provision of appropriate

education and improved skills for learners and school leavers. Critical problems persist in the schooling system with a lack of adequately trained and motivated teachers, poor infrastructure in many areas and the impoverished communities and backgrounds from which the majority of pupils come. The issue of access to schooling has been addressed through the South African Schools Act (RSA, 1996), while problems relating to infrastructure are tackled through the Register of School Needs and differentiated school appropriations. The slow process of curriculum reform is under way with O.B.E. compliant Curriculum Statements published both for the Compulsory Phase (grades 1 to 9) and the Further Education and Training Phase (grades 10 to 12). In the Compulsory Phase Mathematics, Science and Technology are part of the mandatory curriculum. While in the FET Phase all learners are required to take either Mathematical Literacy or Mathematics itself.

The system appears to be improving and government and numerous stakeholders have been involved in various interventions at national and provincial level, such as the national learner performance improvement strategy, to address these problems. There have been significant improvements in the Senior Certificate pass rates from 2000 to 2001, and again from 2001 to 2002 (a 68.9% overall pass rate was achieved in 2002). The two gateway subjects of Mathematics and Physical Science continue as bottlenecks for future higher education careers. Indeed the number of African students attaining higher grade remains around 3000 for Mathematics and 5000 for Physical Science (Kahn, 2001). The National Strategy for Science, Mathematics and Technology Education (DoE, 2001a) seeks to address these shortcomings through targeting resources both at teacher education and at 102 so-called 'focus schools.' There are now signs that the Strategy with its high-profile advocacy campaign is yielding dividends. At standard grade where enrolments are far in excess of standard grade entrants, there still appears to be insufficient opportunity for quality teaching and hence a limitation on higher education choices and opportunities available to the majority of school leavers.

For example, in 2002, of the 440 000 learners who wrote the matriculation examination only 35 000 (8.0%) wrote mathematics on the higher grade and only 20 000 (4.5% of candidates) passed higher grade mathematics. While policies will be needed to address this serious supply problem, much action and commitment on the ground at community level will be key to improving the quality of primary and secondary education. Government, higher education institutions, business and other stakeholders are keenly aware that unless this critical bottleneck is addressed the medium- and long-term future and sustainability of the South African workforce, in comparison to other emerging economies, is in jeopardy.

The broader initiative of technology-enhanced learning is being addressed through the ICT in Education Strategy (DoE, 2001b), which seeks to provide a framework that will coordinate provincial department efforts to deploy ICTs in the schools.

Upgrading worker skills

The National Qualifications Framework (NQF) is a plan for education and training. This consists of strategies to develop an accessible, integrated approach towards education and training, relevant to South Africa at this time. The guidelines say how

the different education and training standards and/or qualifications must be set and how courses will be accredited. The aim is for everyone to be able to learn throughout their lives, and accumulate qualification credits as they learn and work, including getting credits for work experience.

Workforce skills development previously relied on the apprenticeship model, which gradually collapsed in the 1980s, and which in any case had tended to concentrate on white workers. In order to address the training vacuum, and to meet trade union demands for competency-based training, a new approach was needed. The Skills Development Act (No. 97 of 1998) provides an institutional framework to devise and implement national, sector and workplace strategies to develop and improve the skills of the South African workforce and to integrate these strategies within the National Qualifications Framework as contemplated in the South African Qualifications Authority Act of 1995. The aim of the Skills Development Act is to provide for learnerships that lead to recognized occupational qualifications and to provide for the financing of skills development by means of a levy-grant scheme and a National Skills Fund (NSF). The NQF is of course much wider than the training dimension and includes both schooling and higher education as well.

Along with the Skills Development Levies Act (No. 9 of 1999), the objectives of these Acts are to raise employers' investments in workforce education and training, promote education and training in the workplace and introduce occupation-based learning for students and the unemployed.

The Acts came into effect on 1 April 2000, and qualifying employers are currently required to pay a levy, and to budget for the education and training of their staff, at the level of 1% of their total remuneration.

A National Skills Authority (NSA) was established in order to advise the Minister on

- A national skills development policy
- A national skills development strategy
- Guidelines on implementation of the strategy
- Allocation of funds
- Regulations

The Skills Development Act defines the following structures to implement the NQF:

- South African Qualifications Authority (SAQA)

This is the body responsible for overseeing the development and implementation of the NQF. SAQA members are drawn from stakeholders, and it is accountable to the Departments of Labor and of Education. SAQA establishes National Standards Bodies, Standards Generating Bodies and Education and Training Quality Assurers.

- National Standards Bodies (NSB)

These bodies set standards about what needs to be learnt in one particular field of learning. SAQA has established 12 fields of learning, such as agriculture, communication and manufacturing. Each NSB organises its field of learning into sub-

fields, approves standards and qualifications generated by Standards Generating Bodies, and sends them to SAQA to be registered.

- Standards Generating Bodies (SGBs)

An SGB develops standards and qualifications in a particular sub-field of learning The standards are written in the form of unit standards, which describe what learners should be able to do at the end of this 'chunk' of learning and say how many credits will be awarded for attaining that unit standard.

- Education and Training Quality Assurers

Besides developing learning standards and qualifications, SAQA is also responsible for ensuring that the quality of education and training provided is good enough, and that learners are properly assessed to an agreed standard. This is done via Education and Training Quality Assurers bodies. Anyone wanting to provide education and training will have to be approved by an Education and Training Quality Assurer. Education and Training Quality Assurers will issue qualification certificates to learners.

- Sector Education and Training Authorities (SETAs)

Each separate economic sector has one SETA. There are 27 SETAs which cover all work sectors in South Africa, including government sectors. The members of SETAs include trade unions, government and Bargaining Councils from appropriate industries. The South African Revenue Service has details of the SETAs established. Any employer must choose which SETA their business falls under.

SETAs replace and extend the work of the old industry training boards. Within its own sector, SETA must develop and implement a skills development plan including workplace skills development plans, act as the Education and Training Quality Assurer, and pay out Skills Development Grants.

About 80% of the funds raised by the Skills Development Levy are allocated to the SETAs which use the funds for training and education activities within their sector and according to plans. The remaining 20%, as well as funds from any sector that may not have a representative SETA, are paid to the National Skills Fund (NSF). The SETAs are more focused on developing the skills and abilities of low and medium skilled workers and are not specifically directed at developing high level skills needed for research. While there are concerns that the SETA system has created a whole sector of employment in itself along with adherent bureaucratic problems, the longer-term view is that the emphasis on skilling of the workforce will provide an upward movement of skills that will enhance the base of the S&T and R&D workforce.

The restructuring of the higher education sector

One of the more controversial areas of transformation in South Africa is the restructuring of the public higher education system. The 21 universities and 15 technikons are the most important institutions in the system maintaining and replenishing the science and technology and R&D workforce. The *Education White*

Paper 3, A Programme for the Transformation of Higher Education (1997) was generally welcomed by the research community, particularly because of its emphasis on the importance of research. It outlined a comprehensive set of initiatives for the transformation of higher education, through the development of a single coordinated system with new planning, governing and funding arrangements.

The Education White Paper 3 underlined the importance of the higher education sector in supporting the development needs of society by providing the labour market, in a knowledge-driven and knowledge-dependent society, with the ever-changing high-level competencies and expertise necessary for the growth and prosperity of a modern economy as well as the creation, sharing and evaluation of knowledge. It also noted the gross discrepancies in the participation rates of women and students from different population groups and, importantly, the chronic mismatch between the output of higher education and the needs of a modernising economy. In this respect it noted that national growth and competitiveness are dependent on continuous technological improvement and innovation, driven by a well-organised, vibrant research and development system that integrates the research and training capacity of higher education with the needs of industry and of social reconstruction. (Clause 1.12).

One of the goals of higher education stipulated in the White Paper reads:

At the national or system level, to secure and advance high-level research capacity which can ensure both the continuation of self-initiated, open-ended intellectual inquiry, and the sustained application of research activities to technological improvement and social development. (Clause 1.27)

The White Paper expresses some concern about the current capacity, distribution and outcomes of research in the higher education system. In particular:

- There is insufficient articulation between the different elements of the research system, and between the research system and national needs for social, economic, cultural and intellectual reconstruction
- There are stark race and gender imbalances in the demographic composition of researchers in higher education, research councils, and private sector research establishments (2.83)

The research system in South Africa faces two main challenges: to redress past inequalities and strengthen and diversify research capacity, and to keep abreast with the emerging global trends, especially the development of participatory and applications-driven research addressing critical national needs, which requires collaboration between knowledge producers, knowledge interpreters and knowledge managers and implementers. (Clause 2.86)

The White paper also recommends that:

In view of the national strategic importance of research, and in order to ensure that the relatively scarce funds available for the development of research capability are well targeted, public funds for participation in research, whether basic or applied, should not be spread across all faculties or schools in all institutions but should rather be concentrated in those areas where there is demonstrable research capacity or

potential, in both HDIs and HWIs. To give practical effect to this view, the Ministry will provide earmarked funds to:

- preserve and strengthen existing areas of research excellence
- develop new areas and centres of research excellence
- develop research links with industry and to facilitate industry-related collaborative research
- facilitate inter-institutional research collaboration
- facilitate collaborative research and technology development with Science, Engineering and Technology Institutions (SETIs), as defined in the White Paper on Science and Technology

The White Paper stresses other key aims concerning the higher education sector, in particular to:

- correct the discrepancies of the past
- develop new policies and mechanisms for funding higher education institutions
- develop a national research plan

In February 2001 the National Plan for Higher Education was published which provided the framework and mechanisms for the restructuring of the higher education system to achieve the vision and goals for the transformation of the higher education system as outlined in the Education White Paper 3. The National Plan established indicative targets for the size and shape of the higher education system, including overall growth and participation rates, institutional and programme mixes and equity and efficiency goals.

The most controversial aspect of the National Plan was the introduction of specific proposals for mergers of certain institutions. This gave rise to a lengthy and heated process which, by December 2002, had led to a plan to reduce the country's higher education institutions from the current 36 to 23 (11 universities, six technikons and six new hybrid institutions) in order to "foster the growth and rejuvenation of higher education". Arrangements for the mergers and associated activities will be announced early in 2003. About R3.1 billion has been budgeted to cover the cost of the mergers and a merger unit will be established within the Department of Education to assist the institutions with the changes which will take place through to 2005.

The outcome of these mergers and the impact on research intensity, skills development and the production of new researchers will need to be carefully assessed over the coming years. The pessimistic attitudes of a large number of academics concerning the mergers may well be self-fulfilling and hinder the process. Mergers are rarely easy processes and there are bound to be perceptions of "losers" and "winners" in the outcomes obtained. The mergers will therefore need to be carefully managed if the morale of researchers is to be maintained. The signals that the mergers send to potential young researchers will also be important. If the processes appear to create new opportunities for young researchers to enter the academic system, without the loss of key experienced researchers from the system, this will have a positive effect.

The targets set in the National Plan concerning the supply side for the S&T and R&D workforce have important implications regarding the flows of students through the sector. The National Plan proposes that the participation rates in higher education

must be shifted from 15% to 20% in the long-term (i.e. ten to fifteen years), to address both the imperative for equity, as well as changing human resource and labour needs. Institutions are also expected to establish equity targets with the emphasis on the programmes in which black and women students are under-represented (such as commerce, science, engineering and technology and postgraduate programmes in general) and to develop strategies to ensure equity of outcomes. The National Plan proposes to shift the balance in enrolments over the next five to ten years between the humanities, business and commerce and science, engineering and technology from the current ratio of 49%:26%:25% to 40%:30%:30% respectively. The National Plan notes that further changes to the proposed ratios are not possible in the short to medium-term because of the low number of students leaving the school system with the required proficiency in mathematics. The importance of maintaining a balance of humanities graduates for key professions is also emphasised.

The National Plan proposes that a target will be to increase the total number of graduates by a minimum of 10 000 per year over the next five years. This can be interpreted to mean that total graduates (including those obtaining diplomas) from universities and technikons should increase from an annual level of some 88 249 in 2000 to about 138 249 by the year 2006.

What has not yet been addressed is the broader area of student funding. While it is true that the general public is quite unaware of the full cost of a student place, students' fees even at current levels place a severe restriction on access, the National Student Financial Aid Scheme notwithstanding. The problem is even more critical for mature students with family commitments and for part-time postgraduates. If government is serious about wanting to increase the number of postgraduates and to broaden access to higher education, a more generous grant scheme is a necessity. Larger loans that carry much lower rates of interest are a possible mechanism.

The National Plan also proposes that research will be funded through a separate formula based on research outputs, including at a minimum, masters and doctoral graduates and research publications. In a subsequent Ministry of Education Discussion Document *Funding of Public Higher Education: A New Framework* it is proposed that the institutional rewards for masters and doctoral graduates be set at a level of R40 000 and R160 000 respectively (in comparison, a publication output unit would receive R30 000). The Department is aware that higher education financial incentives are open to possible manipulation by institutions and there will be a need to monitor the quality and appropriateness of masters and doctoral programmes, particularly regarding their research content.

Since 1996, the National Student Financial Aid Scheme (NSFAS) has allocated some R2.9 billion to academically able students who do not have the financial resources to pursue higher education studies. In 2000 a total of 81 609 students were funded through the NSFAS. However, the Ministry of Education has expressed reservations regarding the effectiveness of the fund which does not provide the full costs of study in order to allow the limited funds to be spread over a wider net of students. The Ministry is reviewing the suitability and likely impact of the NSDFAS particularly

regarding priority fields of study and academic programmes where black students are under-represented. The NSFAS is basically aimed at undergraduate support. The NRF provides funds for postgraduate research students, and supports about 4500 students per year (out of a total of some 31 000 masters and doctoral students at universities and technikons) but these funds only provide for fees and a small amount of additional expenses and students usually have to supplement their income. There is also very little NRF support available for part-time postgraduate students (particularly in the social sciences and humanities where part-time enrolments are common). Honours students are particularly poorly catered for in terms of South Africa's funding system. Honours students are unlikely to qualify for NSFAS support and the NRF concentrates on masters and doctoral students. Considering that about 30 000 honours students enroll at universities each year this is a serious gap in the system The honours year is the crucial stepping stone from undergraduate training to a career in research and this gap needs to be bridged. There is also little support for mature students re-entering the system.

Flows within the national S&T and R&D workforce

The National System of Innovation

The concept of a national system of innovation (NSI), was the central tenet of the *1996 White Paper on Science and Technology: Preparing for the 21st Century* The NSI was envisaged through the following descriptions in that White Paper:

"South Africa's national system of innovation consists of all individuals and organisations involved in creating and using a knowledge base in order to build a better South Africa".

"A prime objective of the NSI is to enhance the rate and quality of technology transfer and diffusion from the science, engineering and technology (SET) sector by the provision of quality human resources, effective hard technology transfer mechanisms and the creation of more effective and efficient users of technology in the business and governmental sectors."

Understanding the process of research and innovation through the NSI model has a long history traceable back to the pioneering work of Nelson, Oldham and others. The elements of a NSI have long existed in the country, being embedded in its firms, higher education institutions, science councils, government departments, infrastructure and its policy, cultural, legal and regulatory environment. What has been lacking is some kind of steering mechanism. Arguably 'totale aanslag' provided that steering mechanism in the apartheid years. The attainment of democracy clearly required a new pilot.

The National Research and Development Strategy

South Africa's National Research and Development Strategy of August 2002 (Government of South Africa, 2002) is a more directed strategy aiming at enhancing R&D and boosting the NSI.

The strategy deals with many concerns regarding the NSI and in the chapter on Human Capital and Transformation in Science, Engineering and Technology it deals with global trends in the migration of scientists.

The end of the Cold War along with globalisation and new value chain approaches has led to tremendous dispersal of R&D effort out of the previously centralized research labs (Branscomb, 1996). Multinationals of the United States, Japan and Germany for example have all established labs on foreign soil. A second phenomenon in the US has been a large increase in university-based research, which has in turn created huge skills demands.

Section 6.1 of the strategy states:

"Science today is a highly globalised activity. Even in advanced economies (e.g. Germany, Canada), policy analysts express concern that the best scientists are being drawn towards the highly dynamic United States system. To counteract this trend the affected countries are attempting a range of interventions, for example, Canada has set aside funds for the creation of two thousand university chairs in science and engineering over the next five years. Both France and Germany are in the process of radically overhauling their legislation and practices to promote science-industry linkages in line with the United States' highly successful Bayh-Dole Act. In South Africa, recent studies show attrition rates for researchers of approximately 11% per annum from universities. Of those who leave employment, some 5% of the government laboratory scientists and about 22% of the academics emigrate."

"The recent offshore listings of several large technology-intensive South African companies pose awkward questions regarding the retention of the strategic skills in our country. Already there is a tendency for these companies to source research outside South Africa. Clearly, they do this for economic reasons, but South Africa needs to develop an effective response to what, in many cases may be the loss of strategic control over companies originally built on South African knowledge capital. The end game here revolves around being relegated to a sales outlet in contradistinction to developing as centre of innovation."

The R&D Strategy is indicator based and rests on three pillars:

- Innovation
- Science, engineering and technology (SET) human resources and transformation
- Creating an effective government S&T system

The human resource development approach is aimed at radically increasing the number of women and people from previously disadvantaged communities entering the sciences as well as a strategy to maximize the pursuit of excellence. The strategy sees the human resource pillar as critically linked to the innovation pillar in that innovation creates opportunities and incentives for human resource development. The aim is to focus basic research in areas of important natural or knowledge advantage such as astronomy, human paleontology and indigenous knowledge. The key institution mentioned, in the context of this strategy, is the National Research

Foundation (NRF), which is linked to the higher education sector through the National Plan for Higher Education.

The National Research Foundation

According to the National Research Foundation Act of 1998, "The object of the Foundation is to support and promote research through funding, human resource development and the provision of the necessary research facilities in order to facilitate the creation of knowledge, innovation and development in all fields of science and technology, including indigenous knowledge, and thereby to contribute to the improvement of the quality of life of all the people of the Republic." Some of its specific objectives are to:

4.(1)(j) facilitate and promote nationally and internationally liaison between researchers and research institutions;
4.(1)(a) promote the development of appropriate human resources and research capacity in the areas of science and technology;
4.(1)(e) promote and support research by the awarding of contracts, grants, scholarships or bursaries to persons or research institutions;
4.(1)(k) promote participation in international scientific activities through maintaining membership of appropriate international science organisations;
4.(2)(a) make grants to persons or research institutions for research, research infrastructure and the development of human resources;

Clause 4.(3)(b) *advise the Minister and, if so required, the Minister of Education through the Minister, in regard to research relating to its object* presents the NRF with a golden opportunity to forge links with the Department of Education in coordinating research funding in the higher education sector in the interests of the national system of innovation. This opportunity is reciprocated in some detail in the Education White Paper 3.

The above clause has not really come into effect and the development and retention of high-level human resources and researchers has not been addressed though the amount of funding provided by the Department of Education and the NRF.

The NRF also manages the Technology and Human Resources for Industry Programme (THRIP) on behalf of the Department of Trade and Industry. This is the best example of a successful "triple-helix" programme between government, industry and higher education in South Africa. In 2001/2002 THRIP provided funding of R134 million for 296 projects, leveraging a R165 million contribution from industry. Projects involved 2390 students, 220 grantholders and 767 other researchers. THRIP is an important mechanism for introducing postgraduate students to working directly with industry and many students migrate to jobs in industry directly as a result of the contacts made through THRIP-funded projects they undertook for their degrees. It also provides firms with the opportunity to get to know and work with postgraduate students before they employ them.

The Human Resource Development Strategy for South Africa

The Human Resource Development Strategy for South Africa was launched in 2001 and is an integrative strategy, indicator-based, aimed to achieve three overarching goals:

- To achieve an improvement in the UNDP Human Development Index for South Africa, as a result of improvements to the social infrastructure
- To reduce disparities between the rich and the poor, reflected in an improved "Gini coefficient" rating
- To improve the country's position in the International Competitiveness League

To achieve these objectives there are five strategic objectives:

- To improve the foundations for human development
- To improve the supply of high quality skills, especially scarce skills, which are more responsive to social and economic needs
- To increase employer participation in lifelong learning
- To support employment growth through industrial policies, innovation, research and development
- Ensuring that the above four initiatives are linked

Some of the S&T and R&D and mobility related initiatives include:

- Improving results in mathematics and science
- Improving participation in further and higher education
- Recruitment of foreign skilled workers, where necessary, in the short term
- Increasing the amount of scientific innovation occurring in further and higher education institutions, in response to social needs, and in collaboration with industry
- Increasing R&D through targeted support by science councils
- Increasing the number of "Science-Industry partnerships"

An important aspect of the strategy is its integrative approach and recognition of the importance of innovation as a driving force for economic growth and human resource development. The success of the strategy will largely depend on the cooperation and synergy obtained by the four main government departments involved, namely Science and technology, Education, Trade and Industry and Labour. The SETAs are at the core of the strategy and their efficient functioning is critical to its progress

In line with this strategy is the Human Resources Development Strategy for the Public Service, which is aimed at skills development for transformation and service delivery in the government sector. Here the focus is on the development of critical skills in government employees with the aim of making the sector more efficient and attractive to work in. The strategy emphasises the importance of mathematics and science backgrounds, particularly for black students, and it also aims to boost the pool of appropriately qualified engineers in government by being able to compete with the private sector for these scarce individuals.

The HSRC has been tasked to monitor progress on all the identified indicators for both the National Human Resource Development Strategy and that in the public service sector and it is a significant move for government to involve a science council at this strategic national level.

Equity and redress in the workforce

Legislation aimed at redressing inequalities in South African society also has an effect on the flows of R&D workers in the national system of innovation. Previously advantaged researchers may feel threatened by this legislation. However, looking at the policies driving the NSI and human resources development programmes in the country it is clear that the intention of government is to grow the skills base in the country and not simply replace the existing base. As a result of apartheid and its attendant discriminatory laws and practices, there are disparities in employment, occupation and income in society and the labour market. Equity legislation is based on the premise that disadvantage and inequality are of such an extent and magnitude that they cannot be redressed simply by repealing discriminatory laws.

Chapter 2, Clause 9 of the Constitution of the Republic of South Africa (Act no. 108, 1996) states that "Equality includes the full and equal enjoyment of all rights and freedoms. To promote the achievement of equality, legislative and other measures designed to protect or advance persons or categories of persons disadvantaged by unfair discrimination may be taken."

One such piece of legislation is the Employment Equity Act (Act no. 55 of 1998), the major objectives of which are to:

- Promote the constitutional right of equality and the exercise of true democracy
- Eliminate unfair discrimination in employment
- Ensure the implementation of employment equity to redress the effects of discrimination
- Achieve a diverse workforce broadly representative of the South African population

Another Act passed to bring democracy and equality to a society wracked by systemic inequality is the Promotion of Equality and Prevention of Unfair Discrimination Act (Act No. 4, 2000)

This Act endeavors to facilitate the transition to a democratic society, united in its diversity, marked by human relations that are caring and compassionate, and guided by the principles of equality, fairness, equity, social progress, justice, human dignity and freedom.

The Act prohibits unfair discrimination, including the denial of access to opportunities on the grounds of race, gender and disability. It is not unfair discrimination to take measures designed to protect or advance persons or categories of person disadvantaged by unfair discrimination (including members of a group that suffers from patterns of disadvantage). The State has a duty and responsibility to promote and achieve equality – as do all persons, Clauses 24(1) and 24(2) – and must therefore, with the assistance of constitutional institutions, take measures to develop and implement programmes in order to promote equality.

Registration of scientists

The Minister of Arts, Culture, Science and Technology introduced the Natural Scientific Professions Bill to the National Assembly in 2002. It is a review of the Natural Scientific Professions Act, which was assented to in 1993 and strengthens the stipulations regarding appointment of council members, addresses matters for efficient management and reflects changes and developments in the higher education sector such as the establishment of SAQA and the NQF. The Bill has not appeared to elicit intense response from the research community despite the fact that it states that professional natural scientists, candidate natural scientists and certified natural scientists may not practice in any of the 26 scheduled fields of practice (e.g. agricultural science, geological science) without being registered. The Bill stipulates that a certified natural scientist or candidate natural scientist may only perform work in the natural scientific profession under the supervision and control of a professional natural scientist. It also indicates that only a registered person may practice in a consultant capacity. A South African Council for Natural Scientific Professions has been appointed, and presumably when the Bill becomes an Act the Council will be able to provide useful information on the extent and location of practicing natural scientists (information which is not currently readily available). There is not an equivalent statutory council for the social sciences although professionals such as psychologists have to be registered with the Health Professions Council of South Africa. Whether the new Act will have any effect on the mobility of researchers between professional fields or whether researchers with certain foreign qualifications will have difficulty in registering as natural scientists remain to be seen. Researchers in multidisciplinary or innovative niche areas might find difficulty in identifying with the scheduled fields but the Bill does allow for the Council to define new fields for registration.

International flows and forces

The Immigration Act of 2002

The overriding legislation affecting the flow of foreigners, including researchers, to their residence in, and their departure from South Africa is the Immigration Act of 2002. The Act aims to both facilitate and simplify the issuance of permanent and temporary residences to those who are entitled to them and also to discourage illegal foreigners. The Act provides for the establishment of an Advisory Board, chaired by a designee of the Minister and consisting of up to 20 people with representatives from Departments such as Education and Trade and Industry (but does not specifically include the Department of Science and Technology). The Act prescribes that visitor's permits may be issued to foreigners by the Department for a period up to three years for people engaged in academic sabbaticals and research. However the holder of a visitor's permit may not conduct work for remuneration except with a stipulated permit. The Act allows for exchange permits to be issued for official exchange programmes and foreigners under 25 years old may, under certain conditions, receive an exchange permit to work for up to a year.

The new Act appears to impose rather onerous responsibilities on the Department of Home Affairs by requiring it to consult extensively with the Departments of Labour and Trade and Industry in the creation of a set of quota and skills certification requirements and then to enforce these rules. Higher education institutions and other research bodies have expressed concern at the complicated procedures required to

enable foreign researchers to work or study in South Africa. However, the Departments of Science and Technology, Education, Trade and Industry and Labour are aware of the importance and stimulatory effect of brining international research skills to South Africa and will be expected to work on these matters in collaboration with the Ministry of Home Affairs. The aim should be to enable specific research institutions to simplify and streamline procedures for access to foreign researchers, particularly within the ambit of international research agreements.

Further regulations have been introduced such as, as from 12 March 2003, the requirement that European visitors staying longer than three months, will require visas and have to provide certified proof of funds of R20 000 per month per person Permanent residence will require proof of a net worth of R15 million accompanied by payment of R100 000 to government. This tightening up of regulations for visitors does not apply to students.

Regulation 22 (Government Gazette No. 24100 of 25 November 2002) deals with study permits. Study means "...study at a primary, secondary or tertiary educational institution or any other bona fide institution of learning including but not limited to – professional, training, cultural, technical, research, vocational, sportive, language and entertainment institutions of learning." Study permit holders are permitted to conduct work for periods not exceeding 20 hours per week (with written consent of the registrar of the institution) meaning that postgraduate students with permits can derive some income to support their studies.

Section 27 of the Immigration Act deals with permanent residence for foreigners who have been offered permanent employment. A chartered accountant must certify that the position exists and that no suitably qualified citizen or resident was able to fill it. The application also needs to fall within the yearly limits of available limits as determined for each sector of industry, trade and commerce after consultation with the Departments of Trade and Industry, Labour and Education. The regulations to the Act prescribe these limits for eight sectors. The limits appear to be ample, providing for 10 000 positions in the chemicals and biotechnology professions, 10 000 in information and communication technology professions and 15 000 in academic research positions.

Institutions are likely to encounter difficulties in initially complying with the complexity of the Immigration Act and subsequent regulations. It is likely that specialists referred to in the Act as "immigration practitioners" (who have to have required qualifications and be registered with the Department) will rapidly emerge and be engaged by institutions such as universities wishing to import special skills. Presumably these practitioners will soon establish sound working relationships with the Department and smooth the way for organizations experiencing difficulties in this regard.

Overview of legislation and interventions affecting the mobility of the S&T and R&D workforce

It is clear from the various policies in place that innovation is seen as central for economic growth and for the creation of employment opportunities. This is in line with the policies of many successful economies. While the supply of students and resources for this innovation should mostly come from the public sector it is industry

which must turn these resources into innovations for the market. It is therefore essential that industry is more involved in the implementation and direction of strategies for human resource development and research. Government cannot do this on its own and needs to involve industry more through mechanisms such as THRIP, the SETAs, advisory boards and exchange programmes. The apparent mismatch between the outputs of higher education institutions and the needs of industry and society need to be seriously addressed.

An overall coherence in the various policies and interventions affecting the growth and mobility of the S&T workforce appears to be emerging. There are no real contradictions between the policies although there would seem to be some duplication in the system that will need to be attended to through partnerships and cooperation between the various bodies responsible for implementation. At present, the main stumbling block appears to be the Immigration Act. This complex Act is being implemented by the Department of Home Affairs, which is not one of the government departments with a specific science and technology mission or focus. This will require negotiation and communication at the highest level if the importation and exchange of researcher skills is to be effectively encouraged.

There are some common themes and problems that emerge in the various strategies and interventions such as the paucity of mathematics and science training available in many schools, the importance of innovation for international competitiveness and the importance of science, technology and research for building the profile and competencies of the workforce. The two main strategies, the HRD Strategy for South Africa and The National R&D Strategy are both strongly indicator based. This is an important step, especially since South Africa has generally struggled to provide accurate and reliable information on its S&T and R&D resources and workforce. Now with indicators and survey tools in place to measure the various components of the system in order to provide the data for these indicators there will be a reasonable basis for monitoring success and problems in the coming years. This will allow for the fine-tuning of instruments and strategies as the country's needs and the international environment change over the coming decade.

2.4 Methodology

There are three primary empirical components in this project. The first is the quantification of national R&D workers. This is being conducted in conjunction with the 2002 R&D Survey and is therefore not considered in this discussion. The second is the organisational perspective and the third is the individual perspective on mobility, their methodologies are reviewed below.

Mobility from the Experiences of Organisations

In the early stages of this project the necessity of an organizational perspective on mobility was agreed upon. The advisory committee identified five fields of technology in which to focus research efforts: automotive technologies, biotechnologies, environmental technologies, information and communication technologies, and mining and metallurgical extraction technologies. Functional, dysfunctional and outstanding features of mobility were identified through the use of iterative interviews with a cross section of organizations in these fields.

South African organizations[3] active in these five fields of research were the sample population for this component. In each field of technology a profile of the supply and demand of R&D personnel was desired. Organizations training individuals in suitable qualifications for R&D in the selected research fields were included on the supply-side. These are the faculties and/or departments at universities and technikons training or advancing individuals' qualifications and thereby creating inflows to or improving the quality of HRST stock upon which R&D personnel are a subset. On the demand-side, organizations representative of the respective fields' innovative systems in South Africa were concentrated upon. These were organizations from both the private and public sectors. Finally, where possible statutory professional societies with members in the research fields were interviewed. A total of 58 interviews were conducted, a list of the organizations is contained in Appendix 4.1.

The process of selecting these organization and institutions depended upon contacting and compiling a list of representative entities from experts in the respective fields. Thus, a process of co-nomination was used to identify important players in the innovative system for these fields of technology[4]. The interviews themselves followed the iterative methodology of fourth generation evaluation[5]. Positive, negative and unresolved features of mobility were first identified and then verified over successive interviews with organizations in the five fields of technology. When a feature recurred across the fields, it was taken to be representative of general features of R&D personnel mobility in South Africa.

In order to ensure consistency across components of this research project, the five fields of technology were placed within research field (RF) classifications used in the South African Frascati compliant 2002 R&D survey. By establishing congruence between, research fields in the R&D survey and the organizations interviewed at the outset, quantitative profiles of the individual fields have been developed to complement the qualitative description of the fields.

Mobility and the Experiences of Individuals

In life history research, the researcher conducts an in-depth interview with the participant about her experiences and the subjective meaning of her life experiences. The core of life story is the historically situated experience with all its contradictions, ambiguities, ironies and uniqueness that such experiences usually implies (Plummer 1983). Life history research attempts to locate the individual experiences in the overall life experience as well as the broader socio-historical background within which we live. The stories illuminate the dynamics involved in the unfolding of a life in a particular direction at a particular time and place. During the interviews we found that because of the protracted nature of the relationship between the research and the research participant this methodology afforded the researchers the opportunity to go beyond the initial 'whinging' of participants to gain a deeper understanding of mobility. Another issue that emerged was that in telling their stories the experiences

[3] Multi-national organizations with South African R&D operation were also included.
[4] Details on the co-nomination process can be found in Nedeva et al. (1996) and Georghiou et al (1988).
[5] See Guba and Lincoln (1989) for an elaboration of this methodology

of individuals, especially in the private sector, are closely linked to the history of the organisations.

One of the concerns of life history work is whether the stories are individual, solipsistic and idiosyncratic or whether they are connected to larger socio-historical events. The power of life history work is the dialectic relationship between the unique experiences of individuals and the broad constraints of social, political and economic structures. Thus when individual stories are set against a larger historical context, "the reminiscences of obscure individuals begin to reshape our understanding of major forces of social change" Keegan (1988:131). Individuals live within a context – this could be the family, the community or the state. Any study about human and social action must shift between the intimate features of the human self and the impersonal remote structures present at the time.

Another issue for the life history researcher is the decision about the sample. Should there be a random sample to ensure representativeness? Life history research is exploratory and intensive. There is little chance of a large, representative sample. A life history research could be hypothesis generating and these hypotheses could be tested with a more representative sample at a later stage. Life history informants are not taken as typical or representative. The sampling is strategic rather than random. Like Strauss and Glaser (1967) who use 'theoretical sampling' strategies, similarly in life history interviews people are chosen for what they can say rather than whom they represent.

Interviews were conducted with 20 participants to understand the issues of mobility. It was a purposive sample and because of convenience Reddy interviewed people in the KwaZuluNatal and Gauteng regions and Cele interviewed people around Cape Town. In drawing the sample the following criteria was considered: race, gender, age, nationality, institutional type (academia, government, industry), sector type (automotive, ICT, mining and metallurgy, biotechnology, environmental technology, extractive), qualifications and whether people had come into the South African or were about to leave South Africa. The choice of the sample was based on suggestions made about whom to interview and the interviews illuminate both common and unique issues. The interviews lasted about an hour long and focused on the R&D trajectory of individuals since 1990. The sample is skewed towards people who are either in or have come into the South African R&D system. We interviewed two people that were about to leave the country. The data is limited because, for financial and practical reasons, we could not interview people who had left the country.

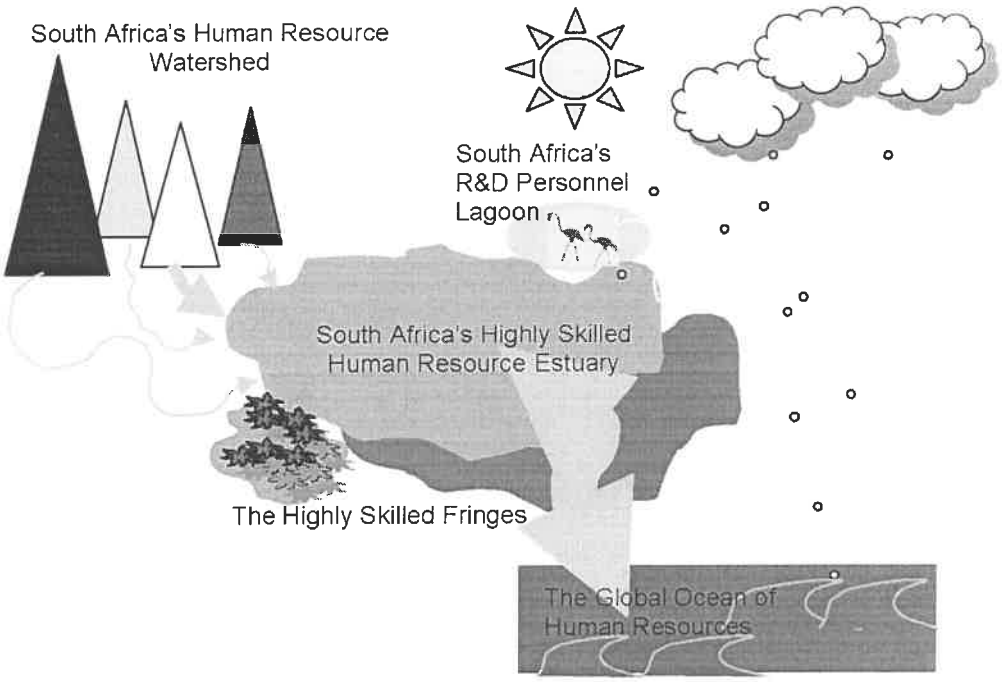
The interviews were transcribed and the career trajectory of individuals summarized in a matrix. Then there was a cross case analysis of the interviews to determine the key issues to understanding mobility of Research and Development workers.

Chapter 3 - Quantifying Mobility of South Africa's Research and Development Workers

3.1 Introduction

This chapter presents a systemic overview of the dynamics in South Africa's research and development (R&D) workforce. It quantifies important aspects of mobility by combining original data generated for this project with previous analyses and data on South Africa's R&D workers. In order to do this a systems perspective is adopted. Viewing the 'system of mobility' in South Africa allows review of relationships between the R&D workforce, the highly skilled, and the general population. It also allows relationships between other nations and regions to be analysed in a more organized manner.

Figure 3.1 South Africa's Human Resource Basin



To facilitate presentation of the diverse data and analyses, an estuary analogy is adopted. Figure 3.1 is a representation of the estuary. In this analogy attention can be shifted amongst the various levels influencing South Africa's R&D workforce. At the highest level, global and national characteristics are considered within 'South Africa's Human Resource Basin'. Moving down a level to that of all potential and actual R&D workers, highly skilled South African's are reviewed within 'South Africa's Highly Skilled Human Resource Estuary'. Finally, South Africa's actual R&D workforce is analysed inside 'South Africa's R&D Personnel Lagoon'.

The South African Human Resource Basin is surveyed in this chapter. It analyses evidence and conjectures about the features of the basin. Throughout, relations between the general population, the highly skilled and the R&D workforce are stressed.

The dynamics of attraction to, retention in, and general health of R&D employment are primarily considered in Chapters Four and Five with perspectives from organizations employing and individuals working in R&D. This chapter looks at similar features across a broader horizon, describing the stocks and then the flows of human resources into and out of actual and potential employment in the R&D workforce.

Finally, it is important to remember that the South African Human Resource Basin is one of many other basins. Particularly given the general mobility of an R&D worker's skills, the South African Human Resource Basin has to be attractive compared to other basins. In this another metaphor from nature is recalled, the flamingos migrate only to return when the brackish waters are replenished.

3.2 SOUTH AFRICA'S HUMAN RESOURCES IN SCIENCE & TECHNOLOGY

3.2.1 Characteristics (Stocks)

This section surveys the stock of South Africa's human resources in science and technology (HRST). The two other sections in this part of the chapter then analyse flows and dynamics of the HRST. Figure 3.2 shows the 'estuary', which is the descriptive focus of this section. For empirical analysis HRST can be defined on a basis of an individual's formal qualifications or their occupation.

Figure 3.2 South Africa's Highly Skilled Human Resource Estuary

Based on organizational feedback in the project, a very broad definition of HRST is adopted, which combines occupations and qualifications. Thus, all individuals with a first diploma or degree or higher are considered part of the HRST. It also includes individuals not formally qualified, but in an occupation that requires such an equivalent level of training even if it has been informally acquired. A definition of HRST by occupation is therefore given as all individuals whose jobs fall under the professional and associate professional categories.

Within our analogy, the HRST stock is all water that is part of the estuary. A relatively restricted definition of HRST might therefore be translated as considering only the 'open waters' that constitute the estuary, while a relatively liberal definition could include marsh and border grasslands (The Highly Skilled Fringes) surrounding the estuary.

In this overview of the stock, statistics on South Africa's HRST by occupation[6] and qualification[7] are presented from 1988 to 2002. Table 3.1 presents some of the time series data collected. The primary data sources used in compiling these statistics are the Manpower surveys, the 1996 Census, the October Household Survey (OHS), and the Labour Force Survey (LFS).

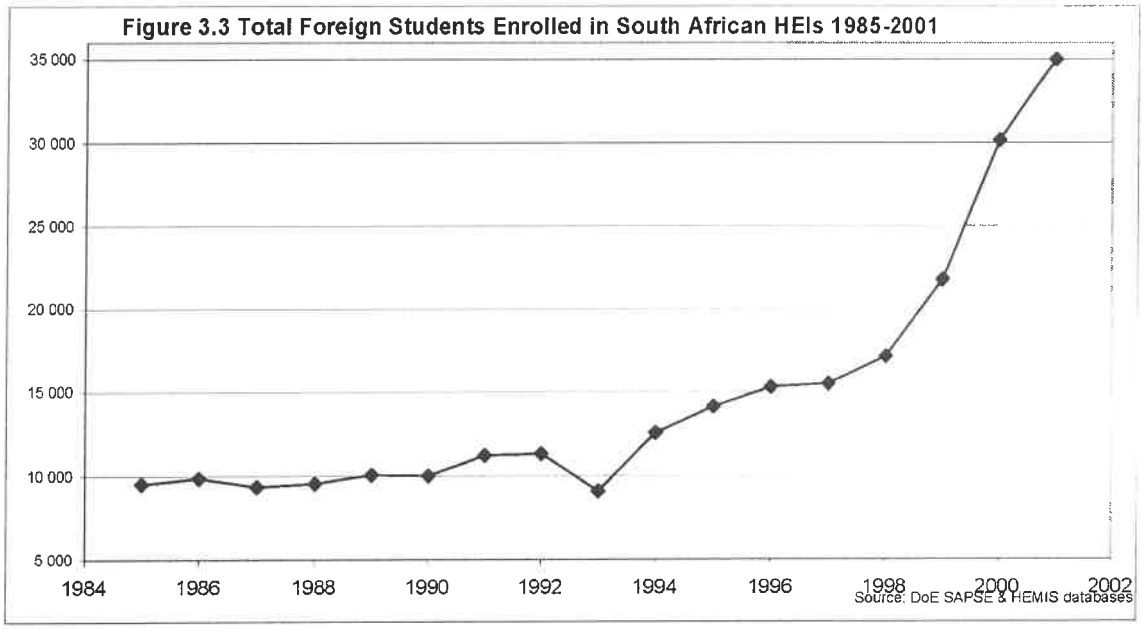
Table 3.1 South Africa's Human Resources in Science and Technology 1988-2002

Year	South African HRST by Occupation	South African HRST by Qualification	Foreign Students Enrolled in South African Higher Education Institutions
1988	533 567*		9 551 #
1989	517 993*		10 063 #
1990	553 990*		9 998 #
1991	569 128*		11 220 #
1992	573 821*		11 306 #
1993	727 143*		9 101 #
1994	725 918*		12 561 #
1995	731 683*		14 124 #
1996	778 621*	1 635 000**	15 307 #
1997	1 599 000***	1 937 000***	15 508 #
1998	1 495 000***	2 167 000***	17 130 #
1999	1 714 000***	2 154 000***	21 784 ##
2000	1 605 000****	2 412 000****	30 159 ##
2001	1 631 000****	2 329 000****	35 002 ##
2002	1 716 000****	2 509 000****	N/A

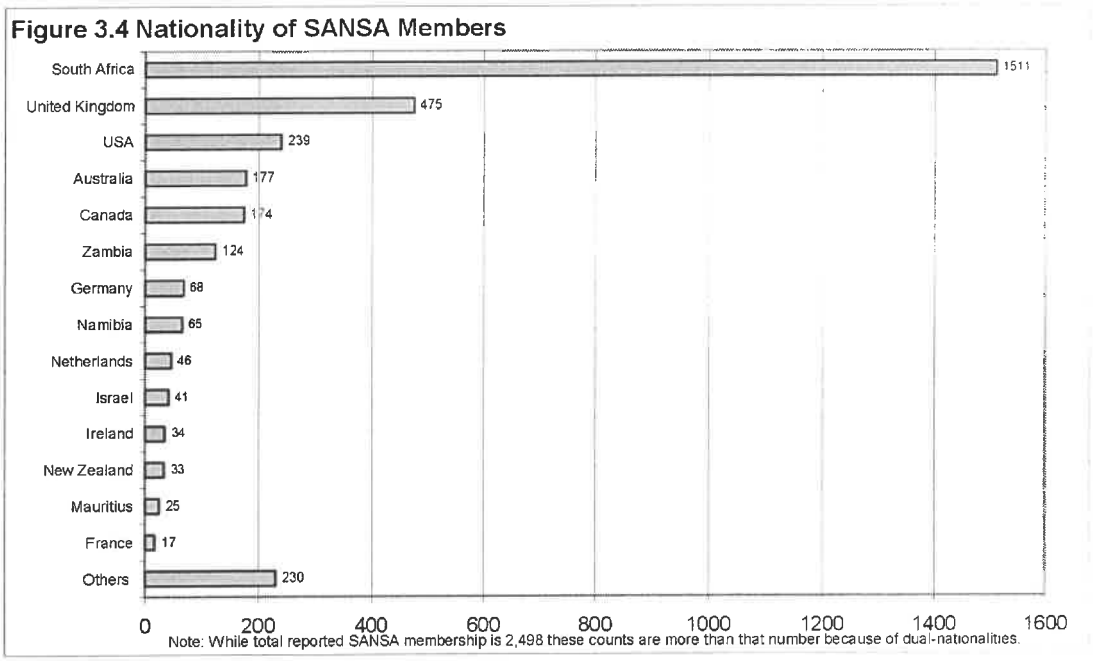
Notes: *MS=Manpower Survey, **CS '96=Census 1996, ***OHS=October household Survey, ****LFS=Labour Force Survey.
#SAPSE= South African Post-Secondary Education data, ##HEMIS= Higher Education Management Information System.

Foreign students enrolled in South African higher education institutions, despite their being temporary, are part of the HRST stock. Department of education data shows the increasing numbers of foreign students in South Africa, a point which is seen in Figure 3.3. This is a significant trend and is discussed further with respect to its relative share of the HRST in Section 3.2.1.1 below.

[6] South Africans whose highest level of education is at least the equivalent to a degree or diploma from a higher education institution (HEI).
[7] South Africans whose jobs are classified under the professional and associate professional categories.



In the modern globalised world, looking at the estuary in isolation misses the network of relations with others, be they other governments, organization, or individuals. Accessing ties with non-resident South Africans is one means to use these connections positively. An important initiative to develop these ties is the South African Network of Skills Abroad (SANSA). Members are recruited based on their having an interest in South Africa's development. Figure 3.4 shows the nationality of SANSA members[8]. The expatriate skills of these individuals are shown in Figure 3.5 and Figure 3.6.



[8] The data for figures 3.4 to 3.6 were provided by SANSA for this project.

Figure 3.5 Professional Sectors of SANSA members

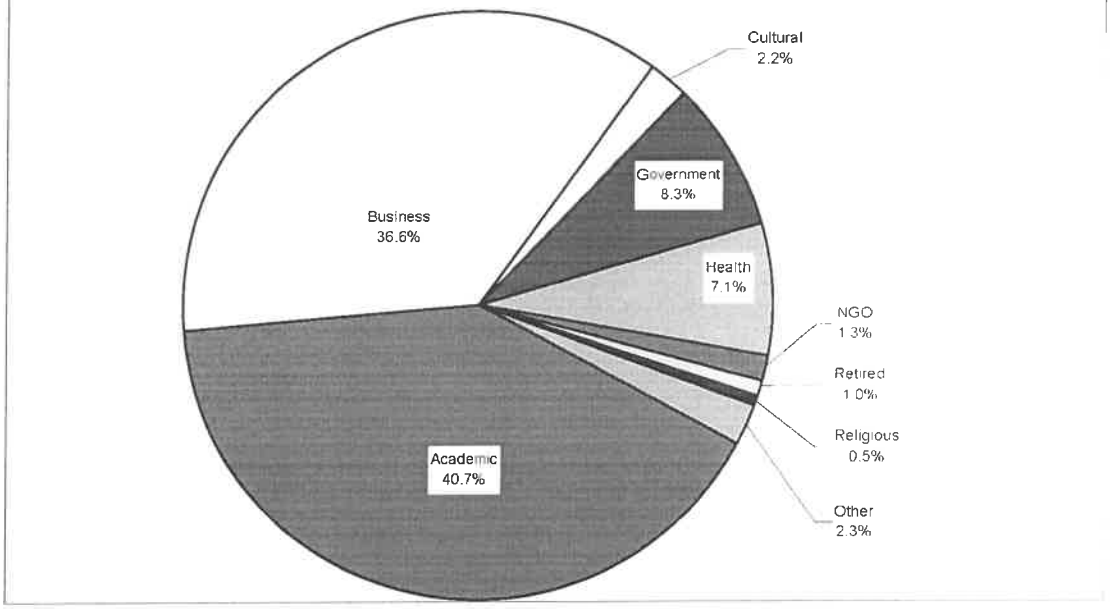
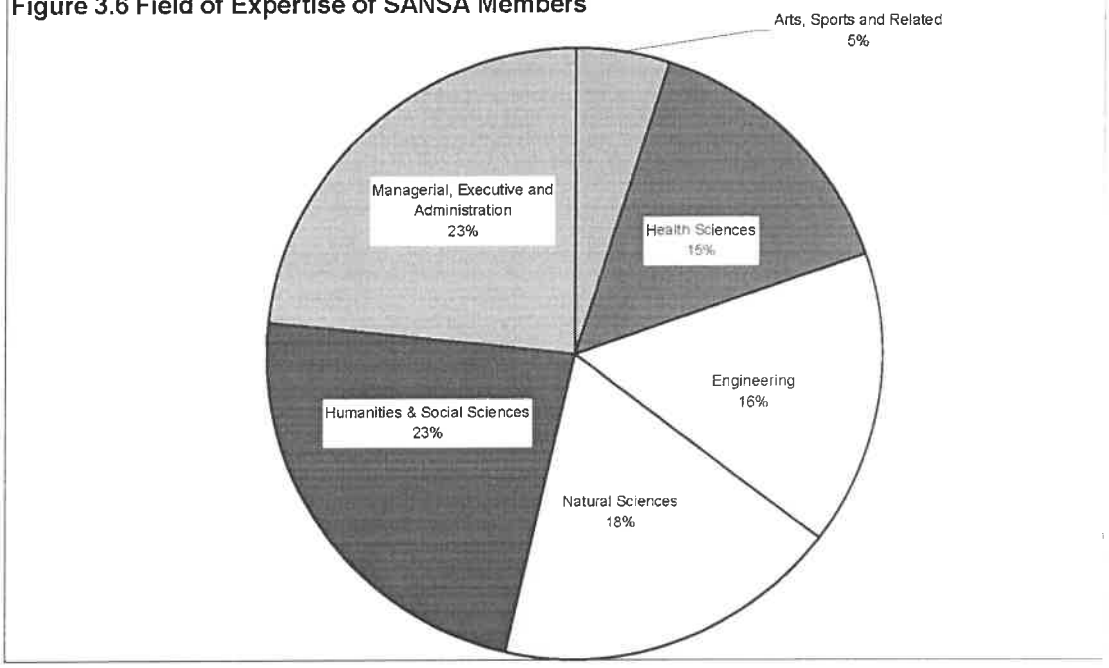


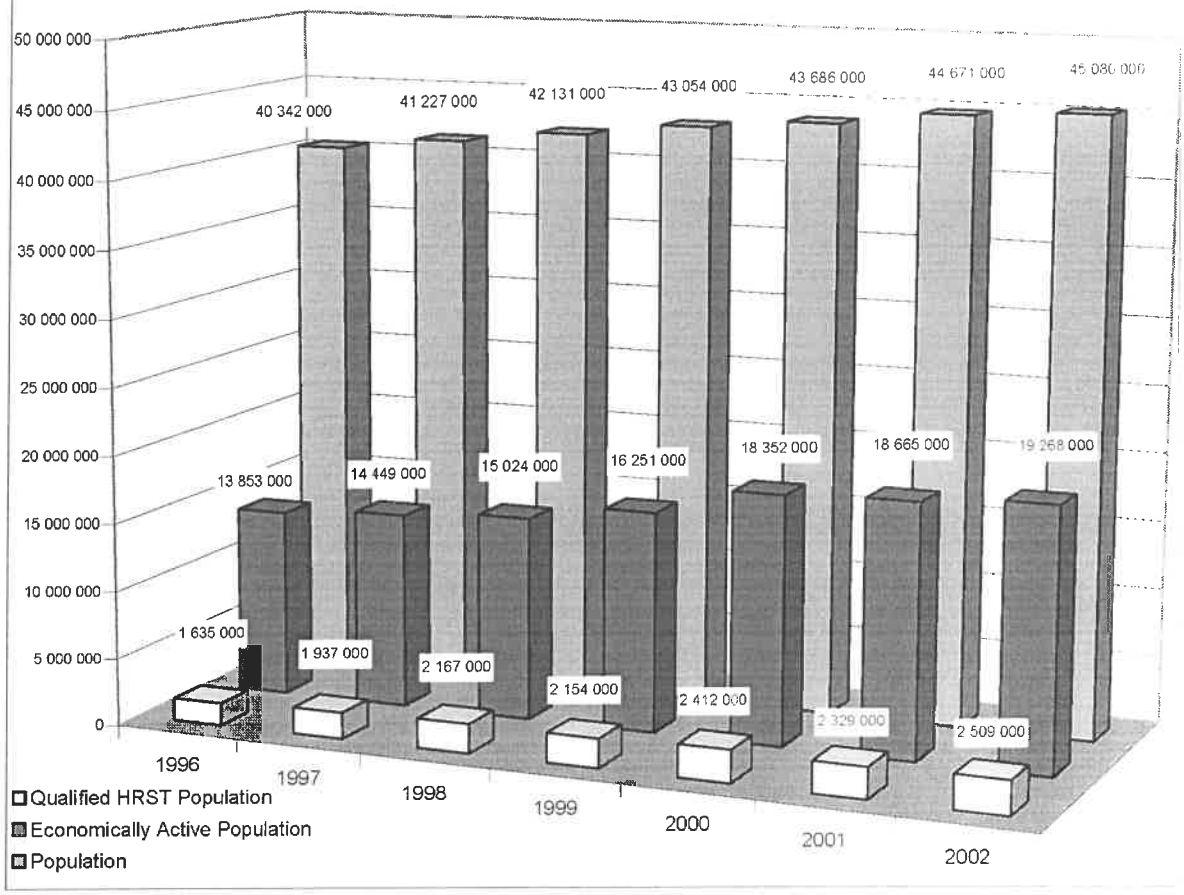
Figure 3.6 Field of Expertise of SANSA Members



3.2.1.1 Relative Size of South Africa's HRST

This subsection reviews some trends in the relative size of the HRST to the total South African population and the economically active population. The economically active population is derived from the Statistics South Africa October Household Survey and the Labour Force Survey. Anyone with at least a diploma or degree is retained as the definition of qualified HRST. Figure 3.7 shows the HRST by qualifications to be a relatively constant percentage of the total population, while the total economically active population has grown in real and relative terms.

Figure 3.7 South African Population Changes 1996-2002



International comparison of the proportionate size of HRST population is possible and Table 3.2 presents some comparative figures. Unfortunately, the South African statistic of nine percent is based on data from 1996, while that of the other nations is from 1998 and 1999 data[9]. Nonetheless, an idea of South Africa's international position is given from this table.

Table 3.2 Comparative Percentages of HRST in the Adult Population

Nation	Percentage of the 25 to 64-year-old population who are qualified HRST	Nation	Percentage of the 25 to 64-year-old population who are qualified HRST
United States*	35%	Thailand**	9%
Australia*	27%	Malaysia**	8%
United Kingdom*	25%	Turkey*	8%
Korea*	23%	Brazil**	7%
Mexico*	13%	Indonesia**	5%
Zimbabwe*	10%	Tunisia*	5%
South Africa*	**9%**		

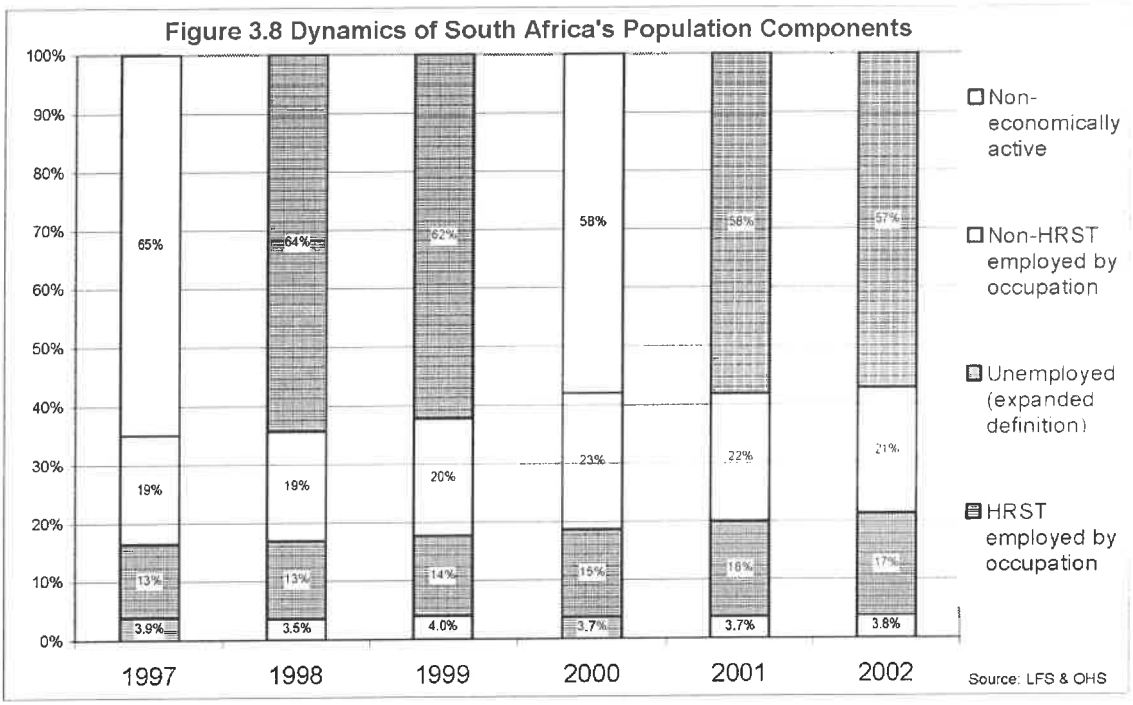
Year of Reference: *=1999, **=1998, ***=1996

Source: OECD (2001) and 1996 Census

[9] As data for 2001 is also available for most of the other nations (OECD 2002) when South African 2001 census data becomes available an update of this table should be made.

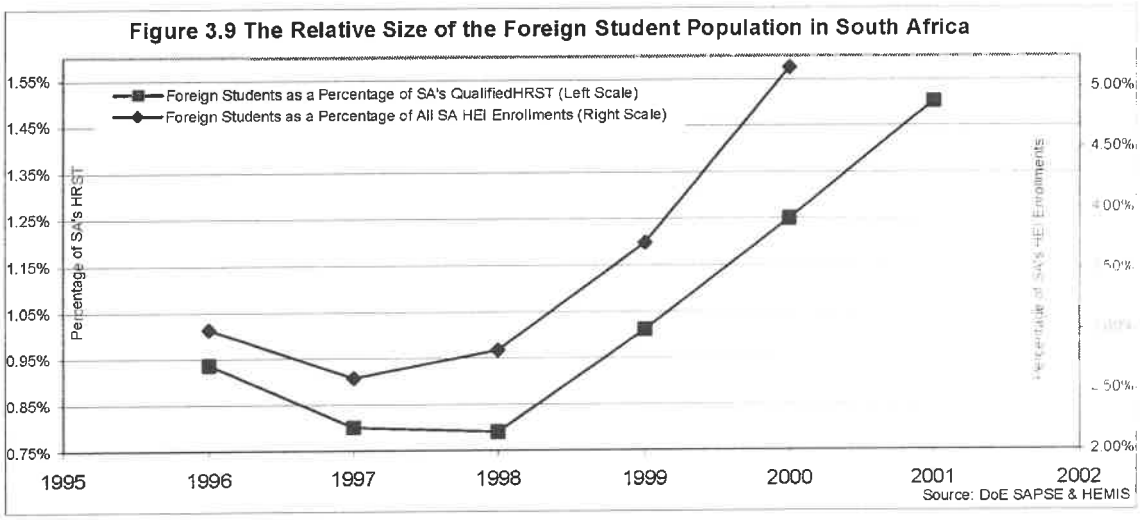
The dynamics of proportionate changes in the South African population are shown in more detail in Figure 3.8. It shows the relatively consistent proportion of HRST employed and a slightly increasing percentage of employed non-HRST. In interpreting the figure it should be remembered that this decomposition is for the entire population and not just the adult population[10].

Figure 3.8 Dynamics of South Africa's Population Components



Finally, Figure 3.9 examines the relative size of foreign student tertiary enrolments. This shows that both as a percentage of total enrolments and as a percentage of the national HRST, foreign students have rapidly grown from 1997/1998.

Figure 3.9 The Relative Size of the Foreign Student Population in South Africa



[10] The adult population is taken to be individuals between 25 and 64-years-old.

An international comparison of the proportionate size of foreign students at tertiary education institutions is given in Table 3.3. It shows the relatively large tertiary foreign student population in South Africa, both in relative and absolute terms. It is interesting that at 5.2% of its student enrolments, South Africa is in a level similar to nations like Australia (12.5%), the U.K. (11%) and the U.S. (3.6%) and distinctly more international than nations like Malaysia (0.7%), Argentina (0.2%), and Korea (0.1%). As the discussion in Section 3.2.1.2 below shows, a significant factor in placing South Africa in this position is the rising number of students from the Southern African Development Community (SADC) region[11].

Table 3.3 Comparative International Statistics on Foreign Student Composition for the Year 2000

Nation	Total National Population (1)	Number of Foreign Students in HEIs (2)	Percentage of Foreign Students out of Total HEI Enrolment (3)
Australia	19,138,000	105,764	12.5%
United Kingdom	59,415,000	222,936	11.0%
South Africa	**43,309,000**	**30,159**	**5.2%**
United States	283,230,000	475,169	3.6%
Turkey	66,668,000	17,654	1.7%
Tunisia	9,459,000	2,756	1.5%
Malaysia	22,218,000	3,508	0.7%
Argentina	37,032,000	3,181	0.2%
Korea	46,740,000	3,373	0.1%
Mexico	98,872,000	2,430	0.1%

Notes: (1) Medium Variant Population data. Source: United Nations Population Division (2001)

(2) Source: OECD Education Database and South African DoE HEMIS Database

(3) Source: OECD (2002) and South African DoE HEMIS Database

3.2.1.2 Demographics of South Africa's HRST

This section gives some demographic detail about the HRST stock and how it has changed overtime. Within our analogy, composition of the estuary is being reviewed. Table 3.4 looks at trends in comparative unemployment rates in 1997, 2000, and 2002. Unemployment rates by gender and education levels are also presented for 2002. The lower level of similarly qualified male unemployment is a trend reflected in the data back to 1997. Time series data with greater disaggregation of qualification levels was not available, however a relatively detailed snapshot is available from data in the 1996 Census and it is presented below.

Table 3.4 Unemployment (expanded) of Economically Active Population in 1997, 2000 & 2002

	1997	2000	2002	2002 Male	2002 Female
National Rate (All Levels of Education)	**37.4%**	**35.9%**	**40.9%**	**35.3%**	**46.4%**
Diploma or Cert. With Grade 11	13.9%	19.4%	23.5%	22.3%	24.5%
Diploma or Cert. With Grade 12	10.2%	17.8%	20.5%	16.0%	24.1%
Degree or higher	5.6%	6.5%	9.0%	5.0%	13.0%
HRST	**9.1%**	**13.7%**	**16.5%**	**12.1%**	**29.3%**

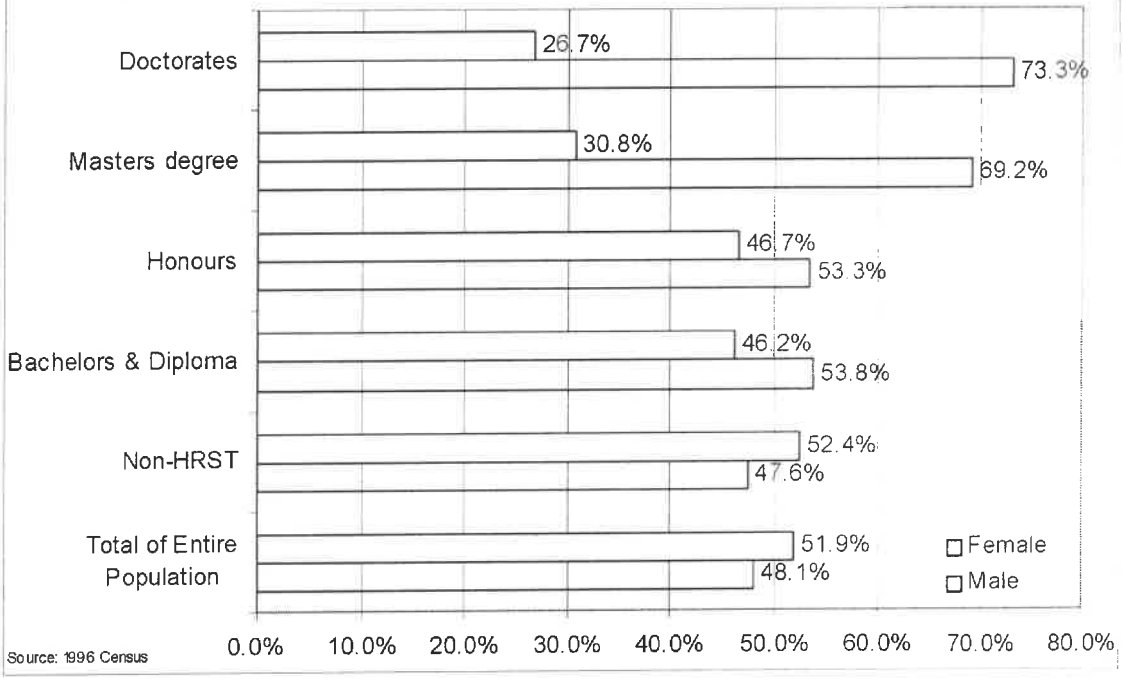
Source: LFS 2002, LFS 2000, and OHS 1997.

Note: In 1997 EAP does not include the informal sector. Estimates made in 2002 for Degree or higher-level unemployment rates by gender

[11] SADC membership consists of Angola, Botswana, Democratic Republic of the Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.

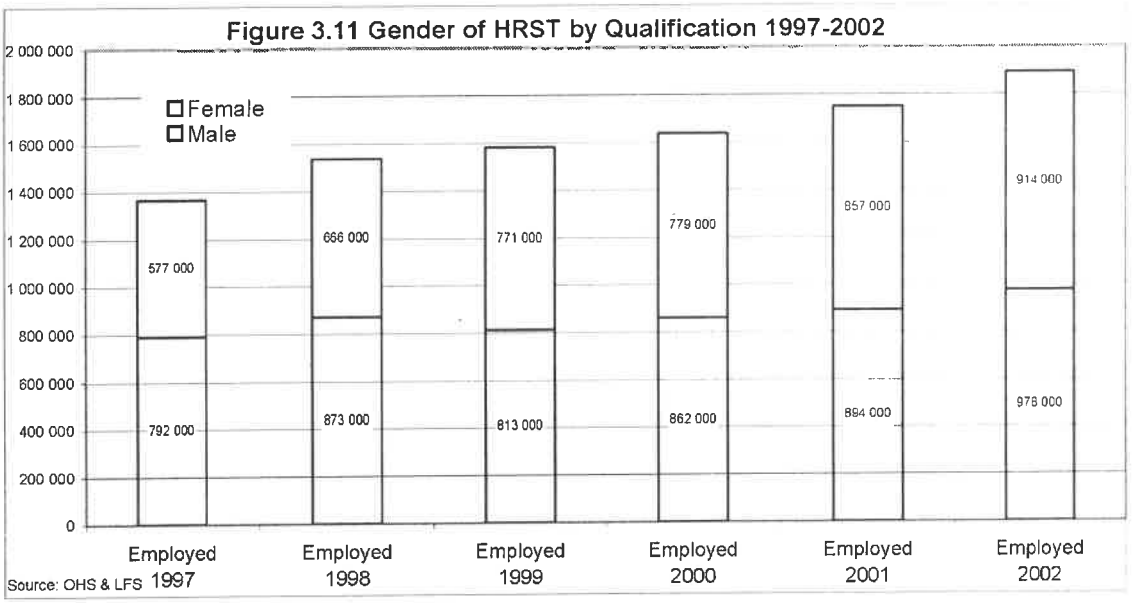
Details of the HRST by gender in 1996 are seen in Figure 3.10. This shows a strong gender bias at the higher levels of qualifications. While males account for 73 percent of the doctorates in South Africa, they only account for 48 percent of the total population.

Figure 3.10 Highest Level of Education Achieved by Gender in 1996



Statistics over time are available at a more general level for the employed HRST population. Figure 3.11 presents this data from the October Household Survey and the Labour Force Survey. It shows a significant growth in female HRST employment between 1997 and 2002.

Figure 3.11 Gender of HRST by Qualification 1997-2002



Employment of HRST by race is given in Table 3.5. There is an apparent discrepancy between the total employment of HRST by race and employment of non-racially defined HRST. This is discrepancy emerges because racial comparisons are made on HRST defined by qualifications and not occupations. Data availability has forced this change in the base of measure. In comparing 1997 to 2002 there is growth in employment for all qualified HRST, although with significant differences across races.

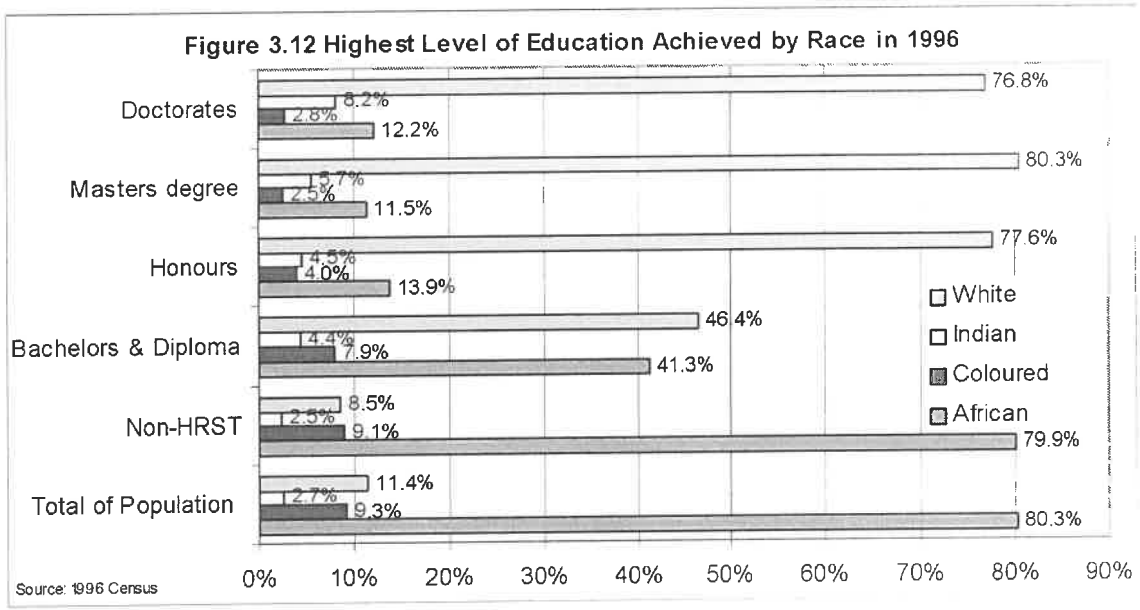
Table 3.5 Employment Status by Race in 1997 and 2002

(Numbers in 000s)	Total 1997	Total 2002	African 1997	African 2002	Coloured 1997	Coloured 2002	Indian 1997	Indian 2002	Whites 1997	Whites 2002
Total Population	41 444	45 080	32 106	34 879	3 751	4 002	1 065	1 400	4 521	4 716
Non-Employed Population	79.0%	74.7%	83.2%	78.5%	69.2%	68.4%	66.2%	64.5%	60.5%	55.2%
Employed Non-HRST	17.7%	21.1%	15.2%	19.2%	28.1%	28.1%	27.9%	27.6%	24.7%	26.9%
Employed HRST	3.3%	4.2%	1.7%	2.3%	2.6%	3.5%	5.9%	7.9%	14.9%	18.0%

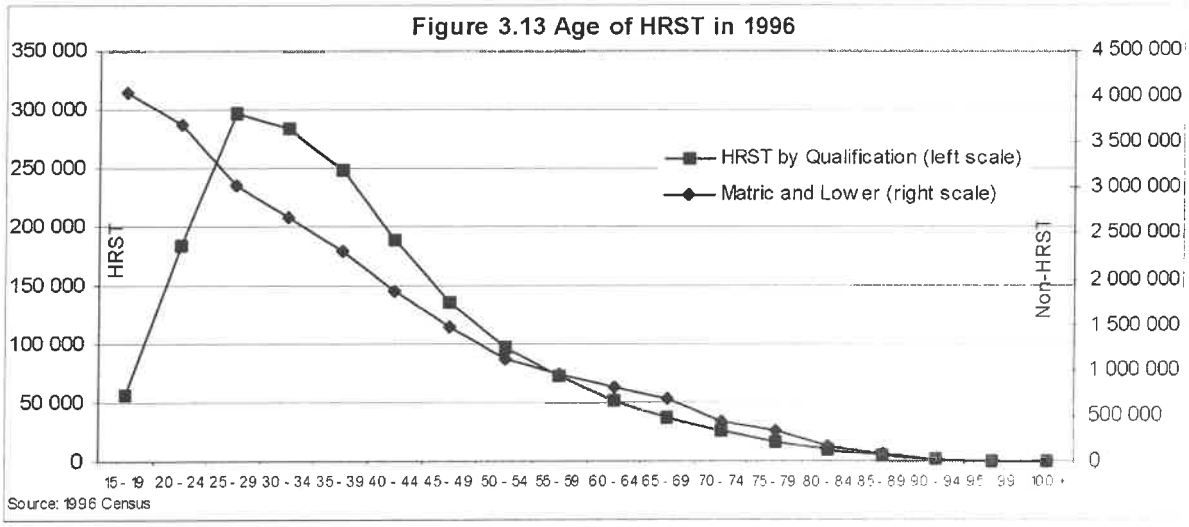
Source: OHS 1997 & LFS 2002. Note: HRST is defined by qualifications of the employed.

As with gender, disaggregated data over time is not yet available by race for the level of highest education. The 1996 Census again provides an informative snap-shot and as such it is presented in Figure 3.12. Among the four racial groups, whites predominate the higher-level qualifications. While whites accounted for 11 percent of the total population, they composed 77 percent of South Africa's doctorates. Indians were the next highest disproportionately represented group, accounting for 3 percent of the population and 8 percent of doctorates. Notably at the bachelors and diploma level this racial distortion was less pronounced. In assessing the long run transformation of South Africa this will be an important area and so the figures from the 2001 Census will be informative.

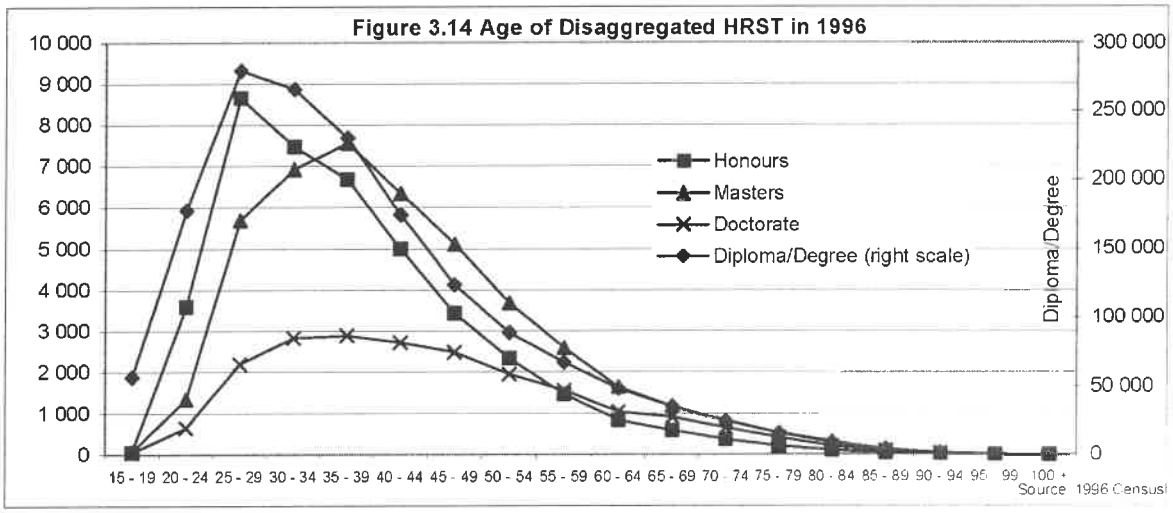
Figure 3.12 Highest Level of Education Achieved by Race in 1996



The 1996 Census also allows a detailed look at the age structure of the HRST. Figure 3.13 gives comparative age structures of HRST and Non-HRST.

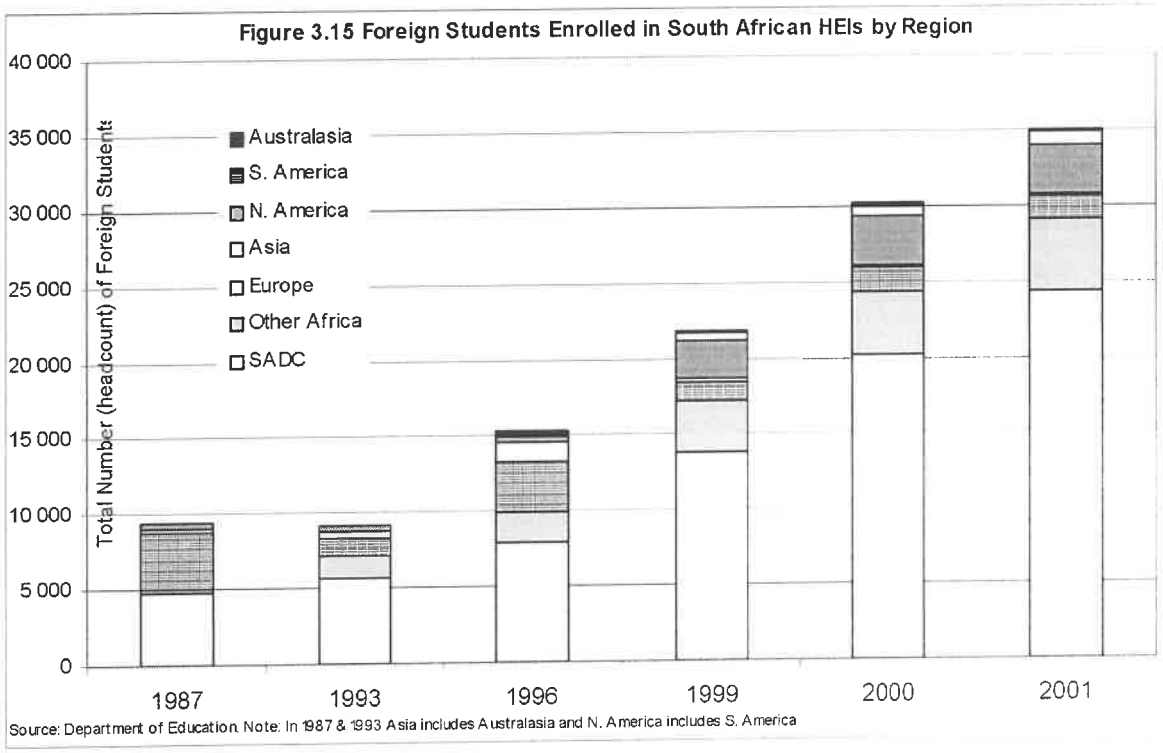


Using the same data, Figure 3.14 profiles the disaggregated age structure of the HRST.

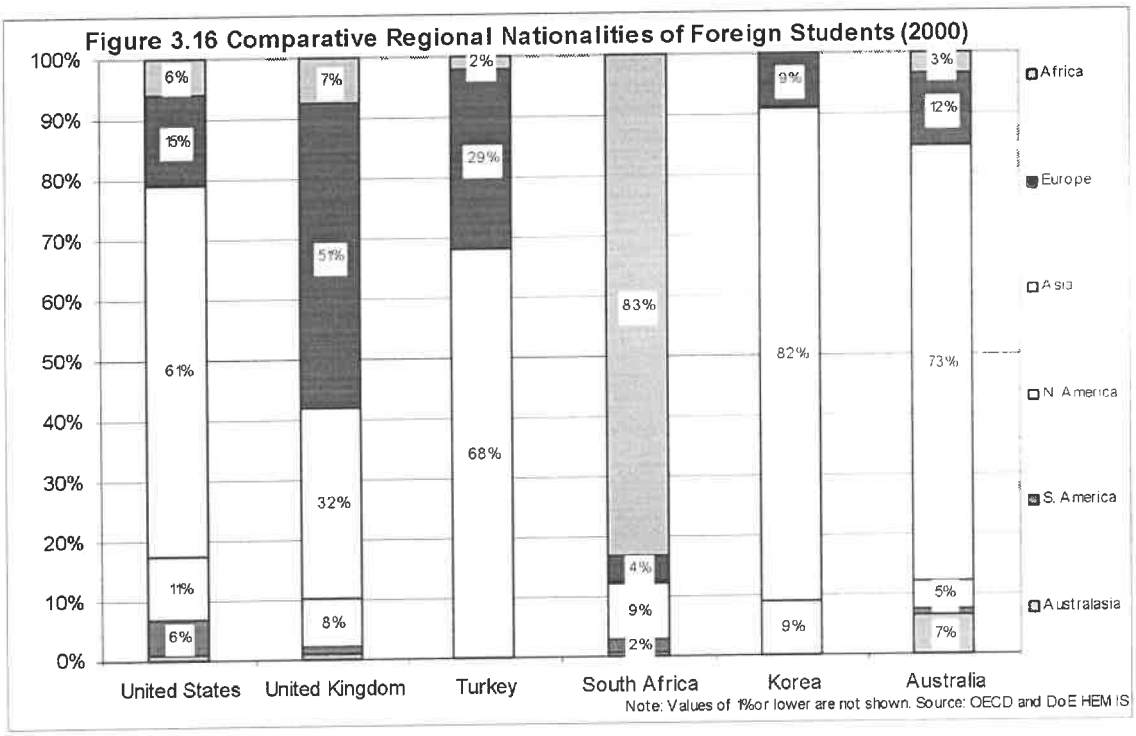


The structure of foreign student enrolment is the final demographic component to be analysed. Figure 3.15 shows the region of origin for foreign students enrolled in South African higher education institutions (HEIs)[12]. It shows a dramatic rise in the numbers of students from the SADC region. This indicates, in conjunction with the data on the comparative size of the international student population in Sections 3.2.1.1, that since the early 1990s South Africa has become an educational hub for the African continent. Its foreign students are not solely Africans as there is also an increase in students from most other regions, the two exceptions being students from Europe and Asia.

[12] While every effort has been made to ensure the accuracy of this data, some discrepancies appear to exist in the data on foreign students. For example in 2001 Home Affairs reported 31,000 foreign student permits were issued, but our figures shows 35,000 foreign student by head-count.



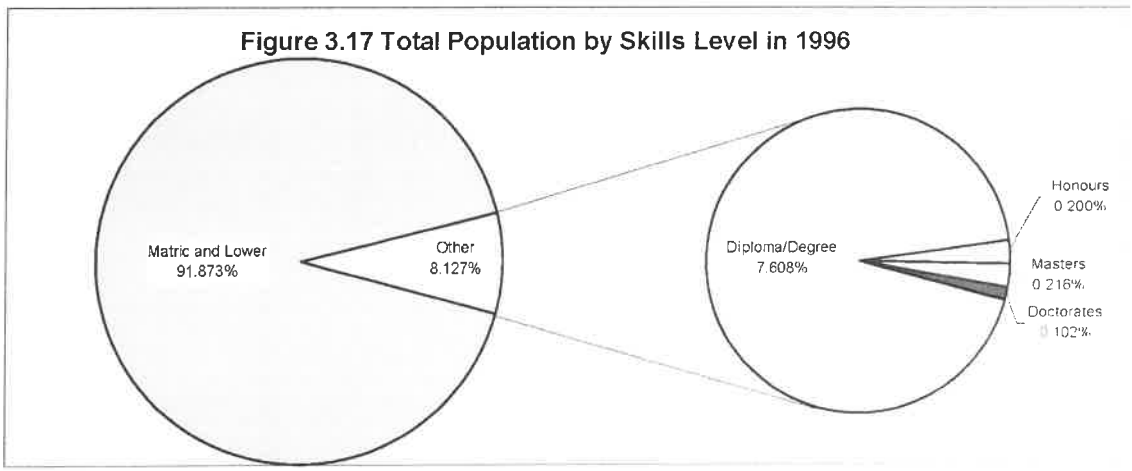
Regional origins of foreign student populations are presented in Figure 3.16 for South Africa and a few other nations in the year 2000. The large portion of Africans in South Africa's tertiary institutions is again apparent. The large number of Asians studying abroad is also a notable general trend, but not one seen in the South African foreign student population, the causes for this uniqueness is not readily apparent.



3.2.1.3 HRST Skills by Level and Discipline of Training

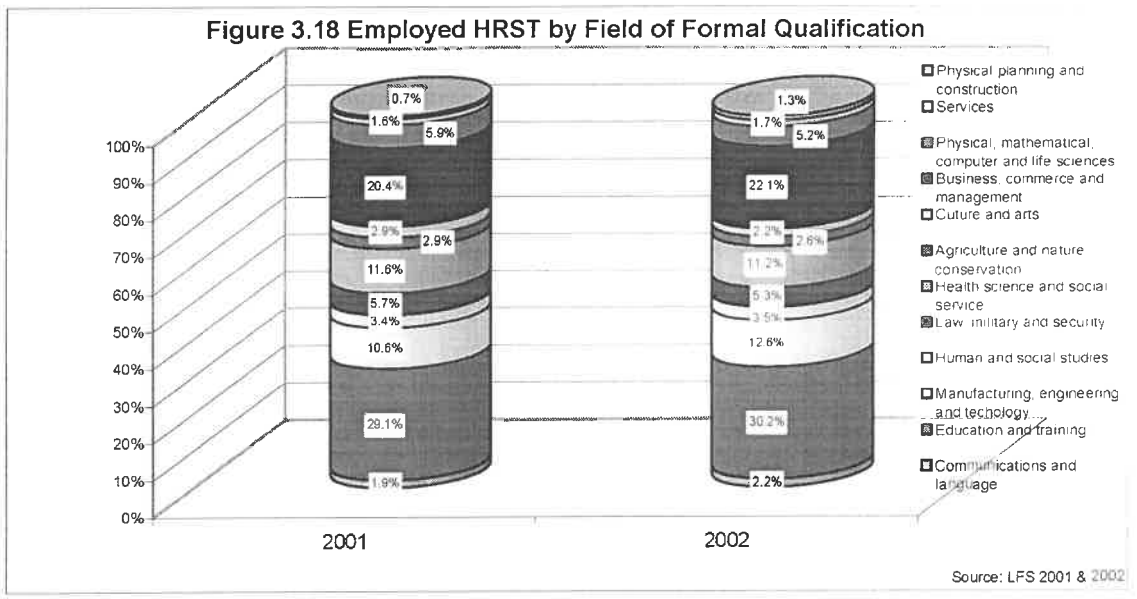
This section uses the available data to consider changes in the level and field of training. The most recent breakdown of the South African populations skills is the 1996 Census report on level of highest formal qualification. Figure 3.17 shows this breakdown for the 20.5 million South Africans over the age of 19 in 1996. It shows just how small a part of the national human resource basin the estuary accounts for i.e. HRST by qualification was just 8 percent of the total population.

Figure 3.17 Total Population by Skills Level in 1996



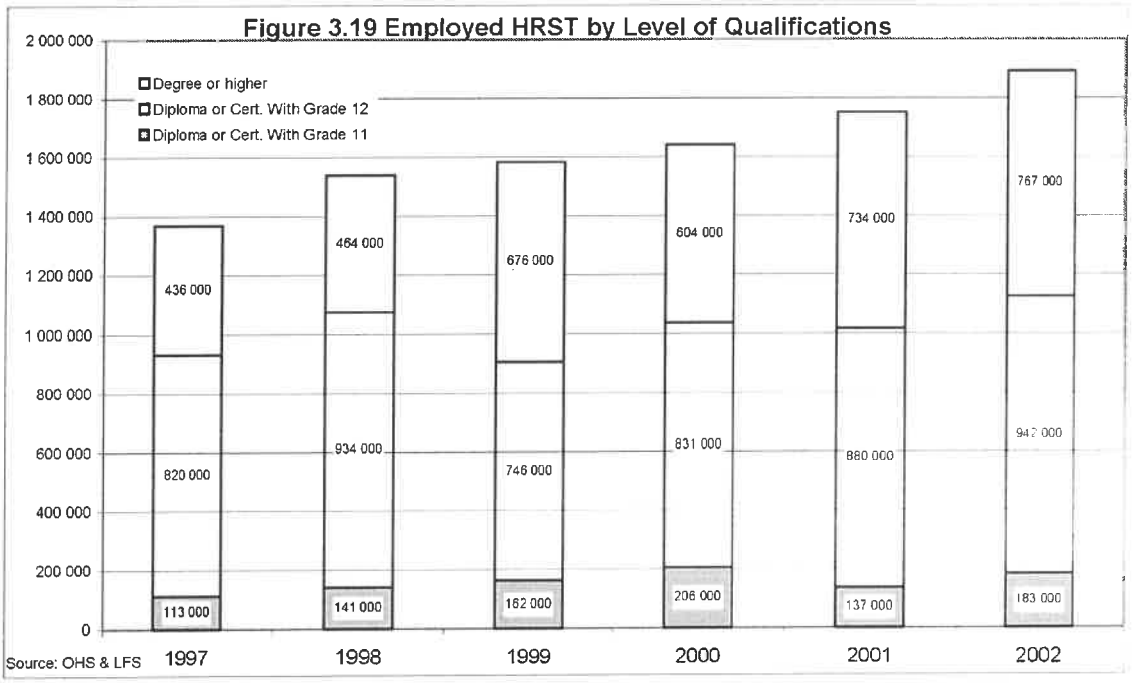
The 2001 and 2002 Labour Force Surveys (LFS) provides a break down of the employed HRST by qualification in their field of training. This is shown in Figure 3.18. The largest fields of training are Education (30 percent), Business (22 percent), and Manufacturing & engineering (13 percent). These three fields also saw growth in their proportions of the formally qualified. In comparison, those qualified in the physical, mathematical, computer and life sciences decreased in the proportion of total HRST employed, as did those in the agricultural sciences and nature conservation.

Figure 3.18 Employed HRST by Field of Formal Qualification

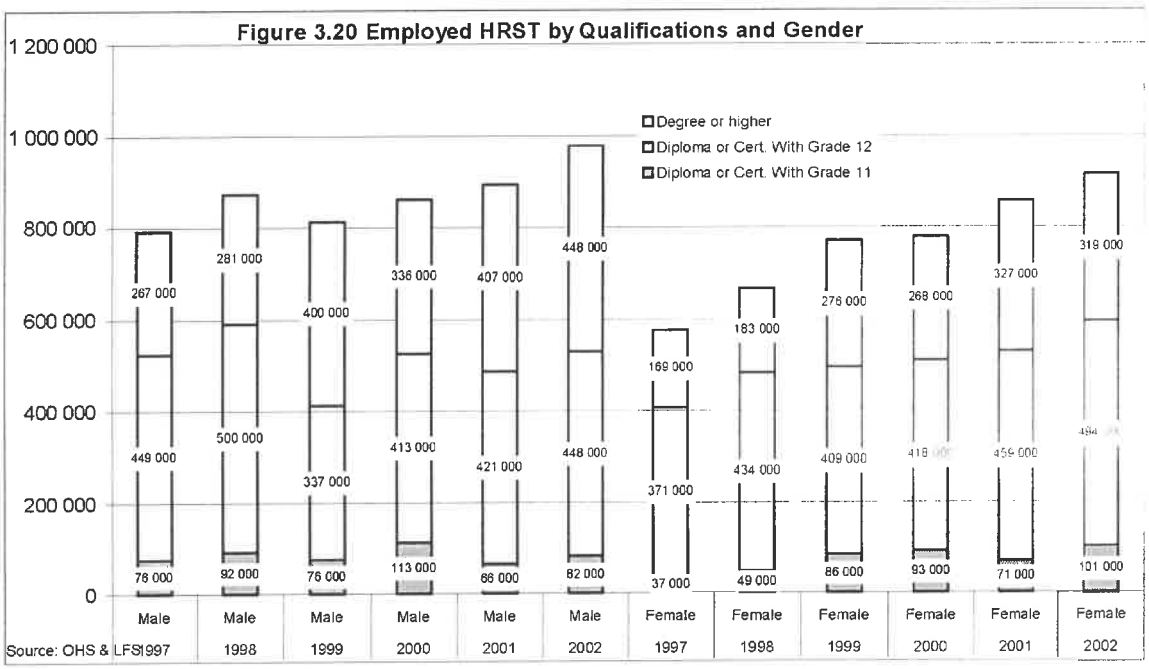


Source: LFS 2001 & 2002

The OHS and LFS also provide some general trend data on the employment of qualified HRST. This is seen in Figure 3.19, it shows growth in employment in the higher levels of qualifications. That of individuals with degrees or higher being the greatest.



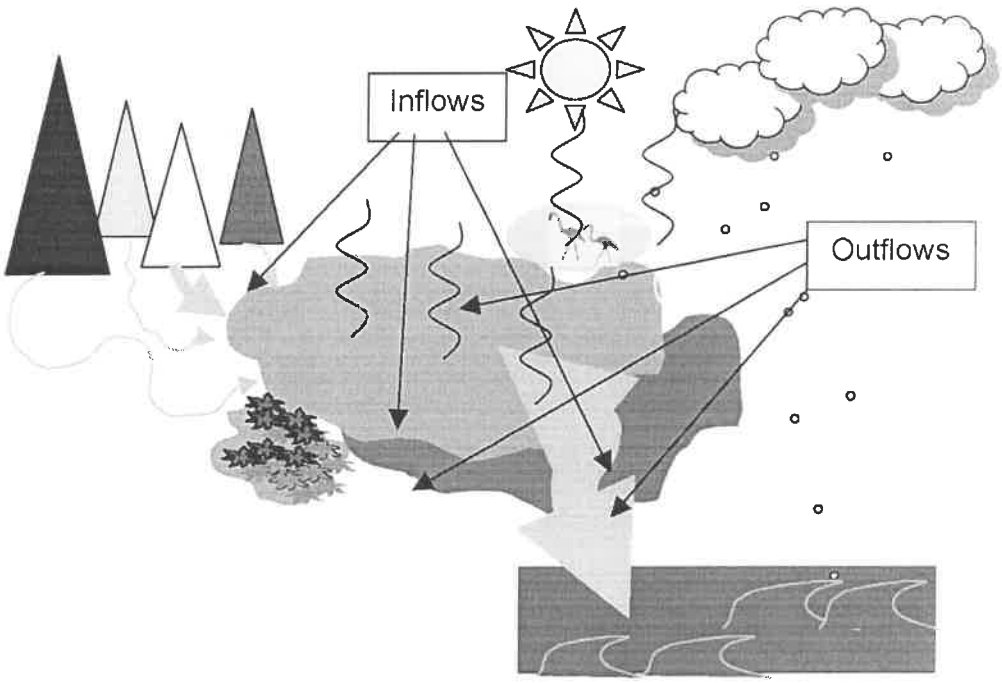
Using the OHS and LFS trends in qualified HRST by level and gender are shown in Figure 3.20. Employment of women with a degree or higher rose by nearly three times, while that of men nearly doubled.



3.2.2 Movements (Flows)

This section examines the flows into and out of the South African HRST. Within the analogy of the human resource estuary inflows and outflows are represented in Figure 3.21. While demographic and skill changes can alter the internal character of the estuary, inflows and outflows are both of three general types. Outflows of an unconditional nature are the evaporation from the estuary; these are primarily losses because of mortality and are not any part of the South African or global skills base. The second type of outflow from the HRST is that of unqualified HRST moving to non-HRST occupations. This is movement outside the fringes of the estuary and while they most likely retain HRST skills, there is no reliable statistical measure of the human resources. The last type of outflow is the losses do to emigration. These are the tidal outflows from the South African estuary. They might return, but not necessarily as they are part of the global ocean of human resources and may find themselves in another estuary depending on the ocean currents that they follow.

Figure 3.21 Flows of South African HRST



On the inflow side, the primary input is typically from domestic persons qualified as HRST for the first time. These are the streams and rivers flowing into the estuary from the South African Human Resource Basin. These inflows are determined by the national educational capacity and its dynamic characteristics. Another type of inflow is movement of non-qualified HRST taking up HRST positions. This effective is the movement of human resources out of the further fringes of the estuary and into the estuary proper. The last type of inflow is from the immigration of non-South African HRST. These are the tidal inflows to the estuary and are in parallel with the tidal outflows, temporary and permanent in nature.

In presenting this data a strong word of caution is needed. Empirical accuracy is very limited and with the present data there is little ability to isolate where data errors

emerge. The state of empirical (im)precision over the flows of South Africa's HRST is illustrated in Table 3.6 below. Taking HRST Stock by qualifications from the OHS and LFS, lagged statistics on the inflows and outflows are used to explain the change in stocks. There is very little explanatory power of these figures as the final two columns of the table attests. The sections that follow discuss some of the causes of these data shortcomings in their presenting figures over the various flows.

Table 3.6 Inflows and Outflows of South Africa's HRST 1997-2001

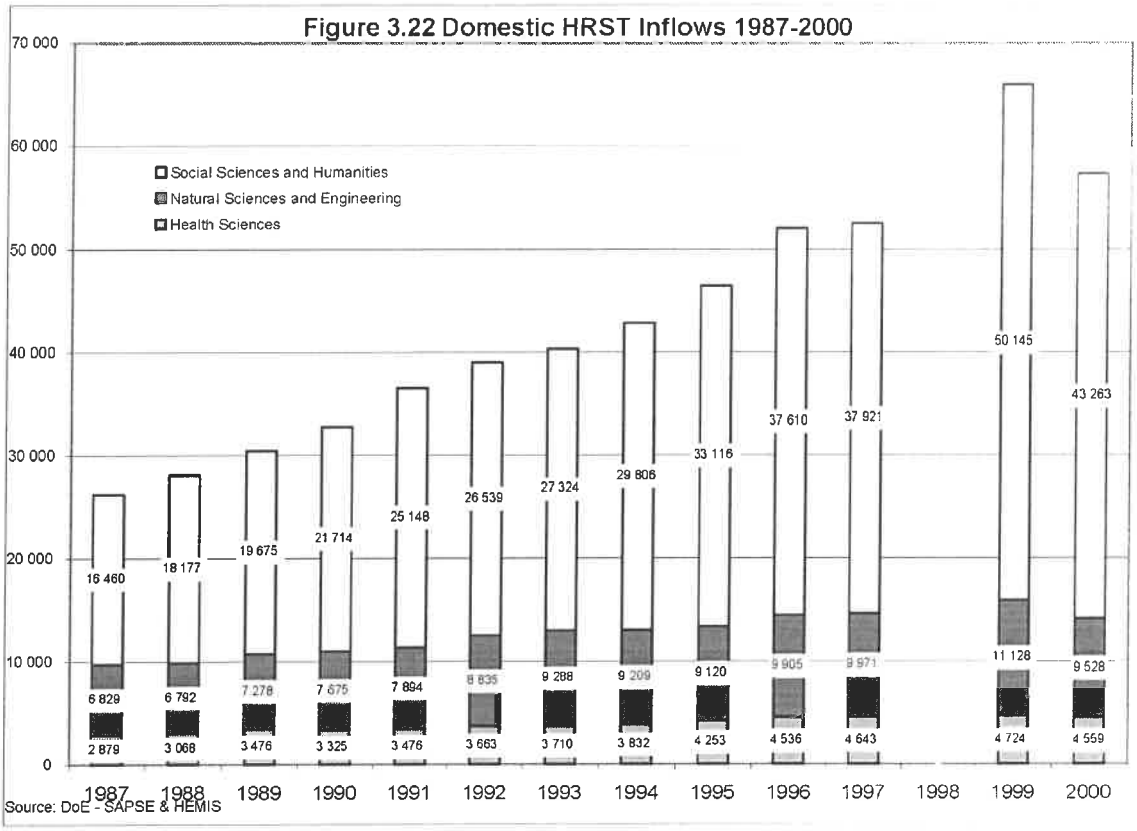
Year	HRST Stock by Qualifications	Change from Previous Year	HRST Inflows from SA HEIs	HRST Inflows from Immigrants	Total Inflows	HRST Outflows from Mortality	HRST Outflows from Emigrants	Total Outflows	Net Explained	Unexplained Change
1997	1 937 000	302 000	52 050	843	52 893	12 233	1 970	14 203	38 690	263 310
1998	2 167 000	230 000	52 535	551	53 086	15 383	1 924	17 307	35 779	194 221
2000	2 412 000	258 000	65 997	378	66 375	20 012	1 855	21 867	44 508	213 492
2001	2 329 000	-83 000	57 350	331	57 681	20 978	2 439	23 417	34 264	-117 264
2002	2 509 000	180 000		524		24 535	2 929	27 464	-27 464	207 464

3.2.2.1 Inflows to the South African HRST

3.2.2.1 (a) Inflows from first qualified nationals at the level of HRST

These inflows are the streams and rivers from the South African human resource basin that feed the estuary. In terms of how the upstream potential is translated into the actual flows into the HRST stock, South Africa's school system and its dynamics are critical. As a proxy for first qualified South Africans, degrees granted from South African HEIs at the diploma or degree level are used. These are presented in Figure 3.6 across the period from 1987 to 2000 by general discipline. While there has been steady growth in all disciplines, the social sciences and humanities have seen the largest proportional growth.

Figure 3.22 Domestic HRST Inflows 1987-2000



In considering the dynamics of these flows it is important that attention also be paid further 'upstream' in the human resource basin and not just at the entrance to the estuary. Consideration of first time student enrolments shifts analytical attention slightly up the input streams. Doing so indicates that the size of the system has been relatively static since 1995, with distance education primarily in teacher training accounting for an enrolment peak in 1998 (CHE, 2002, pp. 26-27). One clear cause accounting for this limited growth in enrolment, and subsequent graduate inflows, has been a decline since 1994 in the number of students qualifying for university entrance. In 1994, there were 89,000 university exemptions granted nationally, but in 2000 there were only 67,000 which was far below predictions in the early 1990s for 130,000 exemptions by 1998 (*Ibid.* 2002, p. 27).

3.2.2.1 (b) Inflows from non-qualified persons in S&T occupations

These individuals have not received formal tertiary training, but are doing jobs that require such qualifications. In this review of available data, there was no reliable data concerning the number of these individuals identified. For this category of inflows therefore, it seems that quantification will depend on future data from a national survey of South Africa's HRST.

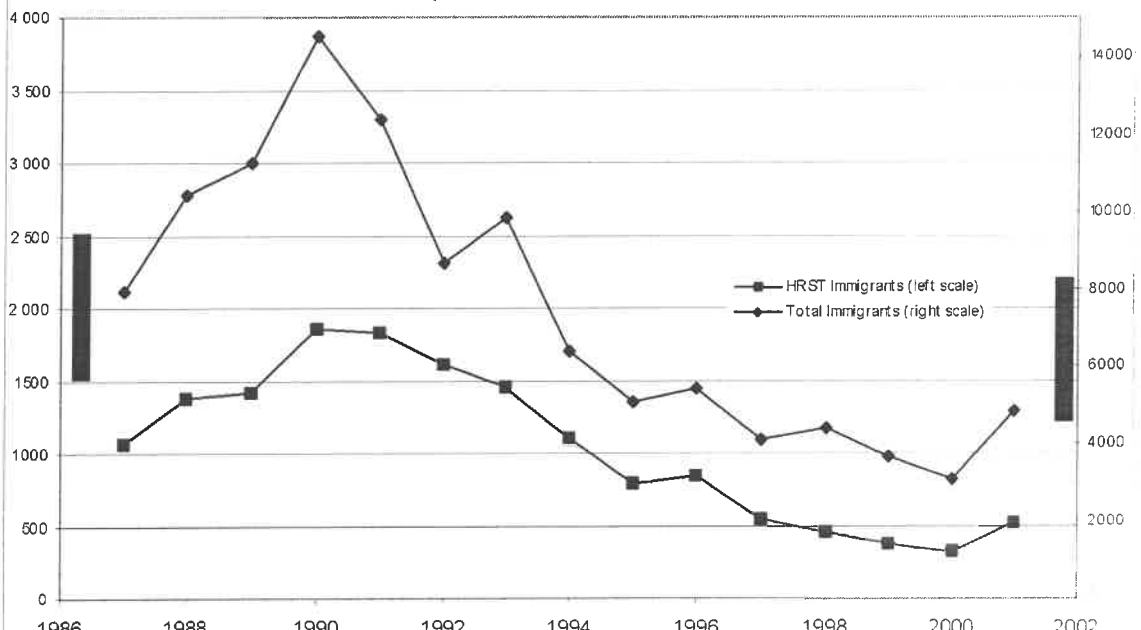
3.2.2.1 (c) Inflows from immigration of non-South African HRST

These are permanent migrants who have moved to South Africa. Appendix 3.1 discusses issues surrounding official statistics regarding these inflows as well as the outflows (emigrants). An interesting issue to emerge from the report in Appendix 3.1

that has not been investigated in detail to date is the fact that official figures appear to be undercounting inflows of immigrants as well as outflows[13].

Despite their shortcomings, official statistics provide the only comprehensive time series data. Figure 3.23 shows historic inflows of immigrants from the official Statistics South Africa migration reports. In the migration statistics, HRST is defined by occupation alone[14]. There is notable symmetry between the annual inflow of non-South African HRST and the total annual immigrant inflows. In this period, 1987 to 2001, HRST inflows peaked in 1990 and have been in a general decline since although the most recent figures indicate potential change.

Figure 3.23 Inflows from Immigrating non-South African HRST 1987-2001



Source: Statistics South Africa Annual Tourism and Migration Reports

The general decline in total and HRST immigrants is again shown in Table 3.7. Comparison of four yearly inflows shows that in comparing the 1989-1992 period to the 1998-2001 period, total inflows have declined by nearly three times and inflows of HRST immigrants by nearly three and a half times.

Table 3.7 Comparison of Four Yearly Inflows

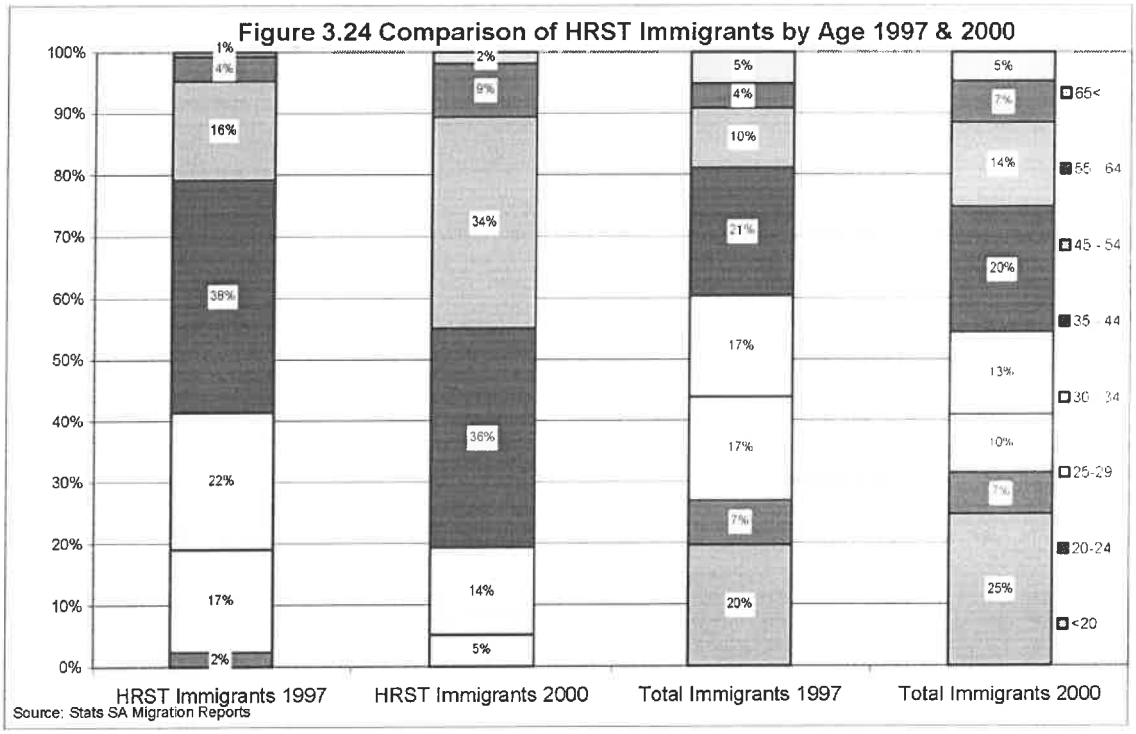
Years:	1989-1992	1994-1997	1998-2001
Total Immigrants	46 834	20 972	15 925
HRST Immigrants	6 715	3 295	1 682

Source: Statistics South Africa Annual Migration Reports.

There has also been a changing nature in the total and HRST immigrant inflows. Immigrants' age structures in 1997 and 2000 are compared in Figure 3.24. A general decrease in 25 to 44 year old immigrants can be seen for both HRST and the total

[13] Section 3.2.2.3 (c).
[14] *e.g.* Professionals and Associate Professionals.

immigrant population. While a slight growth in total under 20 year olds is also seen, the most marked increase is in immigrants over the age of 55. HRST immigrants have a particularly large increase in this respect.



In comparison to age structure, there is relatively little change in the proportion of male to female immigrants in Figure 3.25. There is a slight decrease in the total number of male immigrants, which is more pronounced in the HRST immigrants where the ratio of men to woman went from 8.5 to 1 to 4.7 to 1.

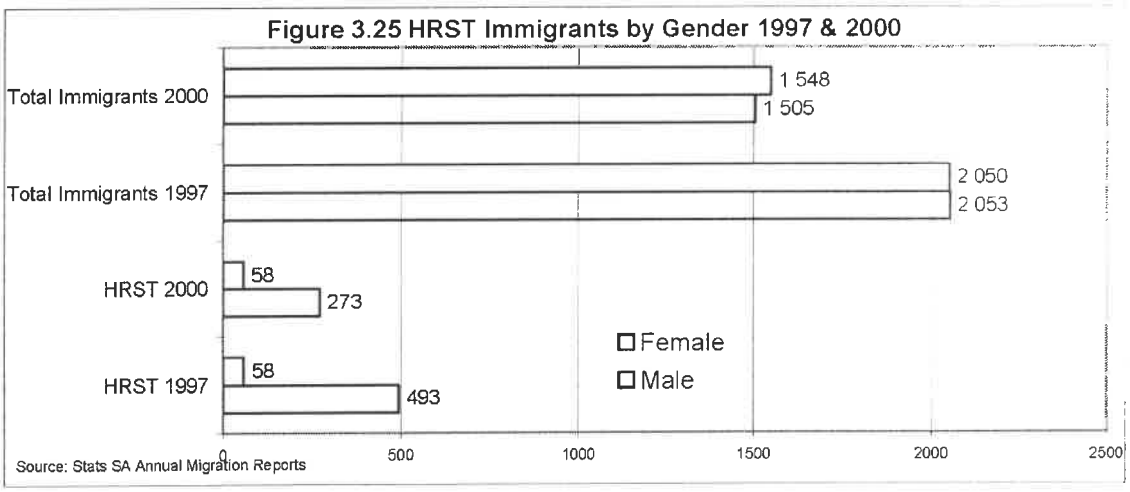
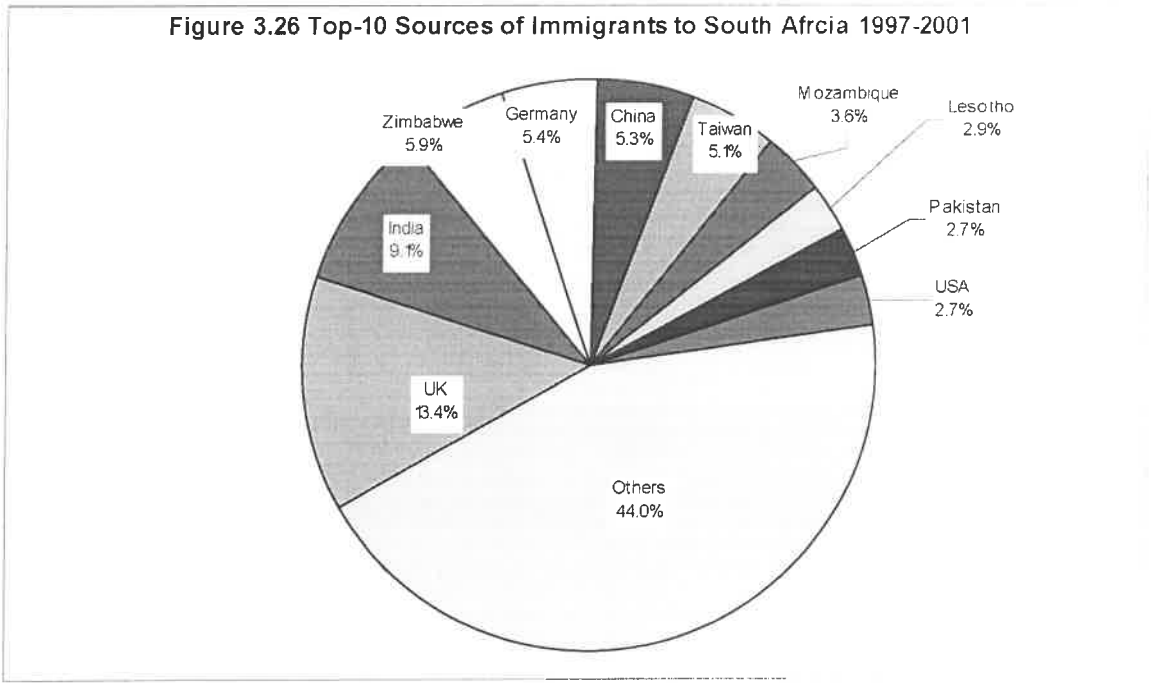


Figure 3.26 shows the top ten source nations of immigrants over the period from 1997 to 2001. In comparison to previous trends there is a notable increase in immigrants from less economically developed nations, which is particularly strong in the most recent years.

Figure 3.26 Top-10 Sources of Immigrants to South Afrcia 1997-2001



In concluding the discussion of inflows of HRST it is worth noting that foreign students enrolled in South Africa HEIs do not count in the immigration statistics. Given their significant and growing numbers, and skilled to highly skilled nature, this is an important factor to remember. While undergraduates might not be engaged in research, there is an important research capacity in foreign post-graduate students. While varying to some extent from year to year, approximately one-fifth of foreign students are post-graduates.

3.2.2.2 Internal Changes to the HRST

This subsection looks at changing characteristics within South Africa's HRST. While inflows and outflows have some influence, internal changes in the estuary's composition is our primary concern.

3.2.2.2 (a) Internal Changes in Fields of Technology Employed

As there has not been any national 'Canberra' type[15] study conducted to date in South Africa, there is no reliable information available on the related technological fields of employed HRST. Some idea about the employment of HRST in various fields of technology is possible through the National R&D Survey. For information on the current division of R&D employment by field of technology see Section 3.3.1.1 and on changes see Section 3.3.2.2 (a).

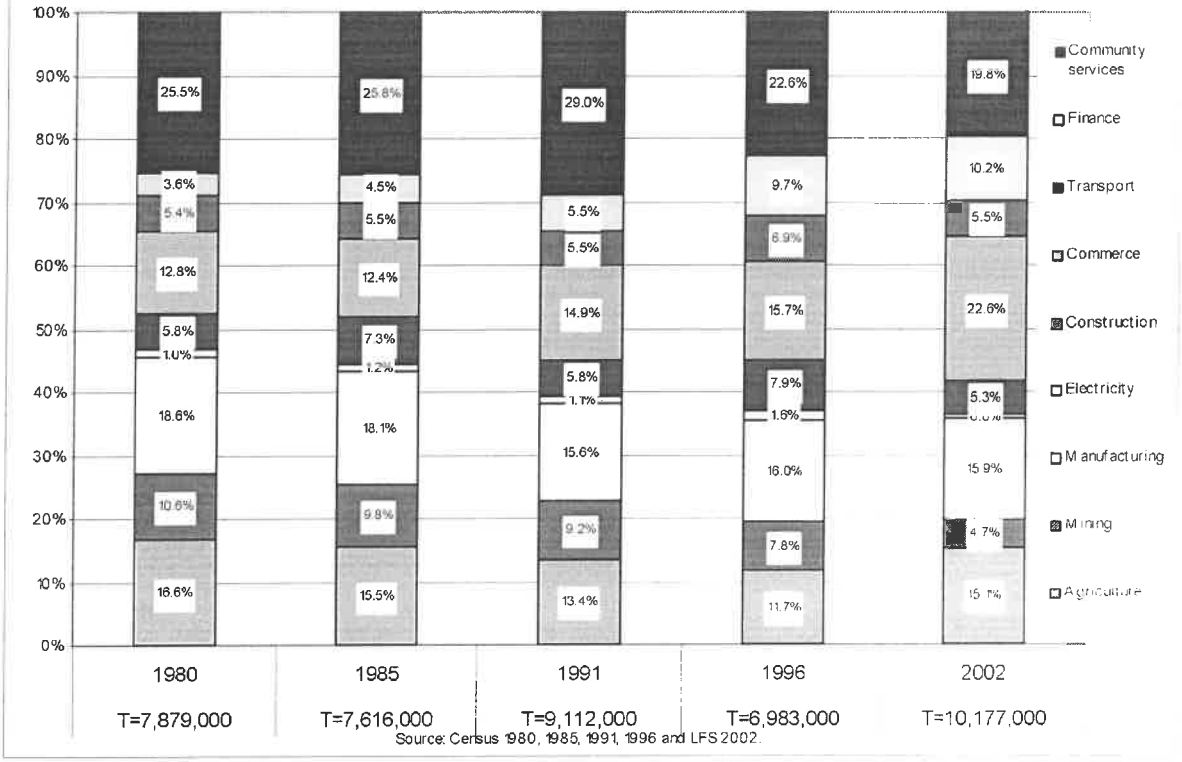
3.2.2.2 (b) Internal Changes in Sector of Employment

Time series data on sectoral employment of South Africa's HRST is not available. Total sectoral employment in South Africa over the last twenty years is seen in Figure

[15] The Canberra manual is a guide published by the OECD on the measure of HRST (OECD 1995).

3.27. Within its nine-sector disaggregation, it shows growth in the proportion employed in finance and commerce, decline in mining and manufacturing, and fluctuating, but relatively constant proportional employment in the other sectors

Figure 3.27 Sectoral Employment in South Africa 1980-2002



Source: Census 1980, 1985, 1991, 1996 and LFS 2002.

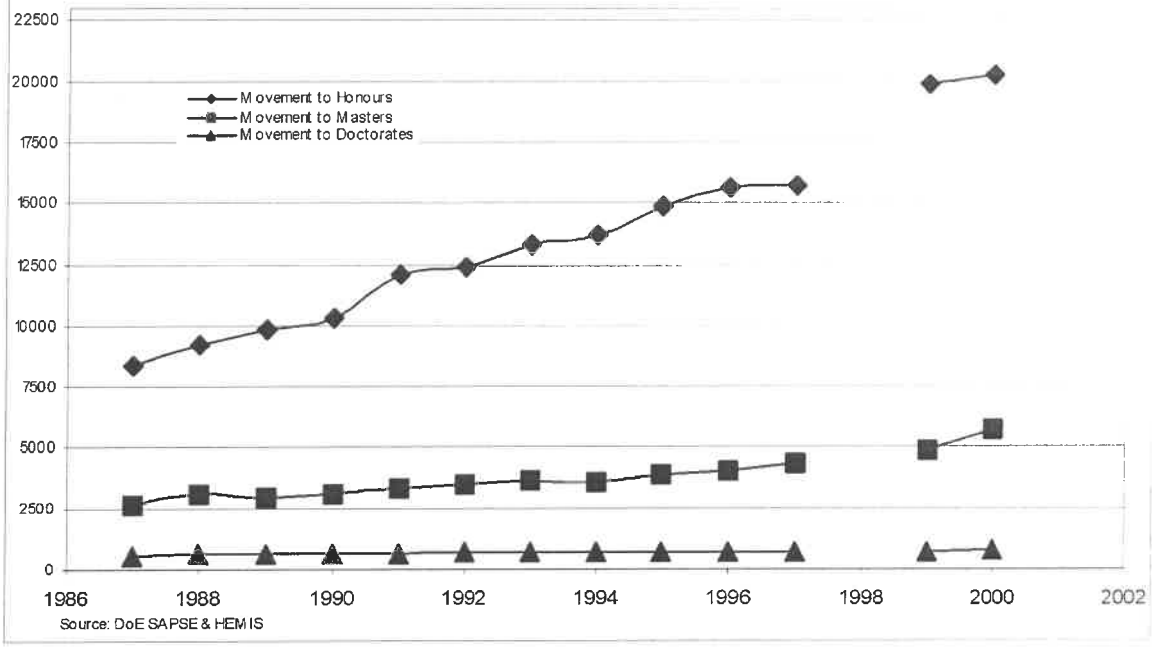
3.2.2.2 (c) Internal Changes in Skills Level and Field of Training

The level and field of formal qualifications is another indicator of change within the HRST. The proxy used to measure these changes is all national post-first degrees granted in by South African tertiary institutions. Ideally data on South Africans training temporarily overseas would also be included in this measure, but it is not available[16].

Another significant component in human capital development is informal training, such as intra-organizational skills development and work experience. Nonetheless, South African honours or higher graduates give an indication of changes in the level and field of training. Figure 3.28 shows trends in the level of HRST training. It shows strong growth in the number of honours level training, slightly lower growth in the masters level, and a relatively static output of doctorates. The last point may be of particular importance in the potential that these highest-level graduates have to influence South Africa's research capacity.

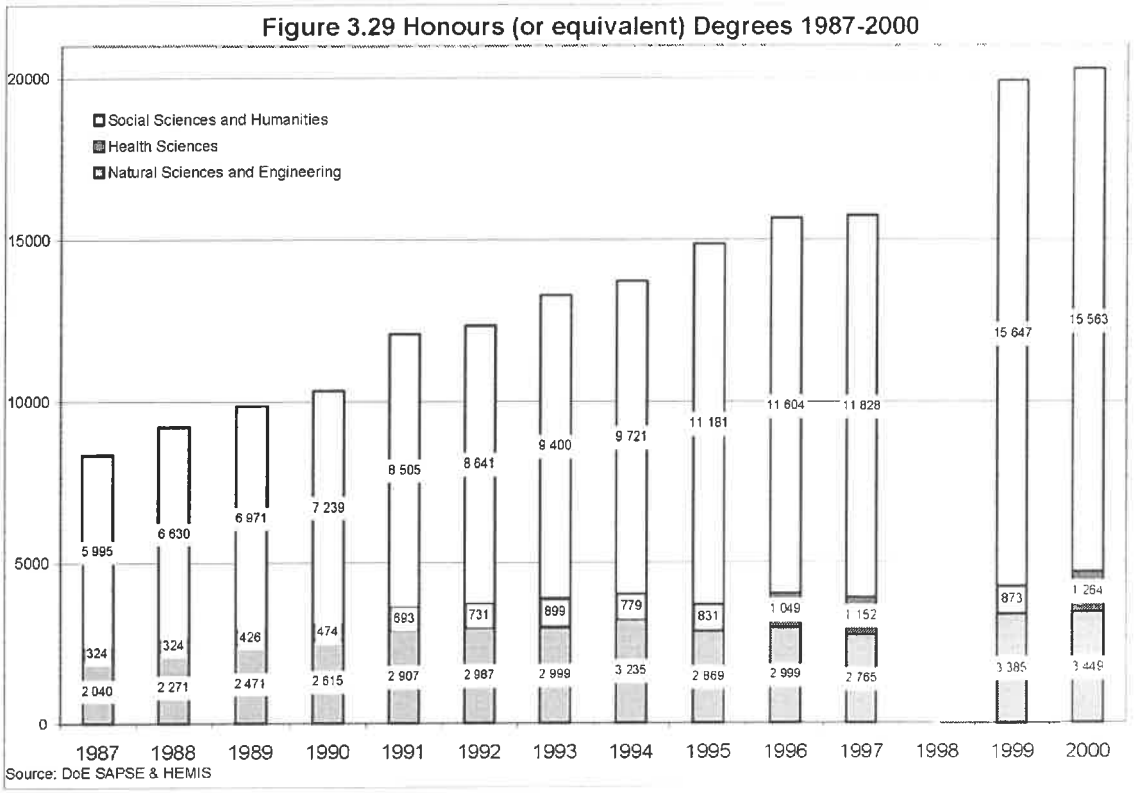
[16] For further discussion on South Africans studying overseas see Section 3.2.2.3 (c).

Figure 3.28 Movements in HRST Skills by Level of Formal Qualificaitons 1987-2000

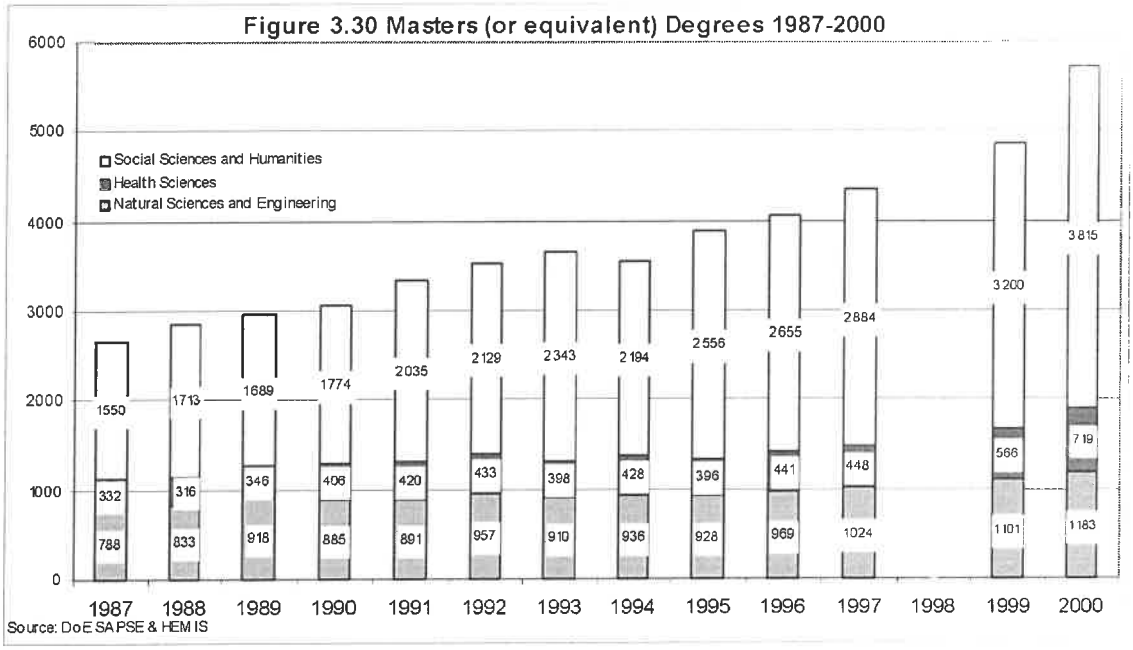


The general field of honours degrees awarded between 1987 and 2000 is shown in Figure 3.29. It shows a growing relative and absolute number of social science and humanities graduates. There is a slight increase in honours graduates in the health sciences, but the number of honours graduates in the natural sciences and engineering has basically remained statistics from the early 1990s.

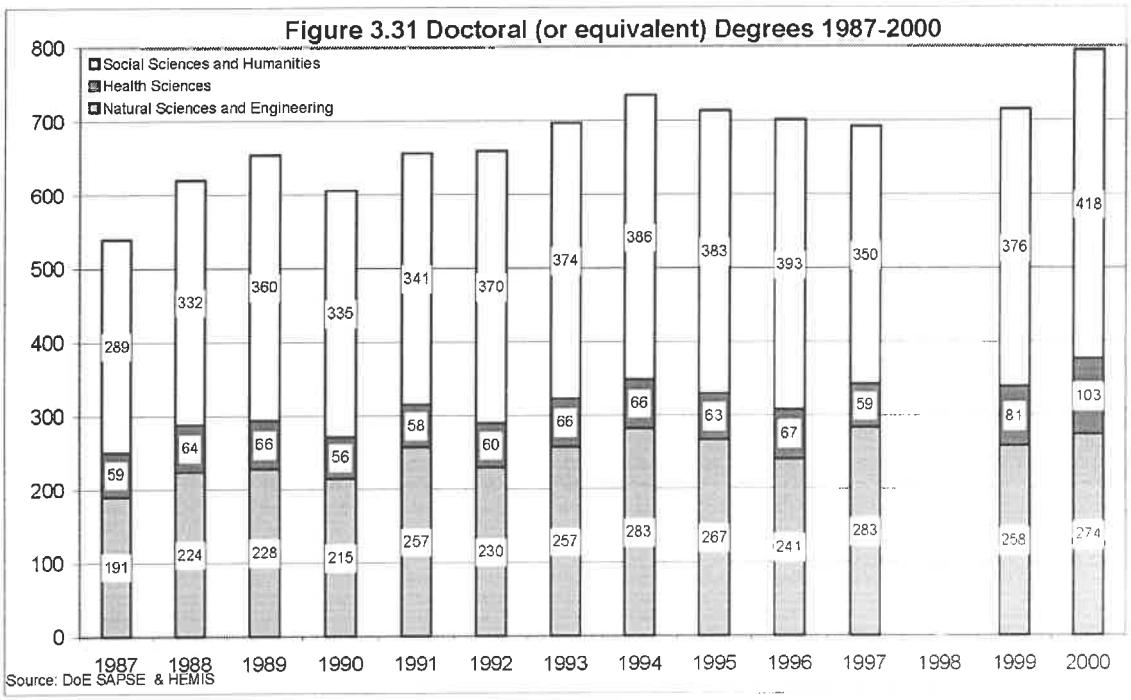
Figure 3.29 Honours (or equivalent) Degrees 1987-2000



The number of masters degrees awarded by general field is presented in Figure 3.30. It is similar to that of the honours level awards, with growth in the social sciences and humanities predominating.



Finally, doctorates by general field of training are presented in Figure 3.31. While much more cyclical and less pronounced than the other levels, there was growth in the annual number of doctorates award from around 550 in 1987 to 800 in 2000. The proportion of natural science and engineering graduates is also much higher at this level.



3.2.2.3 Outflows from South Africa's HRST

3.2.2.3 (a) Outflows from Mortality and Unconditional Retirements

These are the individuals who will not or cannot ever be an active part of the South African HRST again. Within the analogy, this is the evaporation of HRST from the estuary a loss to South African and global human resources. Given that mortality data is not available based on occupation or level of qualification, general mortality rates are used as a rough proxy for this type of HRST outflows. These are presented in Table 3.8. While discussions from the organizational interviews (Chapter Four) indicate that the national rise in mortality is probably less severe for HRST and R&D personnel, the lack of empirical data precludes incorporation in mortality estimates.

Table 3.8 Annual HRST Outflows from Mortality 1997-2002

	National Mortality Rate	Estimated loss of HRST by Qualifications	Estimated loss of HRST by Occupation
1997	0.63%	12 233	10 099
1998	0.71%	15 383	10 613
1999	0.76%	16 341	13 003
2000	0.83%	20 012	13 316
2001*	0.90%	20 978	14 691
2002*	0.98%	24 535	16 780

* Estimates based on projections. Source: Stats SA Release on Reported Deaths 1997-2000

3.2.2.3 (b) Outflows of non-qualified persons moving out of S&T occupations

These individuals, because they do not have formal qualifications, are considered as exiting the HRST stock when they leave occupations that require the equivalent of qualifications, since they no longer fall within the empirical definition of HRST. As with inflows from non-qualified persons[17], lack of available data means that there is no reliable way to quantify these outflows.

3.2.2.3 (c) Outflows of emigrating South African HRST

These are permanent migrants who have left South Africa. As mentioned in Section 3.2.2.1 (c) on inflows, there are serious concerns about the accuracy of official measures of permanent migration. These are discussed in greater detail in Appendix 3.1. That appendix updates the analysis of Brown et al. (2002) for the years 1998 to 2001. The problem of undercounting emigrants is caused by a variety of factors. To illustrate the scale of this phenomenon, the reported Stats SA emigration data is compared with data on South African immigrants from the top five destination nations of South Africans. These statistics are presented in Table 3.9. Based on these figures the scale of under reporting is apparently increasing, rising from a ratio of around 3 to 1 'unofficial' to official emigrants in 1989-92 to a ratio of near 4 to 1 in the period 1998-2000.

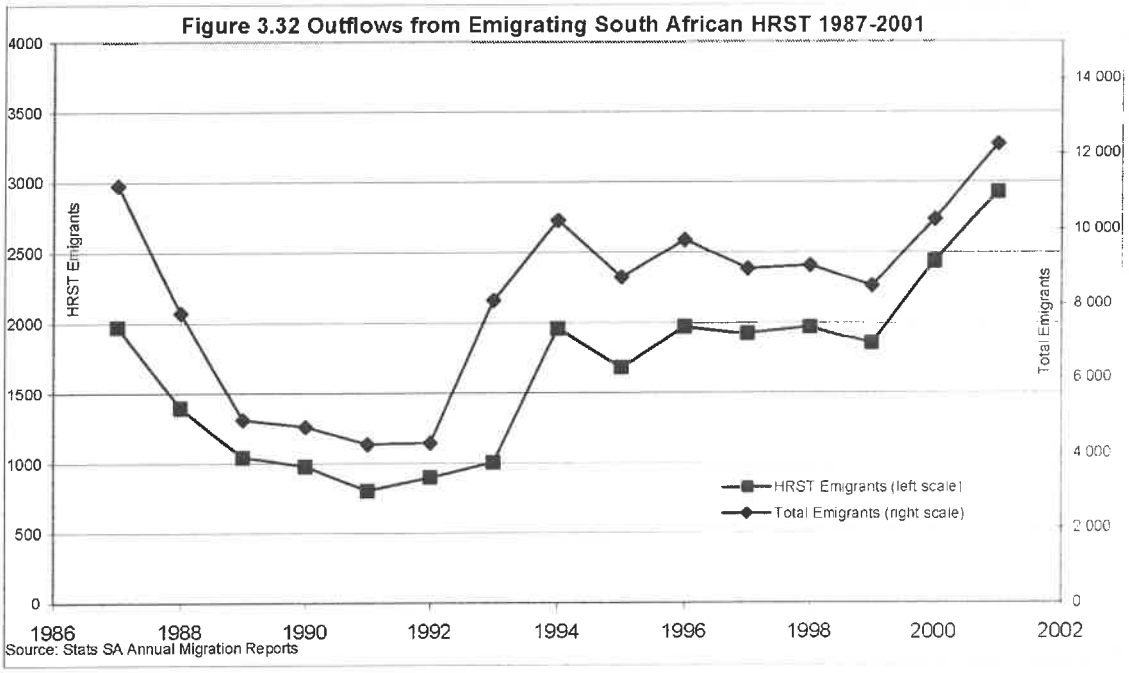
[17] Section 3.2.2.1 (b).

TABLE 3.9 Under Reporting in South African Emigration Statistics for the 'Top 5' Destinations

Total Migration	1989-92	1994-97	1998-2001	HRST Migration	1989-92	1994-97	1998-2001
Immigration Stats SA	12 487	4 866	2 769	HRST Immigration Stats SA	1 949	754	282
Emigration Stats SA	13 988	26 623	27 621	HRST Emigration Stats SA	2 956	5 650	6 563
Emigration based on data from the Top-5 Destinations	54 022	70 344	116 282	HRST Emigration based on data from the Top-5 Destinations	11 772	15 954	25 164

Official statistics are the only comprehensive source of data on emigration and so they are used in Figure 3.32, which shows outflows of emigrating South African HRST. Even more than that with inflows there is a strong correlation between total and HRST emigrants. While annual outflows stabilized in the mid to late 1990s, there seems to be another increase in the early 2000s.

Figure 3.32 Outflows from Emigrating South African HRST 1987-2001



Source: Stats SA Annual Migration Reports

The general increase in emigrants is also seen in Table 3.10, which presents comparative four yearly outflows.

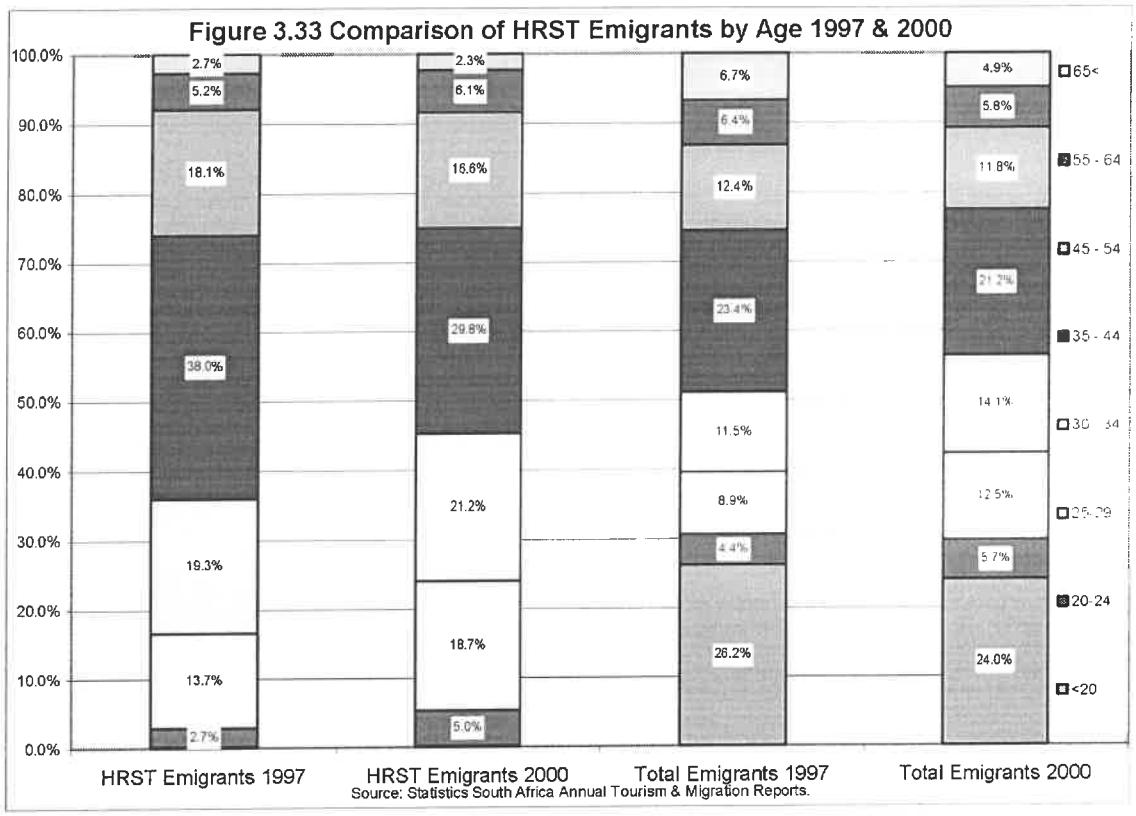
Table 3.10 Comparison of Four Yearly Outflows

Years:	1989-1992	1994-1997	1998-2001
Total Emigrants	18 178	37 614	40 040
HRST Emigrants	3 721	7 534	9 191

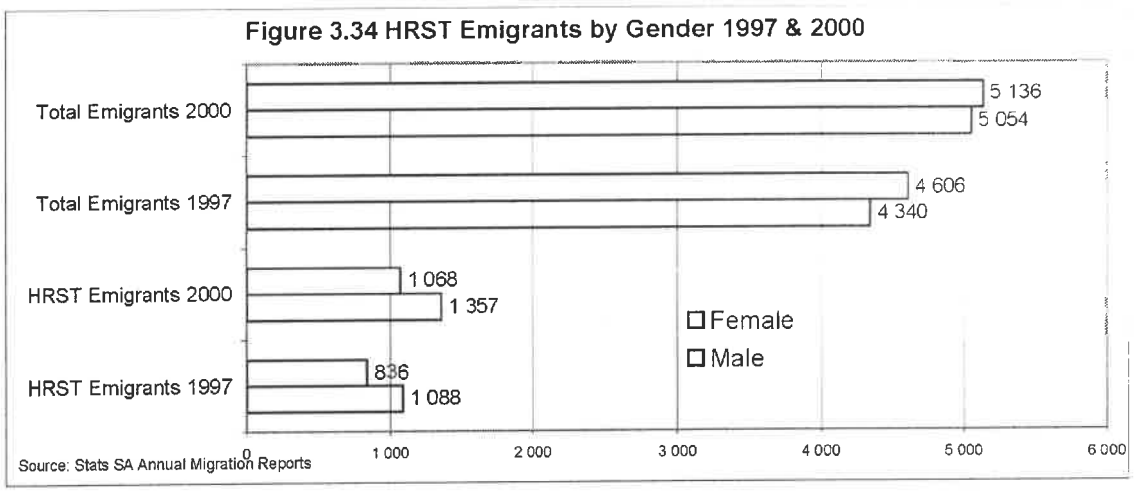
Source: Statistics South Africa Annual Migration Reports.

The trend in age of HRST emigration is nearly completely opposite to that of immigrants. Figure 3.33 compares the age structure in 1997 to 2000. Among migrating HRST South Africans there were increases in those aged from 20 to 34

With decreases in all age categories and type of emigrants over 35 years, except for a slight increase in HRST between the age of 55 and 64.



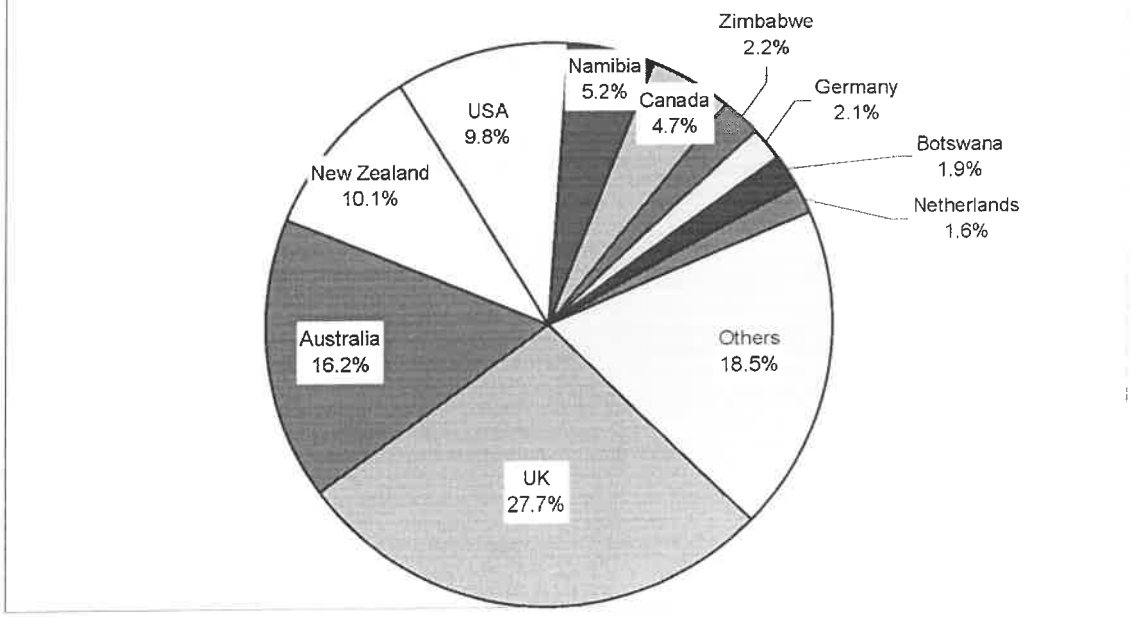
The gender of emigrants has not altered significantly between 1997 and 2000, but Figure 3.34 does show a slight proportional increase in emigrating female HRST. The ratio of emigrating HRST men to women is in notable contrast to immigrants. There is a much less significant gender bias in emigrants than immigrants.



The top ten destination nations of emigrants between 1997 and 2001 are presented in Figure 3.35. Four of these nations were also in the top ten sources of immigrants: U.K., U.S.A., Zimbabwe, and Germany. This would indicate a circulation of human

resources among these nations and South Africa even if the absolute numbers of emigrants were greater than immigrants.

Figure 3.35 Top-10 Destinations of Emigrating South Africans 1997-2001



Another outflow, but one of a temporary nature, is South Africans who study abroad As with foreign students studying in South Africa these flows are not captured in the migration statistics. A detailed study of nations that are destinations for South African students is a useful area of research to develop understanding about the extent by which South Africa's education system is globalised.

Table 3.11 Percentages of Citizens in HEIs Studying Abroad (2000)[18]

Greece	13.09%	Canada	2.38%	Chile	0.98%
Ireland	11.04%	Korea	2.32%	Thailand	0.94%
Malaysia	7.69%	Tunisia	1.52%	Mexico	0.72%
Zimbabwe	7.01%	China	1.47%	Brazil	0.65%
Turkey	4.34%	Spain	1.46%	Australia	0.63%
Germany	2.60%	United Kingdom	1.35%	Argentina	0.39%
France	2.55%	Indonesia	1.01%	United States	0.25%

Source: OECD (2002)

The internationalisation of some nations student populations is given in Table 3.11. It shows the number of the country's nationals studying abroad as a percentage of their total domestic HEI enrolments. For example, based on the data in Table 3.3, total HEI enrolment in Turkey for 2000 was 1,038,500 and there were 45,070 Turks studying in other countries. As not all countries report foreign students in their HEIs these percentages are liable to undercount a nation's population studying abroad

3.2.3 Forces (Dynamics)

[18] These percentages are based on numbers of these nationals reported by other countries in their HEI statistics.

This section surveys analyses on the causes of mobility in South African HRST. It is brief review of a vast literature and attempts to be indicative, rather than comprehensive in coverage. Attention remains at the level HRST, a similar review of forces affecting R&D personnel mobility is left for the chapters dedicated to that purpose, those on organizational and individual perspectives on mobility (Chapters 4 and 5)[19]. Discussion begins with studies on international forces, and then turns to regional (African) dynamics, before concluding with review of analyses specific to South Africa.

3.2.3.1 Global Influences on Mobility of HRST

Globalisation has promoted international specialization. This specialization includes employment opportunities, but globalisation of the labour market is different in nature from globalisation of goods and finance. However, international migrations are not unique to the modern era. Migration of skilled individuals has been complementary to industrial development and integral to individual skills development for centuries.

- There have been two mass migrations in the Western world in recent history. The first was from 1850 to 1913 and the second a 'constrained' mass migration' since the Second World War. Both of these have accompanied major eras of globalisation[20].

- Recent OECD studies on skills development suggest a 'new' environment for internationalisation of higher education is emerging. Nonetheless, there is a long legacy of mobility amongst university students and educators[21].

- To a large extent knowledge circulation depends on individual mobility. This is in part because of the large portion of tacit knowledge that individuals posses. Migration of the highly skilled is therefore a primary means of transferring social capital and integral to the process of scientific legitimacy as well as technology transfer and diffusion[22].

- There is a tendency in economically developing nations to view mobility of HRST as negative. This popular attitude is not clearly demonstrated in the reality. While opportunities and incomes may be pulling a nations HRST to other shores. This mobility generates positive domestic effects, like developing socio-economic networks and potentially even encouraging an aggregate increase in the domestic stock of skills[23].

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[19] The literature survey in Appendix 2.1 discusses the literature on causes of skilled and R&D personnel mobility

[20] See Chiswick and Hutton (2001).

[21] See Throsby (1998), Avvenduto (2000/2001) and Tremblay (2001) for discussion of the recent internationalisation of higher education and its historic context.

[22] See Weel (1999), Mahroum (2000b), and Meyer et al. (2001) for discussions on aspects of this subject.

[23] The potential for migrating HRST to generate incentives for an overall increase in domestic skills is made in Stark and Wang (2001). For a discussion of other positive effects of HRST mobility as well as a historic and terminological discussion of the 'brain drain' phenomenon see Gaillard and Gaillard (1997/1998).

3.2.3.2 Regional Influences on Mobility of HRST

In the southern African region, the size and development of South Africa's economy is an important force in attracting migrants. The Southern African Migration Project (SAMP) has studied the dynamic of migration in the region in considerable detail. They have shown that South Africa is not the only nation in the region attraction skilled immigrants, as Botswana and Namibia are also important destinations (Campbell, 2002). SAMP has traced the evolution of skilled labour mobility in Southern Africa following independence (McDonald and Crush, 2000 and Meso, 2000). As regional trade is advanced and integration with initiatives like the African Union take further form, there is a need for further mobility of skilled personnel and a reconceptualisation of the 'brain drain' that includes a degree of regional 'brain circulation' representing a potential win-win condition.

3.2.3.3 South African Influences on Mobility of HRST

In the late 1990s, the international mobility of skilled South Africans (i.e. brain drain) became part of a significant public debate about skills migration in South Africa. In this environment, several rigorous research efforts were initiated to quantify the 'skills crisis'[24]. Domestic socio-political turmoil and a poor economic climate were seen as pushing South Africans abroad, particularly highly skilled white South Africans. Today, the debate often focuses on the loss on young highly skilled South Africans, seeking job opportunities overseas with higher incomes because of the depreciation of the Rand and with fewer employment constraints from equity legislation. The extent of this 'brain drain' phenomenon has been hard to quantify. What has emerged is a transformation of immigrants, with many skilled Africans from other nations being attracted to South Africa's scientific and technological infrastructure.

- A 1998 survey asked employers whether emigration of their skilled personnel was a concern before and after 1994. Emigration of skilled personnel before 1994 was reported to be of no concern by 78%, negligible concern by 21%, and significant concern by 1% of organisations. After 1994 emigration of skilled personnel was reported of no concern by 41%, negligible concern by 26%, and significant concern by 33% of organisations[25].

- Australia became a major destination of emigrating skilled South Africans, but the U.K., New Zealand, Canada and the U.S. were all major destinations[26].

- A 1996 study found that highly skilled workers in the public sector were not departing at a significant rate and that the vast majority were staying in South Africa.[27]

- Gender appears to be an important influence on mobility, with women being less likely to emigrate than their male counterparts[28].

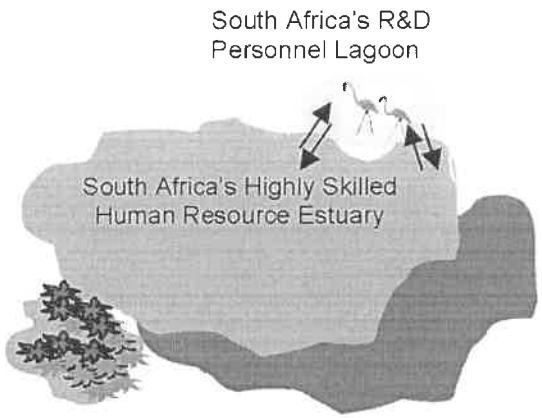
[24] It was in 1996 for example that SAMP was established.
[25] Rogerson and Rogerson (2000b).
[26] See Rule (1990, 1994).
[27] DACST (1996).
[28] Dodson (2002).

3.3 SOUTH AFRICA'S RESEARCH AND DEVELOPMENT WORKERS

This part of the chapter reviews previous analyses of South Africa's research and development (R&D) workers and presents initial data from the current 2002 R&D Survey. As the R&D Survey is ongoing at the time of this writing, complete data is only available for the Science Councils. When data from the Higher Education Institutions, Government and Business becomes available, further analyses will be undertaken.

Within the analogy the South African R&D workforce maybe thought of as a lagoon in the estuary. Thus, conceptually the R&D workforce is a component of the larger HRST estuary. Entrance into and exit out of the R&D workforce requires similar movement into or out of the HRST. In part this is why such a broad definition of HRST has been adopted. In presenting data on South Africa's R&D workforce, some comparisons are made to previous studies. These are merely indicative, as the current 2002 survey is the first to consistently follow an internationally recognized methodology.

Figure 3.36 South Africa's R&D Personnel Lagoon



3.3.1 Characteristics (Stocks)

The size of South Africa's R&D workforce has been measured using various methodologies in previous studies. Table 3.12 gives the reported totals from these studies.

Table 3.12 South Africa's R&D Workforce 1991-2002

Year	Source	Number of R&D Workers Reported
1991	Resources for R&D	37 755
1993	Resources for R&D	30 232
1997	Survey of Resources in R&D (FTE)	19 671
1998	National Technology Audit (FTE)	18 073
2002	R&D Survey	(On-Going)

The figures provided in Table 3.12 need to be interpreted with considerable caution since the surveys that provided the figures for the different years were obtained by different contracted organizations that used different methodologies and approaches for measuring the R&D workforce.

The 1991/92 survey was conducted by the FRD and HSRC and was a fairly thorough survey which covered the business sector more completely than previous surveys and showed that R&D expenditure represented 1.04% of GDP – a figure higher than that recorded in any previous or subsequent surveys.

The 1993/94 survey recorded an apparent 20% drop in the total number of R&D workers and this was accounted for by a 34% drop in the number of R&D workers recorded in the higher education sector. However this R&D survey did not cover the higher education sector as thoroughly as the 1991/92 survey and estimates were apparently made from higher education SAPSE data. Detailed data was only provided for the five largest universities unlike previous surveys which surveyed each institution. Although there might have been some drop in the number of academic research staff at higher education institutions between 1991 and 1993 the drop in the number of personnel involved in research is unlikely to have been as large and dramatic as that indicated by the survey estimates.

In the 1997/98 survey a completely different survey instrument was used compared to previous years and the higher education sector was again not surveyed thoroughly. It must also be noted that the figure provided here is in full time equivalents (FTE) and not headcounts. Full time equivalents measure the proportion of time that researchers, technicians or other support staff spend on R&D during a particular year. One FTE may be thought of as one person-year.

In the 1991 R&D survey the ratio of FTEs to headcounts was 1.7 and in the 1993 survey the equivalent figure was 1.55. Multiplying the 1997 estimate of 19 671 R&D workers by 1.55 gives an approximate headcount of 30 490 R&D workers which is very similar to the figure provided for 1993.

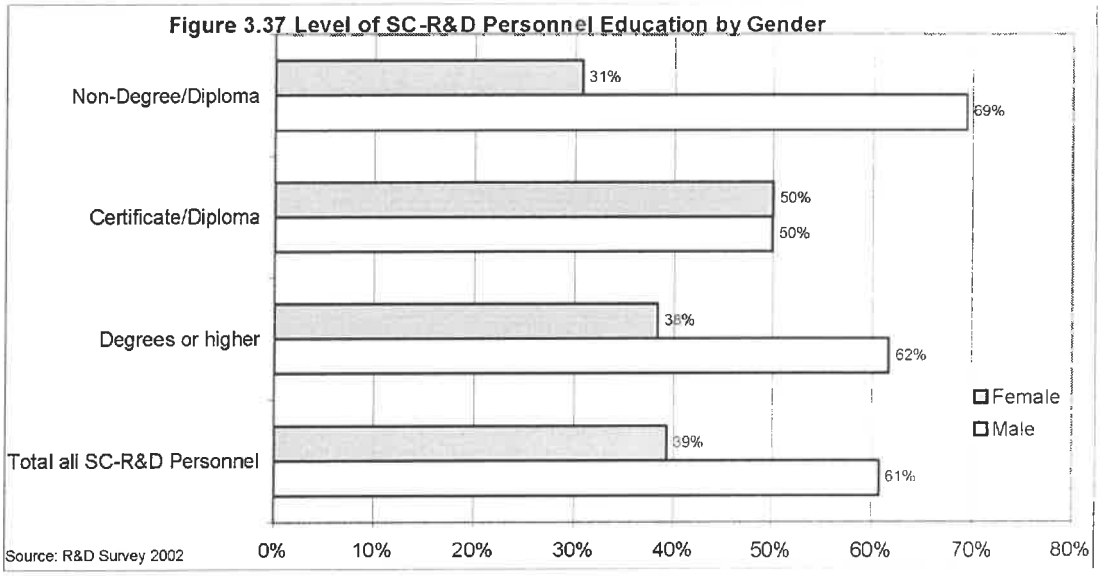
The National Research and Technology Audit figure of R&D workers for 1998 was not based on an R&D survey methodology and in the Audit the business sector was sampled rather than surveyed. The figure provided is an FTE estimate but cannot be regarded as compatible with figures provided by R&D Surveys.

The real concern is that South Africa does not have an accurate record of the number of R&D workers in the S&T system. The 2001/02 R&D Survey is aimed at providing a comprehensive and thorough survey which should provide a more valid and reliable picture than previously available. No real trends or conclusions can be accurately drawn from the previous surveys because of the above and other problems in the way that surveys were conducted, data were gathered and the estimates and assumptions were made in deriving the final figures.

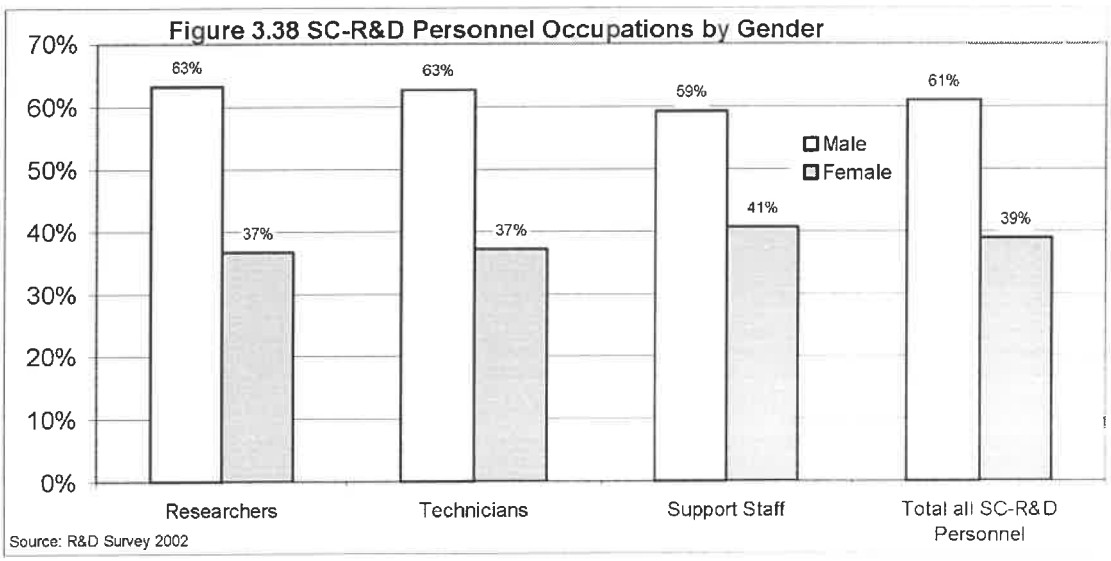
3.3.1.1 Demographics of South Africa's Science Councils R&D Workforce

Demographics of the Science Councils R&D (SC-R&D) workforce are the primary focus of this section. In 2002, the total size of the SC-R&D workforce was 5,800 this

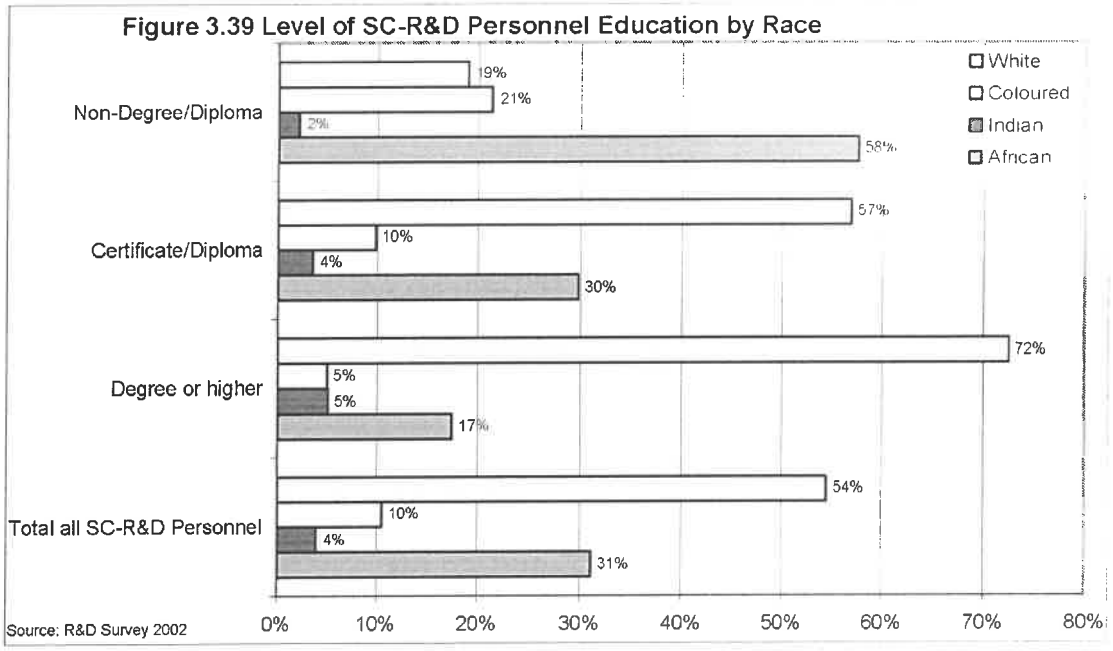
includes all researchers, technicians and support staff. In 2002, 22% of the SC-R&D workforce had qualifications at the level of a degree or higher, 35% had diploma or certificate level qualifications and 42% had no formal qualifications. Figure 3.37 profiles qualifications of the SC-R&D workforce by gender.



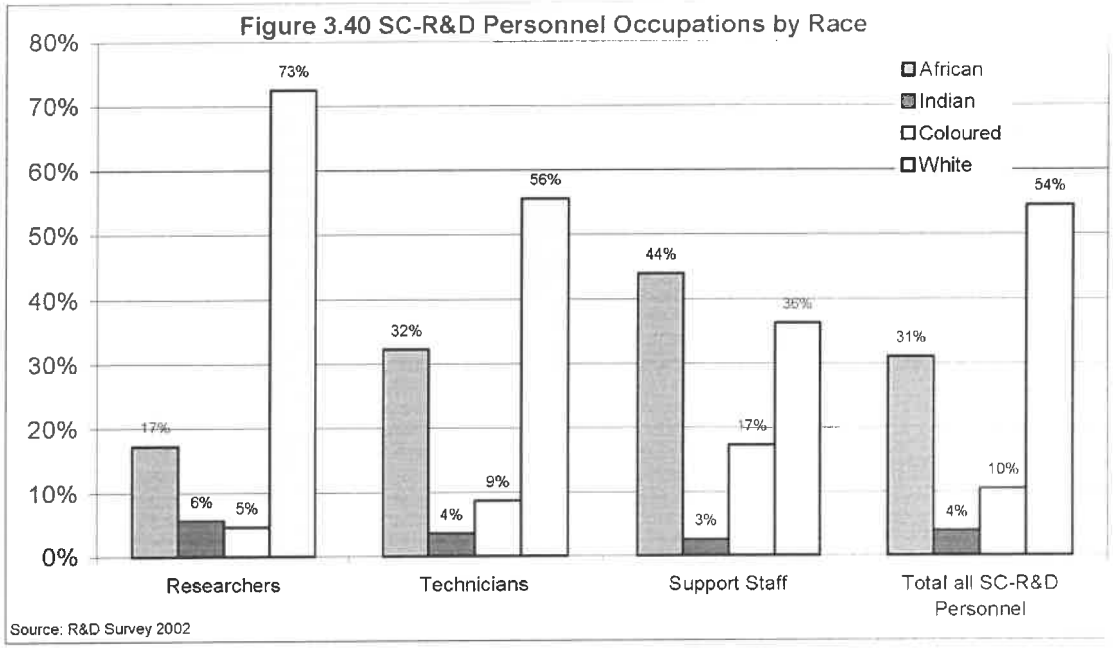
The SC-R&D workforce is composed of three occupational categories, researcher, technician and support staff. In 2002, researchers accounted for 39% of the workforce, technicians 23% and support staff 38%. These categories are reported by gender in Figure 3.38.



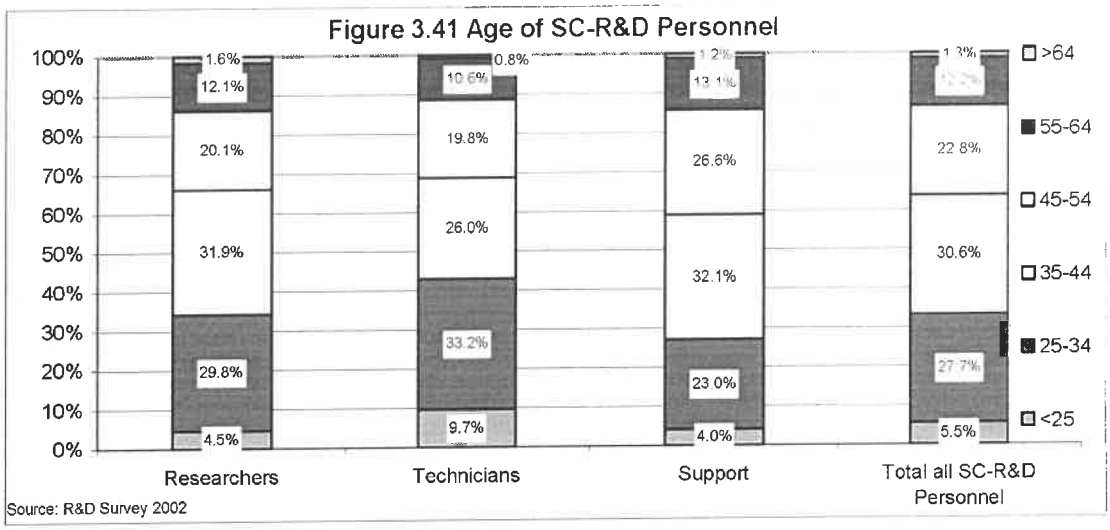
The SC-R&D workforce can be disaggregated according to its racial composition, as such 54% were White, 31% African, 10% Coloured, and 4% Indian. Figure 3.39 subdivides these groups according to their highest level of formal education.



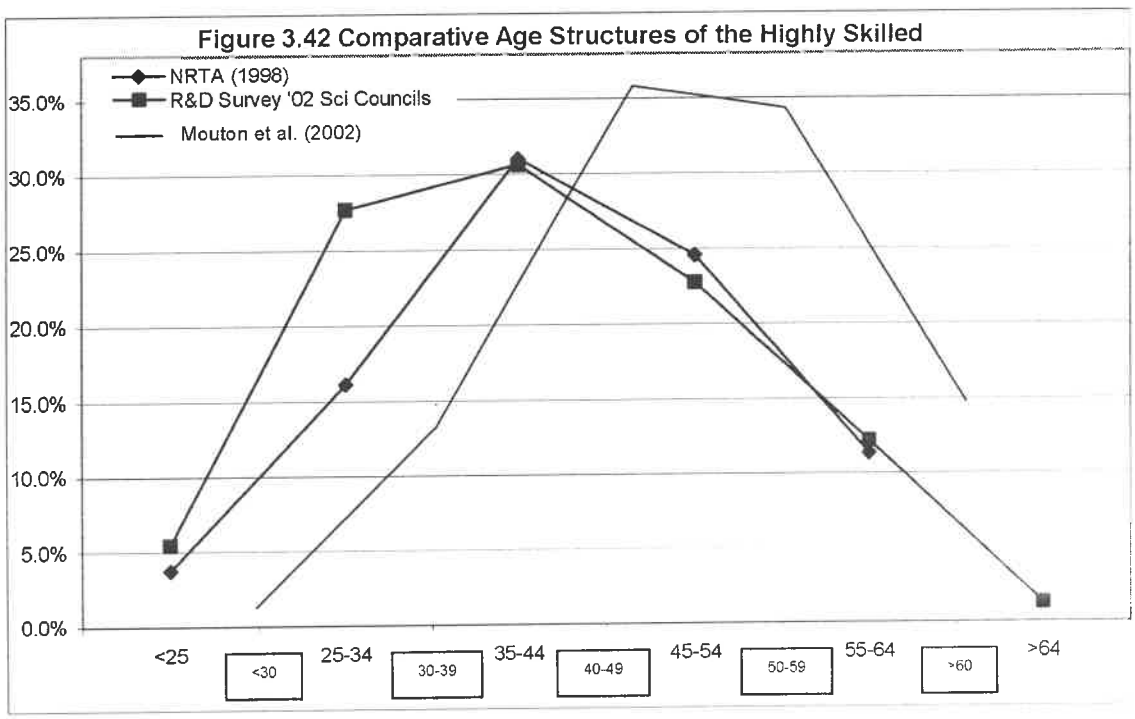
The occupation of SC-R&D personnel is presented in Figure 3.40 by race. In comparison to the total workforce there are a disproportionate number of white researchers (73% versus 54% of total), African support staff (44% versus 31% of total), Coloured support staff (17% versus 10% of total) and Indian researchers (6% versus 4% of total).



The age profile of the SC-R&D workforce is presented in Figure 3.41. It shows the majority of the workforce is between 25 to 44 years old. Amongst the three occupational categories, Technicians have the youngest profile and support staff the oldest.

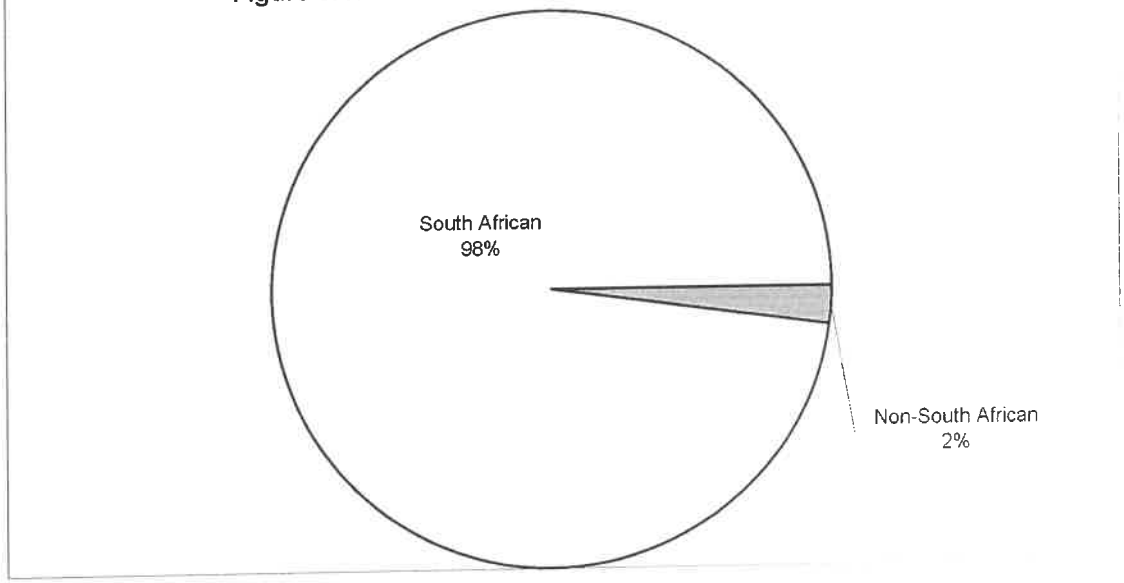


The age profile of SC-R&D workers from the 2002 R&D Survey is compared in Figure 3.42 to that of the 1998 National Technology Audit's profile of the R&D workforce and Mouton et al. (2002) analysis. The 2002 R&D Survey shows a more normal distribution of young and old workers than expected. Studies by the Centre for Interdisciplinary Studies at the University of Stellenbosch indicated that only 15% of research outputs (publications) were produced by researchers less than 40 years old and nearly 50% were produced by researchers older than 50 years old (*Op Cit.* 2002). While academic researchers need to be included for a clearer picture, it appears that there may be more young researchers in the system than previously thought.



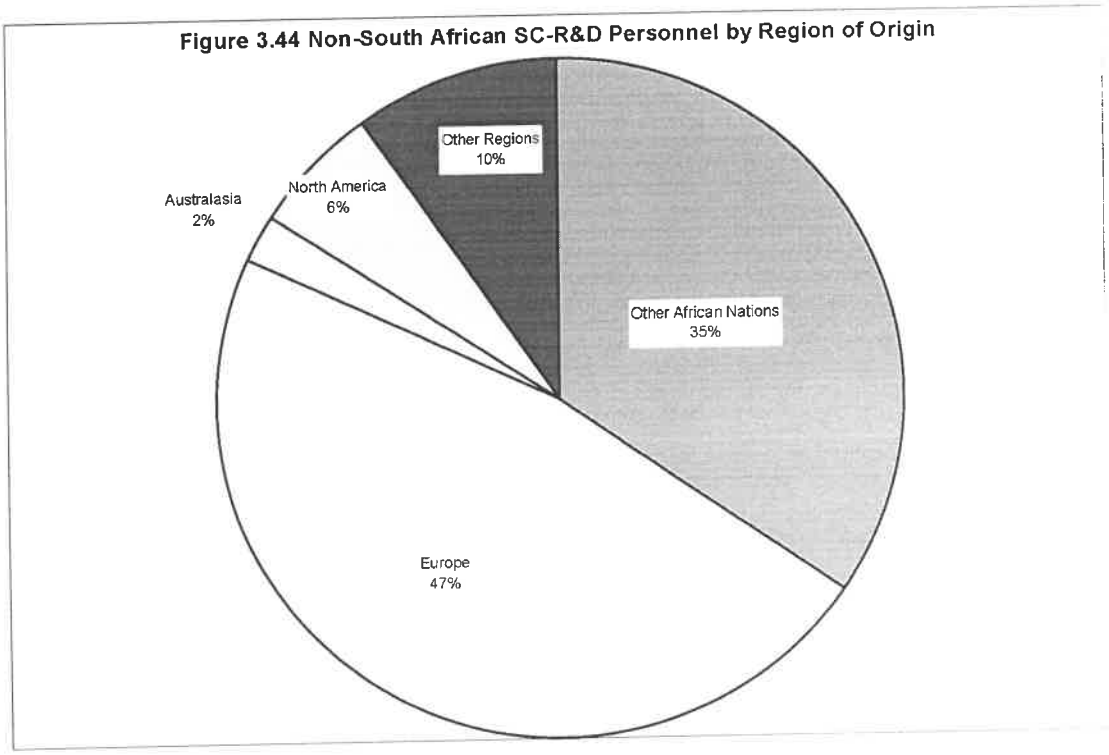
The SC-R&D workforce is overwhelmingly composed of South African citizens as Figure 3.43 shows. Non-South African citizens only accounted for two percent of the workforce.

Figure 3.43 SC-R&D Personnel in 2002 by Nationality



While the absolute number is small, it is worth noting that of the non-South African SC-R&D workers most were either from Europe (47%) or other African nations (35%). Figure 3.44 gives a regional breakdown of the non-South African SC-R&D workforce.

Figure 3.44 Non-South African SC-R&D Personnel by Region of Origin



3.3.2 Movements (Flows)

This section reviews the inflows and outflows to the R&D lagoon from the HRST estuary. As the R&D workforce is a subset of the HRST, external movements from or to South Africa are also reflected in HRST mobility. Again, analysis is limited to information on the Science Councils from the 2002 R&D Survey and in particular from the section in that survey on the mobility of R&D personnel.

3.3.2.1 Inflows to SC-R&D Occupations

These are newly hires for the year 2002 by the Science Councils. This is used as a proxy for inflows, but is problematic in that there is no means to differentiate an individual who is entering the SC-R&D workforce for the first time or one who has been working in an R&D job previously and is just changing occupation. Nonetheless, Table 3.13 presents the inflows to Science Council R&D positions by nationality, level of qualification and occupation.

Table 3.13 Inflows to Science Council R&D Personnel

Occupation	South African	Non-South African	Total New R&D Personnel	Level of Qualifications	South African	Non-South African	Total New R&D Personnel
Researchers	307	21	**328**	Degree or higher	388	21	**409**
Technicians	153	0	**153**	Non-Degree	240	1	**241**
Support Staff	168	1	**169**	**Total**	**628**	**22**	**650**
Total	**628**	**22**	**650**	Source: 2002 R&D Survey			

3.3.2.2 Internal Changes in SC-R&D Personnel

The Science Councils reported departure of 776 members of their R&D workforce in the year 2002. This represents a 13% annual turnover of staff. Employers requested the destination of these workers. There is obviously some discrepancy possible between actual and reported destinations of personnel. Knowledge of staff destinations is also limited. There was a reported 59% knowledge of staff destinations, but this varied substantially according to race and nationality as Table 3.14 illustrates. Thus, destinations of 452 R&D personnel were reported known and these forms the basis upon which the remaining internal change and outflow data is calculated.

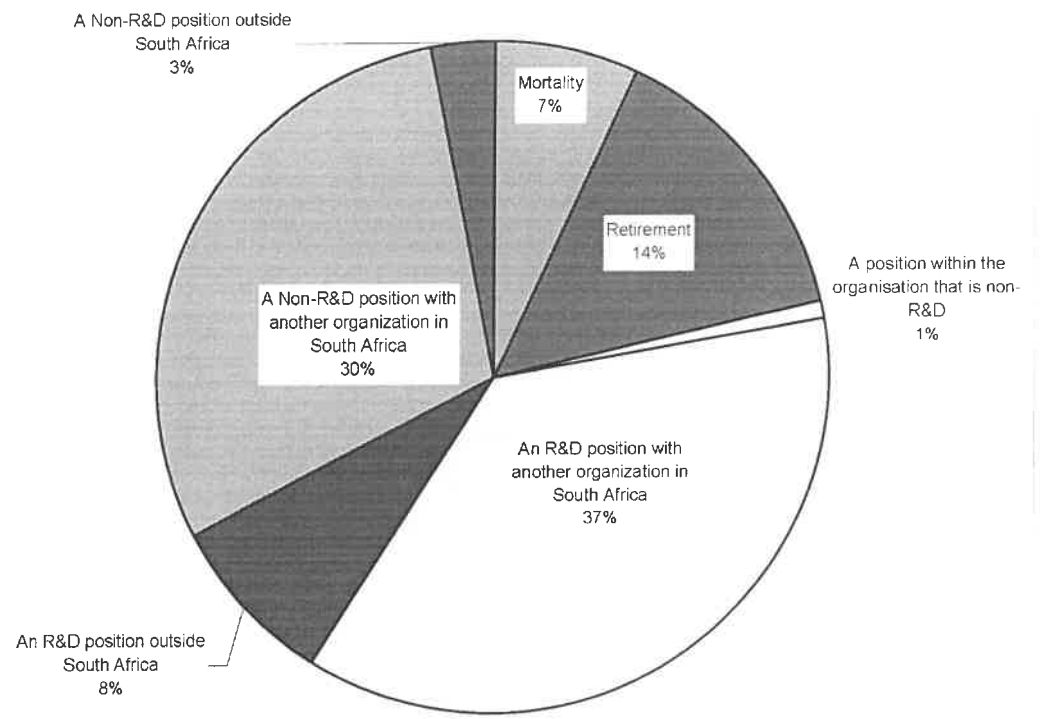
Table 3.14 Reported Knowledge of R&D Staff Destinations

Race / Nationality	Percentage Whose Destination was Reported Known	Race / Nationality	Percentage Whose Destination was Reported Known
White	74%	Coloured	44%
Non-South African	71%	African	39%
Indian	46%	Total all SC-R&D	59%

Within our conception of the national R&D system, movement from one South African R&D organization to another is not an outflow, but an internal change in the 'R&D Lagoon'. Based on the SC-R&D data, at 37% movement to other South African R&D jobs accounted for the largest destination of R&D personnel. The breakdown of destinations for departing R&D workers is given in Figure 3.55. Science Councils role

in the human resource development of South African researchers may be part of the explanation for 'other South African R&D jobs' ranking so high among the departing SC-R&D personnel[29].

Figure 3.45 Reported Destinations of Departing SC-R&D Personnel in 2002



3.3.2.3 Outflows from SC-R&D Occupations

A profile of all departing SC-R&D personnel is given in Table 3.15. The figure of 776 departures includes the 165 personnel who remained in South African R&D occupations and the 315 whose destination was unknown and so is not a true representation of 'outflows' at a national level. From the figures discussed in Section 3.3.2.2 it is estimated that 63% of those who departed moved out of South Africa's R&D Personnel Lagoon.

Table 3.15 Outflows from the Science Councils

Occupation	South African	Non-South African	Total Departing R&D Personnel	Level of Qualifications	South African	Non-South African	Total Departing R&D Personnel
Researchers	308	13	**321**	Degree or higher	381	12	393
Technicians	181	0	**181**	Non-Degree	382	1	383
Support Staff	274	0	**274**	Total	763	13	776
Total	**763**	13	776				

Source: 2002 R&D Survey

[29] For further discussion see Box 4.2 in Chapter Four

3.3.2.3 (a) Outflows from mortality and unconditional retirements

Of the estimated outflows of R&D personnel, mortality/unconditional retirements[30] accounted for 11% of the losses in 2002. These are global losses of skills and can be thought of as evaporation from the R&D personnel lagoon.

3.3.2.3 (b) Domestic outflows to HRST

These are the estimated outflows from the R&D Lagoon that remain within the South African HRST estuary. This was the largest outflow of SC-R&D personnel, accounting for 71% of the total outflows. From the questions in the mobility section of the R&D survey this category of outflow can be broken down according to retirements (32%), non-R&D positions within the same organization (2%), and movements to non-R&D positions with other organizations in South Africa (66%).

3.3.2.3 (c) International outflows to HRST

The final class of outflows are the international 'tidal currents' of mobility. These are flows out of the South African system. This destination accounted for 18% of the SC-R&D personnel outflows in 2002. Data from the mobility section of the R&D survey allows us to differentiate between outflows of this type destined for other R&D positions outside South Africa (73%) and those destined for non-R&D positions outside South Africa (27%).

3.4 Key Issues

- There is a critical need for the development of reliable, enduring and internationally comparable data on mobility. This will allow planning and debates around skills migration to be based around facts and not conjecture.
- Several data sets exist that capture important aspects of mobility. These should be considered as potential sources for mobility data to avoid duplication and unnecessarily burdening organisations.
- Mobility of Skilled South Africans and South Africa's R&D personnel is a part of an international phenomenon that most nations are addressing.
- Many areas in the quantification of human resource mobility warrant further analysis. Currently, several South African studies are adding to our knowledge of mobility. A couple of important areas of further research mentioned in this chapter are:

- Further analyses of R&D personnel mobility from data in the on-going 2002 R&D Survey.
- Up-dating comprehensive national statistics with data from the 2001 Census

[30] Unconditional retirements are those who for medical reasons will never return to an S&T or R&D occupation.

Chapter 4 - Mobility from the Experience of Organizations

4.1 Introduction

Organizations can act to encourage, discourage, and direct the mobility of their research and development personnel. In order to capture the influence that organizations have on the mobility of South African R&D workers, a series of interviews were undertaken with organizations conducting R&D in select fields of technology. This chapter presents the findings of those interviews.

General and then some technology specific characteristics of mobility are reviewed. Emerging from this profile is a clearer understanding of the practical difficulty that exists in examining mobility, but also the crucial nature such an examination has in policy formulation and review. For instance, while temporary mobility is often viewed as a good feature and permanent mobility as a bad feature, permanent mobility may facilitate knowledge diffusion that is notably positive. If one looks further at this example of permanent mobility, the complexity of mobility and incompleteness of quantitative measures alone becomes clearer.

Intra-organizational permanent mobility of a worker from the R&D department to a non-R&D position in operations or management may facilitate knowledge diffusion about critical technologies. This type of permanent mobility of R&D workers to non-R&D position is likely to enhance the organization's competitiveness, particularly if there is a circulation of knowledge back to the R&D division as well. On the other hand, if the organizational culture is such that the technical knowledge of the R&D worker is ignored in their non-R&D position, permanent mobility is of the R&D worker is most probably negative and of the M.B.A. Drain[31] sort. Therefore, a statistic indicating a significant movement of R&D personnel to non-R&D positions in an organization does not tell us about the functionality or dysfunctionality of these moves.

Similar complexities and contextual influences arrive in many aspects of R&D personnel mobility. The present chapter is an initial effort to guide one through these complexities and interactions in an examination of mobility. With its focus on the organization and the field of technology there are several important policy implications that emerge. In particular, it brings attention to the necessity of ongoing reviews of policy effects *vis á vis* policy intentions as part of the process of good governance.

4.2 Issues Concerning Mobility of South African R&D Workers

A basic distinction can be made between issues concerning temporary and permanent mobility. The overwhelming attitude towards temporary mobility was positive. It was seen as facilitating knowledge diffusion and development among R&D personnel. Most organizations had some formal or informal initiative to encourage temporary mobility of their R&D personnel. Often this was an aspect of

[31] M.B.A. Drain is a term mentioned in the interviews to describe the loss of R&D personnel to non-R&D occupations, often within the organisation, but in management positions.

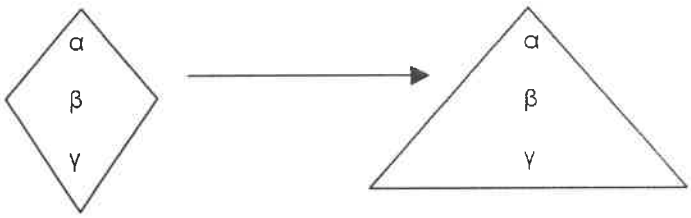
mobility that was mentioned as being an area that an organization was looking to expand because of the positive benefits it created.

An area where temporary mobility was seen as negative was in its generating permanent mobility i.e. turnover. The details of the process varied, as did the destination of R&D personnel[32], but at its essence the inter-personnel networking that occurred during temporary mobility led to turnover. While this was frequently mentioned as a cause of R&D personnel loss, it was also noted as a means of R&D personnel recruitment by several organizations.

Box 4.1 The Geometry of Mobility
Part One: Skill Endowments and Research Structure

Experience and ability varies across an organization. The landscape of skills in South Africa is such that there is a relative scarcity of highly skilled human resource, but a proportionately strong endowment of semi-highly skilled human resources. This has led some organizations to transform the geometry of their research structure to accommodate these endowments.

We can differentiate among three levels of R&D personnel in an organization. At the top (α) are research champions; they are skilled researchers, but also strong managers of research projects. In the middle (β) are the individual researchers. They are skilled researchers, but are not strong research managers. At the base are the research assistants (γ), these are crucial to research in their support of research, but are not individual or multi-project leaders.



In order to utilize the relative endowment of semi-highly skilled human resources some organizations are encouraging a 'triangular' research structure. This is a transformation from the highly skilled foundation of a 'diamond' shaped research structure. While the triangular structure requires a lot more delegation and coordination of research tasks by the more highly skilled researchers, it allows a more efficient use of available human resources.

Permanent mobility was a much more nuanced area, with distinctions being made between inflows and outflows. Inflows were often described as being available, but not at the level of competency to undertake research without some mentorship. In several fields of technology this was noted as being changed from the past and seems to be related to those fields that historically depended on the science councils to develop young researchers.

There are new institutional structures that could be used to fill this gap in research skills; most prominent among these are the sector education and training authority

[32] Destination of R&D personnel in this instance could be to a non-R&D position within the organization, to other South African and non-South African R&D positions, as well as to non-R&D positions both South African and non-South African.

(SETAs). Five SETAs overlap the sectors in four out of our five fields of technology[33], to date the SETAs have been focused on facilitating relatively lower level skills and not those that would increase the number of potential R&D workers.

BOX 4.2 The Impact of Contract Research on the Science Councils

Over the past ten years all of South Africa's national science councils have been under increasing pressure to decrease their dependence of government funding. This has forced them to emphasize short-term contractual research. While this has increased their self-sufficiency it has come at a cost. Research and consulting must co-exist in the science councils. This has been noted as straining R&D personnel, with commercial pressures taxing individuals interested in a research environment and research pressures taxing individuals interested in a commercial consultancy environment.

The pressure for consulting turnover has also decreased the duration of research projects. This has constrained the amount of original R&D within the science councils and also meant that the science councils have had to shed positions of lower researchers because the turn around time on projects does not allow adequate skills development to make a contribution. As such a major structural capacity in R&D personnel development has been removed or reduced from the South African national system of innovation. Changing funding mechanisms within the science councils have therefore altered their role in national research system, both technologically and in human resource development.

Outflows of R&D personnel were often seen as negative, but not because of the headline grabbing 'Brain Drain', rather organizations most frequently expressed their concern about their R&D personnel who left the R&D division, but stayed in South Africa taking up a non-R&D position. Frequently this involved intra-organizational mobility and has been referred to as the 'M.B.A. Drain'. On the positive side, several organizations look at permanent outflows as means to bring new and fresh ideas into the organization, indicating that too little permanent mobility was occurring.

Box 4.3 Mobility of Researchers in Other Nations: The Spanish Experience

As an initial step to develop empirical information to support the European policy priority facilitating mobility of researchers, a study on the mobility of Spanish researchers was recently conducted (Cañibano 2002). Analysing attitudes towards temporary mobility, permanent mobility and perception about the role of mobility. It found:

- Financial considerations were not important motivations for temporary mobility, but were for permanent mobility.
- Scientific interest of research projects were the most important motivation for both temporary and permanent mobility
- While most researchers were satisfied with their own level of mobility, they thought that their colleagues' level of mobility was inadequate.
- As to the role mobility plays: "*Researchers attach great importance to mobility as a means of disseminating knowledge, in terms both of innovation systems in general and their own personal experiences. They consider that mobility has a positive effects on their learning, creative and innovative capacities*" (p. 20).

[33] These are the MERSETA for automotive technologies, the LGWSETA & the FIETA for Environmental technologies, the ISETT for ICTs and the MQA for mining and metallurgical technologies.

The market for South Africa's R&D personnel is fundamentally influenced by its research capacity. Globalisation has been a tremendous influence in changing the national research capacity. In confronting the multi-dimensional socio-economic transformation that globalisation has brought to South Africa it is important to realize the accelerated pace and associated strain integration in the global economy has brought to South Africa. Because of international isolation South Africa kept the global economy at arms length for many years. With the end of isolation in the 1990s South Africa was forced to rapidly face up to the competitive challenges and opportunities that the global market carried. Thus, while most nations have had fifty years following the inter-war era of isolation to adjust to globalisation South Africa has had ten.

Box 4.4 Managing the Forest of R&D Worker Mobility

Managing R&D personnel mobility is a reality that organizations conducting research in South Africa must confront. Several methods of management use a forest analogy. One area were scarcity is particularly strong is in attraction and retention of affirmative action candidates. To meet their equity targets, several organizations are using a practice of 'growing their own timber'; which develops within the skills of lower skilled equity candidates to a point where they are able to undertake research. Another feature of mobility management mentioned was the clearing of 'deadwood', where in turnover of R&D personnel is used to get out stagnating researchers or to refocus research capacity within an organization.

While adjusting to distortions of its past isolation, the South African research system is also challenged by the developing nature of its economy and the relatively small domestic markets it has in which to generate knowledge feedbacks. In this a chicken and egg situation seemingly exists as domestic markets and domestic producers who will support R&D costs support research capacity. Getting a foot in a field of technology is thereby increasingly difficult, because the global structure reinforce the advantage or pre-existing competency and discourage the emergence of new players.

Box 4.5 Inventive Individuals and Innovative Systems

Rajesh Kochhar, Director of the National Institute of Science, Technology and Development Studies in New Delhi, India gives a historic example illustrating the importance of symbiosis between inventive individuals and a nation's industry:

"A telling example of invention versus innovation is furnished by early 18th-century Europe and what is now the U.S.A. In November 1730, Thomas Godfrey, a 'poor glazer' from Philadelphia, invented what evolved into a sextant, which was used in voyages to Jamaica and to Newfoundland. The next year, in May 1731, the invention was independently made in England by John Hadley. America at the time did not need a sea-faring instrument; accordingly, Godfrey's invention remained a dead end. In contrast, Hadley's invention, independent or not, was immediately adopted by all European nations engaged in a hugely profitable maritime activity. Efforts by Godfrey and his mentors to persuade London to concede his priority failed. Even if Godfrey had been recognized as the inventor of the sextant, all fruits of his would still have gone to Europe." (Kochhar, 1999)

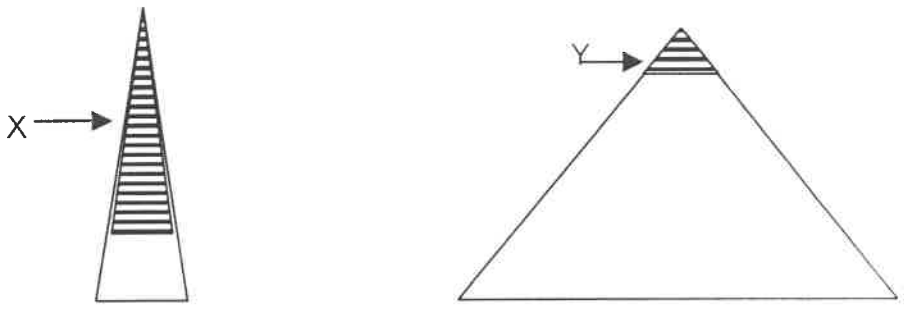
South Africa's research system and capacity in a technology is a crucial influence on the actual mobility and potential entry of R&D workers in that field. If the research

capacity is small, an individual who wants to pursue an R&D career in that field may have to go overseas for training and may remain there if they want to pursue a career specialized in that field. This is not necessarily a bad situation as long as some areas of specialization and unique research capacity remains within the country. Concern arises when there is no field where South Africa can retain an internationally competitive research capacity. If so South Africa will be put in a contentious market of low priced labour competition, with obvious difficulties in improving its overall economic development.

A recent study of African scientists offers some encouraging findings regarding development of Africa's research capacity (Gaillard and Tullberg, 2001). It surveyed over 700 scientists in 20 African nations, including South Africa, who had been supported by two international funding initiatives. An increasing local training capacity was seen in the study, as indicated by less overseas training among younger scientist. While contributing to solving their nation's social and economic problems was mentioned as a leading priority, two-thirds also said that they had not changed their research orientation during their career. In discussing what they saw as the primary constraints on their research, lack of funds was the first, followed by limited equipment and poor library facilities (*Ibid.* 2001, p. 42).

Box 4.6 **The Geometry of Mobility**
Part Two: South Africa's Research System and its Competitiveness

With their competition on an international market, South African companies must keep pace with the innovations of the global competitors. While a lot of important innovation occurs in operations, R&D is an area of strategic competence that many globalised companies are using to retain control over internationally dispersed operations. In this context South Africa's relatively small research capacity and the large proportion of its internationally competitive firms occupy create an area of strategic concern. The situation is illustrated below for the imaginary South African multi-national 'Jozi'. In South African it accounts for X research capacity out the 'South Africa triangle' while if it where to relocate to a more country with a more extensive research capacity it would account for area Y in the 'Nation Z triangle'.



'South Africa' 'Nation Z'

In looking at its dynamic competitiveness as a multinational firm Jozi must consider the comparative likelihood of generating commercially successful innovation in South Africa versus Nation Z. While its national research capacity is not the only determinant of the firms competitiveness or its innovativeness it is an important factor supporting a firm and one that needs to be remembered when promoting South Africa's international business competitiveness.

In many interviews, across the fields of technology, there was some expression of low regard for R&D by the private sector and poor linkages between research at

higher education institutions, the science councils, and business. While obviously inter-related there was also mention of a legacy from South Africa's large-scale, capital intensive development. This led to risk aversion that instilled a cautious and at times contentious attitude towards R&D and its inherent uncertainty on the national business culture. What ever the origins, both the limited linkages between the different types of research organizations and the low industrial regard for R&D need to be transformed if South Africa's research capacity is to be improved and there by the attraction and retention of HRST to R&D occupations.

Box 4.7 South Africa's r&D capacity

Interviews with most of the commercial organizations they mentioned that most of what their R&D division did was development or adaptation of foreign technologies, with only a minimum of applied and even less basic research being conducted. Because of this the term small 'r' and big 'd' was used to describe their R&D activities. As a feature this is an important characteristic since it means that comparatively speaking R&D career opportunities are limited to more development-focused work. It also implies a structural relationship that South Africa can use, through FDI knowledge spillovers for instance to build its research capacity.

Another major difficulty in attracting and retaining South African R&D workers is their international transferability of skills. This means that in a global environment of skills scarcity, overseas salaries and opportunities compete with domestic. While the top rates of pay (cost to company) for qualified active researchers are not well documented in South Africa. Private sector pay tends to be the highest, followed by science councils, parastatatals and government. Rates of pay differ in the numerous higher education institutions but are generally lower than in the other sectors except, possibly, the non-profit sector.

The HSRC has become relatively transparent in its remuneration policies. Therefore, by way of illustration we can compare salaries of public sector employees and those of the HSRC. At the HSRC specialist researchers start at a level of R155 000 per annum while appointments at the level of Director start at R380 000. Researchers appear to find these levels of pay attractive and indicate that the HSRC is offering rates at about the top level of the market. Other science councils appear to be following this trend. These positions would involve research and the management of research activities. In government, Directors (not usually active researchers themselves) start at R371 673, research managers start at R225 502 and deputy directors (active researcher level) start at R167 000.

In the United Kingdom, top paying institutions such as the London Business School pay several top academic more than 150 000 Pounds per year. Cardiff pays up to 90 000 Pounds, while the top salary at Sussex is 70 000 Pounds per year. On average a Professor at an "old university" would get 41 782 Pounds per year while a lecturer can expect an average of 19 371 Pounds per year compared to 37 434 Pounds per year for a Professor and 20 041 Pounds per year for lecturers at "new universities". In 2000/2001, 468 staff at UCL and 293 staff at Imperial College received more than 50 000 Pounds per year[34].

[34] These statistics are from the Times Higher Education website: http://www.thes.co.uk/

In the US the median annual salary for individuals in science and engineering occupations is $60 000 (ranging from $36 000 for political and related scientists to $72 000 for physicists and astronomers). Electrical engineers with a PhD can expect $83 600 per year while sociologists and anthropologists with doctorates can expect a median annual salary of $56 000[35].

In a 2002, Deloitte & Touche Human Capital Corporation's executive remuneration and reward survey it appeared that South African executives in the business sector earn less than half of UK and US packages. South African top executives receive about the same as their counterparts in New Zealand. The same survey found that salary rises for 2002 for all staff in 50 organisations were higher than those of the previous year but were still lower than inflation. The survey manager (Terry Brindle) said the higher cumulative percentage packages paid to top management and key specialist staff reflected a present trend, but predicted a scarcity of these types of employees. Brindle stressed that financial rewards on their own did not guarantee the ability to retain staff. Other factors such as career advancement and growth opportunities should form part of a successful retention strategy. Companies striving to be recognised as the best to work for attract the highest calibre staff.

Scarcity of human resources and in particular those in R&D, is a reality that must be managed not just in South Africa, but also globally. Unfortunately, an evaluation of entering and current R&D employee skill levels by organizations is not available Rogerson and Rogerson (2002) surveyed attitudes towards newly recruited HRST. They found that 86% of organizations reported the quality of new personnel were the same or better than outgoing personnel (p. 91). Their study also showed that 85% of organizations used training to augment their staff's skills. Many used several methods of training. In-house training was used by 62% of organizations, while international training of staff was used by 35% and local training institutions were used by 33% of organizations (*Ibid.* 2002, p.90).

The on-going 2002 R&D Survey asks organizations whether skills shortages and/or deficiencies within their R&D personnel was a significant issue during the past year. All but one of the eight science councils reported that it was. Table 4.1 presents the responses. In-house training was used the most, but South African recruitment was ranked the most important method by which shortages/deficiencies were dealt.

Table 4.1 Skills Development in the SC-R&D Workforce

Measures to Accommodate R&D Skill Shortage/Deficiencies	Number who used	Average Rating of Importance: 1 - least important; 5 - very important
In-house Training	7	4
Internal Recruitment	6	3
Out-Sourced Training	6	3
Out-Sourced R&D	6	3
South African Recruitment	6	5
African Continent Recruitment	5	3
International Recruitment	5	3
Other: Expatriates	1	3

Source: R&D Survey 2002 Note: N=8

[35] These statistics are from the National Science Foundation's S&T Indicators for 2002, they are available through the NSF website at: http://www.nsf.gov/sbe/srs/seind02/start.htm.

4.3 Issues Concerning Mobility in Priority Fields of Technology

Mobility within five priority fields of technology is discussed in this section. As a complete data set for the each field of technology is not yet complete, the profiles are based on information gathered through interviews with organizations active in these fields. This was supplemented by references they suggested and those identified in the literature survey[36].

4.3.1 Automotive Technologies

This field of technology is centred on the automotive industry and is differentiated among original equipment manufactures (OEMs) and component suppliers. OEMs are the companies that assemble or make vehicles, while component suppliers provide components for assembly or aftermarket sales. There is tremendous latent local demand for these technologies[37], but manifest demand has not been at an internationally competitive scale[38]. Technology drivers of the field appear to be large multinational automotive companies in Europe, Japan and the United States. Because of this, South African R&D workers in this field often visit these 'mother countries' to learn about production and product systems related to operations in South Africa.

According to the organizations interviewed, South Africa's successful entry into the global automotive market has reduced the potential for and actual conducting of R&D in automotive technologies. The fundamental force driving this is a global value chain and South Africa's position in it. Downscaling of the national military research capacity has also reduced R&D employment in the field[39]. The government's Motor Industry Development Programme (MIDP) is also generating significant short and long run impacts on R&D employment in automotive technologies, which is encouraging integration into the global automotive industry[40].

South African automotive technologies are increasingly focused upon an international production platform. Integration into the global automotive production chain has made this change crucial. Production volumes are thereby increased as the global market, and not just the South African market, becomes the target. International consumption requires a high degree of standardization and hierarchical specification in order to ensure that when assembled, the globally derived components fit and work together as designed. These standards are created in the vehicle design centres of the major automotive firms in Europe, Japan, and the United States. Therefore, when a vehicle is assembled or a component manufactured in South Africa for these international platforms, it is done so according to blueprints developed in the automotive firm's mother country.

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[36] Further details on methodology can be found in Chapter Two, Section 2.4.
[37] Africa's climate and infrastructure seemingly holds large innovative potential if a greater percentage of its population demanded vehicles.
[38] For more information on the Automotive Industry in South Africa see: Black (2002, 2001, 1996), Barnes & Morris (2000) and Barnes (1999a, 1999b).
[39] While it does not appear to have been a large area of capacity, the military developed an R&D workforce to support its role as a heavy vehicle OEM.
[40] For more information on MIDP see Black (2002)

Effectively in this structure South African R&D in automotive technologies is not needed. Nonetheless, R&D capacity still exists in automotive technologies, but it is in small niche areas and sub-fields where international market integration has not yet dictated an international standard. An R&D director at an organization described the situation as one where despite having identified areas of research with important potential for the South African market, their margins do not allow the necessary investment to undertake the research. They are therefore looking to further establish themselves within the international export market, to increase their margins Unfortunately, in so doing they will be producing components to an internationally specified standard with no allowance for local innovations in design. As the production of vehicles and their assembly continues to be globalised, it is through the 'mother-country' R&D division and design specification that the company retain control over operations. So, as long as this organizational paradigm predominates the industry, R&D employment opportunities in a context like South Africa's is extremely limited for automotive technologies.

Thus, the field is characterized by limited opportunities, stemming from limited funding, which is reinforced by limited opportunities in a negative circle. As such the current low number of R&D workers in the field is an equilibrium, with little incentive for further development of researchers domestically. For those few South Africans that want to pursue an R&D career in this field, higher-level training and industrial applicability is strongly structured to encourage their going outside the country.

Since the MIDP began in 1995 it has promoted South Africa's integration in to the global value chain operating in the automotive industry. This has been done by decreasing tariffs on imported vehicles to increase competitive pressures on the domestic market, while simultaneously giving financial incentive to encourage exports. In supporting export growth of in South Africa's automotive industry production efficiencies have limited job growth (*Ibid.* 2002, p. 17). The context in which South Africa has 'succeeded' in transforming and integrating the automotive industry into the global market needs to be tempered. It is now competing internationally in a highly competitive sector on price, which is being supported by the government. R&D capacity is crucial to developing an ability to compete on qualitative features, but that has been an area untenable given the current placement of South Africa in the international value chain.

While heralded as an economic success, focusing on the R&D workers and their mobility in this sector has indicated significant qualifications. Export promotion and economic growth are obviously important to the economic development of the nation, but they are not without their own potentially negative implications. Competing on price can generate highly dynamic and internationally competitive production capacity that can spin-off to other sectors. However, this is not an automatic result and reiterates the importance of reflecting on policy impacts on a continual basis as an integral part to good governance.

4.3.2 Biotechnologies

Biotechnology does not have a unique industrial sector in which it is primarily applied. It contributes to a range of sectors, such as brewing, food production, waste disposal, mining, and medicine. In terms of defining characteristics of the field, biotechnology

involves the use of living organisms, or substances from these organisms to make or modify a product, improve plants or animals, or develop microorganisms. The diversity of biotechnology applications is seen in recent successes at data storage through encoded DNA inserted in the genomes of multiplying bacteria, creating an alternative to paper and electronic memory within living organisms (McDowell, 2003).

South Africa's relatively advanced research infrastructure and developing socio-economy, gives it an incredibly rich research environment in which to apply and develop biotechnologies. This is further supported by the government's promotion of the field. However, industrial development of the field remains largely in traditional niches. In the organizational interviews, this was noted as translating into a scarcity of employment opportunities, which limits the development of South African human resources in the field[41].

Two related issues were raised in the interviews as to what affects the mobility of biotechnology R&D workers in South Africa. First, is the necessity to expand the South African research capacity in biotechnology. Second, industrial application of biotechnology needs to be developed within a competitive inter-institutional environment.

Biotechnology is a multi-disciplinary field and for a variety of reasons, its final application often must be considered from the earliest stages[42]. Successful commercialisation of biotechnologies often requires a team ranging from lawyers, physicists, and production engineers to chemists, environmental engineers, and physicians. There is an over-riding need for knowledge exchange between individuals in these disciplines if a more dynamic research capacity in biotechnology is going to be developed. One interviewee complained that much of South Africa's research capacity has been concentrated upon the individuals' research interests that are typically defined along traditional disciplines. Accordingly, to promote R&D in biotechnology existing organization need to be restructured to encourage researchers to engage in multi-disciplinary R&D. This is not to say that focused capacity in disciplines is not needed, just that it must also be balanced with an interdisciplinary capacity if commercially viable biotechnologies are to be developed.

Many of the organizations interviewed had either set-up or were in the process of setting up research centres and institutions that are interdisciplinary. These efforts endeavour to promote biotechnology research capacity and develop researchers used to working on an organizationally defined, multi-disciplinary basis. Industrial viability will create a virtuous cycle in South Africa's R&D capacity. It will expand employment opportunities for graduates, allow for greater depth in training at the highest level, and generate commercial support for the non-commercial research capacity.

Without some growth in commercial applications of biotechnologies the field faces limited prospects for expansion. Students are reluctant to enter training as, particularly at the lower levels of qualifications, employment opportunities are very limited. Those that have acquired higher-level qualifications, particularly those with

[41] For a far more comprehensive review of the biotechnology field see the Department of Science and Technology's *National Biotechnology Strategy* (2001).
[42] Government regulations in a biotechnology that might be used as a medicine is an example.

overseas experience, find themselves looking for employment opportunities that do not exist in the country. For instance, one organization mentioned that it recently advertised internationally for a position only to be swamped by applications of excellently qualified candidates, at least a half dozen of whom were expatriate South Africans looking for employment opportunities to return home.

Biotechnologies hold tremendous promise as being an area where South Africa can establish a strong internationally competitive R&D capacity. It will not realize this potential until a more entrepreneurial flavour is developed. Without it, crucial commercial viability to support the research does not appear likely. Government can play an important role in this as its biotechnology initiative has already demonstrated. However, it is not something that can be done singularly and will require co-ordination and cooperation across organizations.

4.3.3 Environmental Technologies

Environmental technologies are taken to facilitate management of a physical environment at some level. There is a multi-disciplinary tendency in most important technologies in the field. The R&D Survey uses R&D work conducted in the environmental sciences as a measure of the R&D workforce in the field. Environmental technologies are primarily applied within four sectors: air, water, and soil pollution control; solid and toxic waste management; site remediation; and environmental monitoring and recycling. In the year 2000, the global market for environmental technologies was estimated to be U.S. $522 billion (ETI, 2003)[43].

South Africa's rich biological environment makes it an attractive location for R&D in environmental technologies. Its semi-arid climate has created a long history of water management technologies for instance. From the interviews with organizations in this field one gets the impression of vibrancy. However, they still face general difficulties in managing the mobility of their R&D workers.

It appears that strong government support for research in this field as well as demand for graduates contributes to the strength of research capacity in environmental technologies. Despite this experience, most organizations noted that South Africa has still not established what areas it is internationally competitive on a sustained basis. Another area where mobility can play an important role is in developing continent wide research networks. One organization mentioned that South Africa's historic isolation from the rest of the continent has inhibited development of what should be a natural research network around the continent.

These interaction with other African researchers in environmental sciences is an area important to developing regional and international competencies and an area in which South Africa, with its relatively advanced research infrastructure, is ideally placed. As a rapidly expanding and increasingly specialized field, there was some expression of concern over South Africa's ability to retain general international competency. An increasing competitive tension seems to be forcing South Africa to consider specializing in a few areas of competence and relying on international supplies of technologies in the others. This would appear to be part of the general

[43] For further information on South Africa's environmental technologies see the National Research and Technology Foresight (NRTF) Project reports on the Environment and Biodiversity (1998)

globalisation phenomenon. As previously discussed, there is a of strong resource constraints in highly skilled people in South Africa. Under such conditions in a growing market there is an important choice of direction to be made. Given the government's strong demand for research in this area, it would appear a potentially important source of direction in choices of specialization.

4.3.4 Information and Communication Technologies (ICTs)

South Africa's R&D capacity in information and communication technologies (ICTs) appears to be focused around adaptation and development of technologies that originate overseas. It therefore is similar to the situation described for R&D workers in automotive technologies. Applications in which ICTs can be used are diverse, but include education, business, health, government, employment, culture, and poverty eradication. Using ICTs and developing the technologies themselves are important distinction to be remembered in considering the statics and dynamics of R&D employment in ICTs[44].

Most of South Africa's ICT R&D is in the development and application of foreign technologies. Commercial ICT R&D is seemingly limited by the relative small local demand. That does not mean local ICT R&D is totally constrained by its local market as niche have emerged, such as in mobile telecommunication technologies, where South African technologies have been internationally competitive. Government support for development and application of ICTs is strong. This is important as ICTs are often designed for relatively more economically developed environments. South African government demand encourages growth of technologies oriented to a relatively less economically developed context.

As with the automotive sector, most of South Africa's competitiveness in ICTs rests in price advantages. Organizational control, research capacity, and technology lock-in all work to concentrate leading edge R&D in the more economically developed nations. South Africa's R&D capacity in ICTs has also been reduced because of relaxation of its protectionist policies. In particular, removal of local content requirements in the telecommunication sector was noted as causing a reduction in local ICT R&D employment as less costly foreign technologies were imported.

There are areas where South African ICT R&D workers are developing local expertise that is qualitatively different from that available elsewhere. Two examples of commercial areas in software where South Africa has developed significant local capacity are inventory control security and visual technologies to accommodate less literate employees. There is also significant potential to expand South Africa's R&D capacity in ICTs that facilitate sustainable development. Doing so will require a growth in the number of individuals capable of undertaking ICT R&D. Particularly as international demand for young workers in ICT has been strong, retention within the country has to be based upon career opportunities. In this respect the supply of individuals in ICTs appears to be a constraint, but one in which attention is being given.

[44] For an overview of the ICT sector in South Africa see the NRTF ICT Project Report (1998) and Henry & Strydom (2002) for an ICT labour market audit.

ICTs are inherently international technologies, facilitating increased interactions and lessoning the barriers of geographical distance. It is also a developing technology in which personnel interactions and clusters of competencies exist. Mobility of South African ICT R&D workers is therefore a natural phenomenon and one that holds potential benefits to the nations through the circulation and diffusion of knowledge which it may facilitate. It is also an important mechanism to develop financial and market networks that can increase local competitiveness and thereby expand South Africa's research capacity in the field. Positives and negatives alike are not automatic and require monitoring if not active direction from government and industry alike.

4.3.5 Mining and Metallurgical Technologies

Mining and metallurgical extraction technologies is a field in which South Africa has a long and well-established R&D history. These technologies are directed towards applications in the mining sector. It is a sector, which during the 1990s witnessed considerable transformation. Increasingly international, rather than nationally focused, its R&D organization and employment structure has similarly transformed over the past decade.

Until the 1990s, most of South African research in mining and metallurgical technologies was conducted by the mining houses, in two large research organizations, and to a lesser degree at a few of its research universities. Today, except for the addition of a national Safety in Mine Research Advisory Committee (SIMRAC), the structure remains the same. However, compared with twenty years ago, the scale of local research has declined.

The changing location of mining activities has contributed to an international decrease in mining and metallurgical research. Traditional research centres in more economically developed countries have either decreased their research efforts or closed down entirely as mining moves to less economically developed nations. In this respect South Africa's experience is part of an international phenomenon.

South African mining houses in the last decade have become global in their operations. If a pattern similar to that described in the other fields is applicable to mining and metallurgical technologies, it is crucial that South Africa retains its R&D capacity. The significant level of mining that continues to be undertaken as well as the established institutional infrastructure should facilitate retention of domestic research competencies and development of new internationally competitive technologies.

While details are beyond the scope of this discussion, the reorganization of the South African mining and metallurgical research structure has changed opportunities for an individual to receive training and pursue career development in the field. The previous structure of research allowed the independent research organizations to play a dual role of undertaking research and providing high-level practical training of researchers suitable for an internationally competitive supply of R&D personnel to the industry. Within the present structure this capacity is gone and with it an emerging sentiments that there is decreasing talent available in South Africa to retain internationally competitive R&D capacity here.

If these impression about the R&D workforce are correct there is a strong incentive to take corrective action. Nevertheless, it appears that part of the present reduction in R&D activity in these technologies is a product of past success, with up-take of new technologies notoriously lagging in this sector because of the large fixed capital costs and limited ability to alter production once a mine has been commissioned. If research activity is merely in cyclical trough, retaining a strong core research capacity will ensure more opportunities in the next up swing. Given its extensive history and rich operating environment, South Africa is a natural environment in which to develop skilled researchers in this field. Given these advantages it is well positioned to continue being a world leader in mining and metallurgical technologies in the future.

4.4 Key Issues

- Policy development needs to facilitate ownership across all players in South Africa's research system to realise actions at a level that will have real impacts. This means bring together organisations employing, training, and regulating R&D as well as the R&D workers themselves.

- As South Africa has increasingly integrated itself in the global economy its domestic R&D capacities and employment opportunities need to be considered with respect to international market structures and value chains.

- In profiling R&D employment dynamics, organisations and individuals perceive similar issues, but often place blame and claim benefits that are most complimentary to their own position in the research system. Thus, integration and comparison of perspectives from players across the system is crucial for a better understanding of what is really happening.

- While varying across organizations, the expression that R&D is something tangential to operations is an area of concern. R&D is crucial to increasing competitiveness through innovation. While an R&D division might not be the only source of innovation in an organization, it is often crucial to ensuring sustainable competitiveness. Changing these attitudes should be part of the broader social efforts to increase appreciation of role science and technology play in advancing South Africa's economic development.

Chapter 5 - Mobility from the Experience of Individuals

5.1 Introduction

he study of the nature, causes and effects of R & D mobility in South Africa could be studied using a systems approach. In fact much of this study is approached through a systems approach. Systems approaches is characterized by "interactions between economic agents in the shaping context of infrastructures and institutions." (Smith 2002, pg. 7). The focus on the policies, infrastructures and institutions will allow us access to perspectives relating to mobility of R&D workers. However the systems approach will not access the human and social dimensions involved in understanding issues of mobility.

An additional methodology, the life history approach, was used to understand the dynamics of mobility from the perspective of individuals. The researchers conducted in-depth interviews with 20 R&D workers about their experiences in the R&D field. This chapter then reports on the issues of mobility as illuminated from the life history interviews.

5.2 What Do The Interviews Tell Us About the Mobility of R&D Workers.

5.2.1 People will and do move

People will move during their working lives. The mobility may be upwards, into the country, out of the country. Migrations may be temporary or permanent. The reasons for mobility vary: it may be for economic or political reasons or it may be a natural part of a career trajectory. Very few people that we interviewed have stayed in the same organization for long periods of time. If they had stayed in the same organization they have moved into different jobs in the organization ladder.

Since the 1990s in South Africa many leading scientists and researchers have moved from the research/ academic work to positions of management. This is especially so for leading Black researchers, post 1994. With the change of political order many Black researchers were called upon to head up leading organizations in the country(Reddy, 2000). While upward career movements are a normal part of a working life, the unique issue in South Africa is that there was a exodus (and black researchers were not present in large numbers) of Black researchers from their R&D position to positions of management thus leaving a big gap of R&D workers. There was not a cadre of newcomer researchers (especially Black) to take up those positions. There is an undersupply of R&D workers because there is an undersupply of graduates from the tertiary sector. One reason for this is an undersupply of suitably qualified school leavers (see chapter 2). Thus addressing the concerns of mobility means that we have to also look at the schooling system and issues of supply and demand. An important research and technology enabler in a country is the quantity and quality of the school leaver.

Within the private sector there has been an upward career pathway from technical to management positions because the management pathway was more financially lucrative. In order to counter this trend many organizations have set up parallel

career pathways (management and technical) where both pathways are equally rewarded and there is minimal loss of research/ technical personnel.

R&D workers who leave the country may do so for different reasons. Some leave for political reasons where they indicate that the crime problems have made them feel unsafe. Mobility of R&D workers, especially young R&D workers is a global phenomenon. South Africa is a small country with a small R&D sector, and therefore it is a 'natural' phenomenon that R&D workers would migrate to other countries. Many would like to work in large research environments with greater challenges, and now that South Africa is part of the global world there are more opportunities.

> G is in her early 30s and worked at a science council where she applied GIS to environmental issues. She is leaving South Africa because her husband, who works in the IT sector, has got a good job in London and they see this as at opportunity for themselves. G says they are not emigrating and will come back to South Africa.

It is also interesting that people who have achieved successes in the South African arena have built up a CV that allows them an opportunity to compete and be accepted in an international arena.

> Q worked at a technicon where the research was service driven with real world customers. Q set up companies that used his technical skills. He has been successful in these companies and with a former student, who has a job in the US, he is moving to the US to set up a company. In order to induce Q to stay he would want to be paid a dollar salary.

R&D workers that come to South Africa do so for different reasons. For many Africans from North of the Limpopo, South Africa provides better research opportunities and environments. Many African scientists and researchers who had left their home countries, because they could not do the kind of work that they like, and worked in Western countries feel that working in South Africa gives them an opportunity to be closer to home and make a contribution to the African continent. South Africa offers an infrastructure and environment to support their work. However, it is not always easy for them and they have to constantly prove themselves and find acceptance among both White and Black colleagues. They have to be cautious about how they engage about South African issues. They also have difficulty in breaking into networks to have platforms to talk about their work and the implications of the work for the South African society.

> H was born in Mali and studied in Paris and US where he obtained doctorates in mathematics and economics. He worked in the US because if he went back to his home country he would be pulled into politics. He wanted to work in South Africa because he was impressed by the change process and wanted to work on economic structures.

Some R&D workers were brought into the country because they have specific skills and these skills are bought for a specific period of time. This raises the issues of the decisions we need to make about the skills that need to be grown and the skills that need to be bought.

> L is a Polish national. He specialized in optical engineering and worked at the Space Research Centre in Poland. In 2000 he was recruited by the Southern African Large Telescope Project (SALT) on a 5 year contract to work on the lenses and mirrors used in telescopes. He came because SALT is an international project and he will return to Poland

after 5 years. L is concerned that he is the only person with the skill and there are no mechanisms within SALT for capacity building of locals.

There are academics who have come to South Africa from leading institutions of Europe. Their stories illustrate that while there are R&D workers who are leaving the country there are others who consider South Africa as an exciting place to conduct their research. Sometimes the start was as part of an exploration and adventure and they have enjoyed the experience and chosen to stay on.

N, an applied microbiologist, worked at the University of London and moved to the University of Western Cape. He has international collaborations and has set up a vibrant research center at UWC. He has established a research team with post-doc fellows from South Africa, London and Chile.

O is Canadian and works at UWC. He has a major project in Southern Africa on ICTs. He has established an NGO through the university about coastal and marine life and transferred knowledge to different communities.

There is a strong passion and commitment by many researchers who are work in the country about their commitment to the country and wanting to stay. Black R&D workers who have trained outside the South African system have returned to South Africa after their training. According to the EOC study (Reddy et al, 2001), 95% of the graduates who went to study outside South Africa did return. This is in contrast to countries like India where there is a 5% return of the graduates who train outside the country. Many black academics have indicated that following an academic pathway was a political choice and the reason for returning is a commitment to give back to the communities which gave them a chance.

I is a young African scientist who was born in Venda and now works in Johannesburg. He completed a Ph.D. in Artificial Intelligence at Cambridge and did a post doc at Imperial College as team leader on an EU project. He was approached by various UK banks to work for them. He wanted to return to South Africa because this is home and he wanted to contribute back to the community that supported him.

There is a phenomenon where researchers have flexible working arrangements where they spend a part of their work time at an outside South Africa institution.

B works for 9 months a year at a South African institution an has an appointment at a leading US institution for the other 3 months. The teaching and research at the US institution gives intellectual nourishment and allows an opportunity to keep up in the field. His teaching in the US means that the students get a perspective of African diseases from someone who has worked directly with it.

This 'temporary' migration can be benefit to both the individual and the country. In the migration process there is a transfer of skill and expertise. Encouraging this type of temporary migrations could also be useful for other African R&D workers who could be encouraged to work both within their home countries and South Africa.

5.2.2 Networks: faciliting or inhibiting mobility

An important component of building up expertise in the R&D sector and research is mentorships and apprenticeship. Individuals have benefited from having networks and being in an environment where you are able to pick up skills from the workplace environment and colleagues. Networks can be an enabler for a R&D worker, but a

lack of access to these networks can be frustrating for, especially the newcomer, outsider researcher.

In the private sector much of the training takes place on the job. Private sector does not seem to have much faith in the university sector and indicate that after the first degree they would provide the training. The stories illuminate how people who are now in positions of technical directors started within the organisation and with the support of others moved up the organizational ladder. These stories reflect the power of networks to assist in the process of developing new skills and moving upwards. In sectors like the IT sector there is a great deal of on the job training and gaining of skills from colleagues.

> F is a business manager at a leading biotechnology organization. He qualified as a chemical engineer and joined AECI. When AECI bought a biotechnology plant he wanted to work there and the company sent him to ICI in London for training. He worked with others and learnt on the job. He became a process engineer, then process manager, then operations manager, then plant manager and is now business manager.

Networks work better for people who already have the contacts and know and understand the culture of the organisation. Outsiders have difficulty establishing or breaking through the networks. Black academics return from overseas training to work in South Africa they still experience a feeling of alienation and a lack of networks at white universities. The interviews that were conducted in R&D mobility study in 2002 were reminiscent of the stories that black academics told one of the researchers (VR) of their experiences in the 1990s (Reddy, 2000).

> D is a young, Black academic who is determined to be a brilliant academic He has to prove himself but has to overcome the hurdles of age and race. He does not have a mentor at the university and has had difficulty in getting colleagues to work on collaborative projects unless the initiative comes from White academics. He has difficulty in attracting either Black and White graduate students.

While training in higher education (bachelors, masters, doctorates) is considered as a private investment in most countries, in a country like South Africa where there has been and still is racial inequality, it has to be viewed as a social investment. Because of the difficulty that Black researchers experience in breaking into or establishing research networks, a higher qualification could force the networks to open. The interviews illustrate that while White R&D workers can depend on a first degree and support from the workplace to gain skill, the same cannot be presumed for Black R & D workers. They would need to depend on their own resources and formal higher education qualifications helps.

Those that emigrated from the country have built up networks for their colleagues in the country. Those that have set up short term contracts working in a country outside South Africa, have used the opportunity to built up networks.

5.2.3 Research and Equity

While there is a concern about undersupply of R & D workers there is also concern about the equity and development agenda in relation to R & D workers in South Africa. There is a tension between the agendas of excellence and equity. Both within academia and private sector these two issues have not been resolved. In the quest

to compete for excellence in the international arena and the need for "excellent CVs" there is no room for newcomers to participate in the big, high profile projects and develop their CVs. The private sector is motivated by profits and they would go to the place that would give them the answer in the shortest possible time. With access to global players this means that private sector does not feel obliged to build up local individuals or institutions. They could buy the skill and expertise from a global market. While an option is to buy or grow skills, with South Africa's history the agenda of growing our skills takes on a different dimension.

> B has set up an excellent, high- powered team and has competed successfully for a large, international grant. To be on the team one needs an excellent CV.
> F indicates that when the company needs research, they would look through the international scientific literature and connect with the person doing that work. There is no plan for development of research units at South African institutions.

The life history interviews have been very effective in illuminating the ironies and contradictions within the R&D sector. South Africa had a very robust R&D sector during the time of apartheid when there was a big defence industry. With the closing down of the defence industry spending has decreased and jobs in the R&D defence sector has decreased. It is ironical how the individuals and institutions who gained during the apartheid era, now have the comparative advantage in terms of skill and expertise. These individuals' now head up institutions in the post-apartheid South Africa. Institutions who gained their skills and expertise serving the defence agenda pre 1990, have now used the skills set up leading institutions.

> A indicated how, pre-1994 the company was involved in military electronics and linked to Armscor. They built up expertise and after 1994 had to change their focus. They are now involved in digital and communication electronics and are one of the leading companies in the world.
>
> M joined Denel in 1988 and moved from junior engineer to manager of a project dealing with military based airplanes. Here he picked up technical and management skills. He is now heading up a South African/ international flagship programme to build a large telescope.

There is still a concern about the number of African and woman (especially Black) R&D workers. One of the companies interviewed indicated that the R&D staff complement was around 99% male and 50% white and 50% Indian. This is a concern and we need to probe the contribution of lack of supply or culture of organizations in having this kind of inequitable demographics.

5.2.4 Labour Markets for R&D workers

There is a limited labour market for qualified R&D workers in South Africa. This is because in sectors like the automotive and pharmaceutical there are no research facilities in South Africa and individuals and ideas have to go to the North to use their skills. In addition there is no co-ordinated Human Resource and R & D strategy. We could be training R&D workers who are unable to find employment in this country and will move overseas. South Africa's investment in training that person would have been lost. There needs to be a strategy that would suggest which research areas the country is willing to invest in.

> C works in the automotive industry and his university and the Mechanical Engineering department has built up research expertise around developing automotive component parts.

> The automotive industry (production) in South Africa is incentivised. However the research that is done is not being used by the commercial sector. Research into the automotive industry is done in the North. What happens to all the R&D workers that have been trained in this area?

In addition to a lack of a labour market there in some sectors there are no facilities to translate the research into products. South Africa has to look to the North to finish off cutting edge research in the Indigenous Knowledge field that it had started.

> E is a retired university professor and works in the area of traditional medicines. He has worked with a Zulu traditional healer who told him about the use of a particular plant to treat male impotence. E and his team extracted the compounds from the plant and found that one of the compounds had the property of being a smooth muscle relaxant – a property that is necessary when treating male impotence. They isolated the compound and a patent was registered. Included in the patent is the name of the traditional healer. The knowledge generated from this research has been accepted in scientific journals and the crystallographic picture of the compound has featured on the cover of the scientific journal. Having isolated the compound, the next step was to look for routes for development. In the pharmaceutical industry there was no research and development avenues in South Africa. To move towards development and production the researchers had to contract with a company in the UK. If the venture is successful, the financial arrangement would be that the UK company gets 80% and the South African partners would get 20%.

5.2.5 Exciting research agendas in South Africa

South Africa provides a laboratory for exciting research. The research that is done here, often has immediate impact in dealing with some social, medical or scientific issue. R&D workers acknowledge that while they are able to gain a tremendous amount of technical skills in countries in the North it is the exciting research agendas and the sense of immediate impact of the research agenda that keeps them working in South Africa.

There has been successful multidisciplinary approaches to trying to find solutions in the medical field. There is much that the medical research models with its multidisciplinary approach can teach other sectors where people from different disciplinary backgrounds work on a problem. However this kind of multidisciplinary work requires large amount of money and the National Research Foundation (NRF) may not be equipped to provide that kind of support. A successful multi-disciplinary approach to a medical problem has been funded by a US foundation. To keep the environment intellectually challenging South Africa should encourage this kind of work.

The Indigenous Knowledge Systems provides a very useful arena for the development of knowledge and products. However as illustrated by the use of medicinal plant research, while we can develop the knowledge here there are no facilities for development work and to translate into products. It is an area where there could be growth and could be a niche area which could attract researchers from other parts of the world.

Work in area of IKS is also important from a political viewpoint in that it affirms the work that has been done in local communities for a long time. Researchers working in this area start off with the assumption that the local practices are valuable and

useful. This affirmation particularly useful in an environment where black students are constantly having to face a message of failure in mathematics and science arenas.

5.2.6 Research institutions in South Africa

South African universities have small departments and not a vibrant research culture. The lifestyle benefits from being at an academic institution are small and university academics leave to go to private sector (either in the technical or management field).

There is concern about the lack of a relationship between the private sector and the university sector. Both sides blame the other for the lack of co-operation in building up a vibrant R & D sector. Academia feels that the private sector is not interested in South African partnerships and look elsewhere. Private sector feels that the academic institutions are too slow to respond to the needs of the work and marketplace. Private sector has set up relationships with overseas universities than a local South African institution.

Private sector indicates that they employ people with the first degree and thereafter do their own inhouse training or set up a programme of training at the bench through an apprenticeship and in the process R & D workers gain skills. There are no models of South African university/ research institutions and industry working together.

> A indicated that they have contracted a UK university to run their in-house training. The reason for not going with the South African institution (which may be 15 km away) is the perception that universities sit on the hill and do not keep up with what is happening in industry. The courses do not reflect the changes that have occurred in industry.

5.2.7 Research individuals in South Africa

The South African diaspora represents a group of well trained, capable and uniquely skilled people. It is ironical that the good R&D workers who have opportunity to meet other R&D workers are the ones who realize that the country is too small for their ideas and need to leave. Research managers acknowledge that South African workers are flexible and can work under difficult circumstances and are able 'make a plan'. This creativity and flexible approach is appreciated in both South African and international companies.

It is acknowledged that the research fraternity is largely white and over 55 years old. The challenge would be to encourage the transfer of their skills to new researchers.

> E is a retired academic and wanted to continue doing research. The NRF funded his research on condition that he taught for periods of time at the University of Venda. This arrangement has been successful and E is working with graduate students at the University of Venda.

The stories of people who develop in the IT sector illustrate that for individuals showing an interest and inclination in this area, in a conducive environment they can build up their skills. People who have shown successes in this area, do not necessarily come in with the formal qualifications. And private sector is more interested in peoples productivity rather than formal qualifications.

5.3 Key Issues

Mobility is a global phenomenon and does and will continue to occur. The mobility is upwards, outwards (out of the country) and inward (into the country). With globalisation the opportunities for mobility increases. Because of the South African history the issues of mobility has different nuances. These nuances are seen in how networks could be important component of building up a cadre of R&D workers or of frustrating newcomer researchers. Another dimension that has a South African flavour is that of reconciling the research excellence and research equity agendas.

South Africa is an exciting laboratory for research and the research findings has the potential to make an impact to some social, medical or scientific issue. There are very committed people who feel passionate about the country and the research agendas and it may be this passion which will engender a vibrant research and development community.

Chapter 6 – Policy Implications and Recommendations

6.1 Introduction

This project has explored several areas and dimensions affecting the mobility of R&D workers at both the international and domestic levels. Policies and legal frameworks underpinning this mobility are being strengthened as government restructures and transforms South Africa's human resource development and research and development systems through implementing new strategies. EU member states and other industrialised nations have put considerable effort into policies and instruments for attracting highly skilled people, including researchers, to their economies. South Africa needs to be competitive and also develop mechanisms to maintain and attract people to work in its S&T system.

In countries such as Estonia and Slovenia the experience has been that the main obstacles of entry for foreigners are not legal or language problems. These countries attribute their low level of research infrastructure as the reason why they have difficulty in attracting researchers. South Africa has a fairly well established, albeit unevenly distributed, research infrastructure. It also has scientific areas where it has an obvious geographical advantage (e.g. astronomy, biodiversity, human palaeontology and Antarctic research) and scientific areas where it has clear knowledge advantages (e.g. indigenous knowledge, deep mining technology and encryption technology). These advantageous areas are highlighted in the National R&D Strategy and serve to retain and attract researchers to work in South Africa. However, due to the long period of inequality and isolation that South Africa suffered through apartheid there is a need for a more strategic approach to building up a more equitable R&D workforce and attracting more international interest and constructive participation in this process.

The numerous policies and interventions in place aimed at skilled human resource development and enhancement of the national system of innovation all have short, medium and long term aims. From the present study several other policy implications, recommendations and observations can be drawn from the data and information presented. These can be placed in short, medium and long-term frameworks.

6.2 Recommendations for the short term

It is generally acknowledged, even in the most developed countries, that there are problems surrounding methodology and appropriate sources of data to better understand migration issues (Auriol, 2001). While the best available South African and relevant international sources of these data were examined in the present study these all had their inherent weaknesses. Trying to construct a table of inflows and outflows of South Africa's HRST for 1997-2001 from national data sources proved to be problematic and showed unexplained, dramatic changes that made little sense. Since South African human resource development and R&D strategies are both indicator based there is an urgent need to prioritise and begin developing data that is both targeted to South Africa's unique needs and retains international comparability. Some recommendations for improving South African data sources are:

- The importance for these sources of data for planners needs to be understood by the providers of the information. There also needs to be a greater acceptance of the importance of these data by government, business and educational institutions so that they make the information required more accessible.

- The development of informal skills that contribute to R&D are not clearly understood or measured in South Africa. There is a need for research instruments to be sensitive to measuring these informal skills, such as those recommended in the Canberra Manual, which are currently being revised.

- Keeping standard, accurate and appropriate data series so that flows of migration both within the South African system and internationally can be better documented and understood

- The National R&D Survey for the Department of Science and Technology is currently underway and is the first to explicitly comply with the internationally recognized Frascati framework and is being run by the HSRC on an open consultative basis. The survey carries a number of detailed questions concerning the mobility of R&D workers and will provide this kind of information for the first time in South Africa. Such baseline series need to be established and maintained on a regular basis to monitor the impact of government policies and interventions regarding mobility.

In the short term, conditions of employment for research staff should be made more flexible. For example, opportunities should be made for joint appointments to accommodate flexible conditions for childcare. This would allow a greater engagement of highly skilled women who are otherwise forced to choose between career and family. Dual appointments should also be developed to accommodate the needs and aspirations of mobile black researchers who do not necessarily want to be tenured in full-time academic positions in South Africa.

In the private sector there is an emphasis on in-house training beyond formal higher education qualifications in order to meet the specific needs of the organisation. The importance of this type of specialised training should not be overlooked. The migration of researchers from R&D work to management is an increasing phenomenon and organisations need to set up dual career pathways to cater for these aspirations. There are benefits of having former research workers in management as they can enrich the research culture of an organisation.

An important component of building up expertise in the R&D sector and research is mentorships and apprenticeship. Networks can be an enabler for an R&D worker, but a lack of access to these networks can be frustrating especially for newcomers and outsider researchers.

The shortage of S&T and R&D workers needs to be addressed by more comprehensive funding of postgraduate research students and particularly by the support of postdoctoral fellows. Postdoctoral fellows tend to have a stimulatory and enriching effect on the departments and postgraduate students they work with.

Support for postdoctoral fellows is often discussed and raised as an important issue to be addressed but little support has been forthcoming to boost the number of positions available. There is not the research infrastructure to support postdocs in some fields of research but there are some existing centres of excellence in South Africa and several more are being developed through the National Research Foundation (NRF). To support sufficient postdoctoral fellows and to offer the levels of funding that will make these positions attractive to top young mobile postdocs will be an expensive process. However, this expense should yield important benefits particularly if programmes for postdoctoral fellows are linked to centres of excellence both domestically and internationally.

There are gaps in education policy specifically regarding support, financial and otherwise, for post-graduate, doctoral students and post-doctoral research. For example, South Africa produced only 274 PhD graduates in the natural sciences and engineering in the year 2000. By comparison, Mexico with a population of 99 million is aiming to produce 1000 PhD's in the fields of information and communications technologies per annum by the year 2006. Brazil has also concentrated on boosting higher education outputs and currently produces 6 300 PhD graduates per year, a 600% increase as compared with the early 1990s. In 2000 South Africa produced 820 PhDs or 18.6 per million population. By contrast Korea produced 118 PhD graduates per million population, Australia 170 and Brazil 37. Despite all the hard work regarding improving higher education and upgrading skills in the country South Africa's policy and practice is lagging behind other emerging economies, notably the Latin American/Caribbean region and the APEC grouping (excluding the US and Canada). In Finland a Masters degree is regarded as the "first exit point" for students in the sciences and engineering fields. South Africa needs to review its policies and support measures for postgraduate students to ensure that we have a competitive and viable S&T and R&D workforce for the future.

The benefits of bringing foreign students into the South African higher education system need to be seen as enriching rather than threatening to local students. Foreign students often provide tutorship roles at universities, particularly at postgraduate level. In addition, foreign students bring foreign exchange into the country and also provide a well-trained labour force reserve that is familiar with conditions in the country. Highly trained foreigners represent skills that are mutual human resources that are not exclusionary to the development and enhancement of opportunities for South Africans. In fact, they can be an important force in facilitating development and understanding diversity.

Policy makers need to carefully monitor and appraise the results of instruments and mechanisms available to encourage foreign students studying in the country. Rapid progress is being made in this area and while the percentages of foreign students in Science, Engineering and Technical (SET) subjects falls short of the levels in an open systems such as the USA (26.7%) and UK (31.5%) South African levels are apparently roughly equivalent to those in the Netherlands. South Africa is rapidly approaching its target of a maximum of 10% of student places for students from other SADC countries, according to the Southern African Development Community Protocol, and policy makers need to monitor the effects of this achievement. South

Africa needs to ensure that its policies and strategies regarding foreign students studying in the country leads to a win-win situation.

While this study has been partly concerned with South Africa's policies regarding foreigners and their intake into the S&T system it is clear that the most important need is to develop our endogenous capacity in S&T and R&D by producing highly skilled graduates and also upgrading the skills and abilities of workers.

Policies and mechanisms are needed for harnessing the skills of retired and semi-economically active scientists and R&D workers to assist with development training. This will help develop domestic capacity, but at the same time there is a need to look at the Asian model and consider structured programs to export young South Africans for training abroad. This would mean emphasising mathematics, sciences and writing skills in order to increase their chances of competitive placement along with other foreign students from the South looking for enrolment in the universities of the North.

A short-term focus on mechanisms to encourage skills transfer for people that come into the South African R&D system for a short while is recommended. There is a need to formulate a human mobility strategy to manage the reality of South African and foreign mobility, particularly regarding the highly skilled in a globalised and competitive environment.

There is a strong passion and commitment by many researchers who are working in the country about their commitment to the country and wanting to stay. There is a phenomenon where researchers have flexible working arrangements and spend a part of their work time at an outside South Africa institution. This 'temporary' migration is beneficial to both the individual and the country. In the migration process there is a transfer of skill and expertise and also the provision of novel opportunities for research collaboration.

6.3 Recommendations for the medium term

A recent editor's brief released by Standard Bank group economist Iraj Abedian stated that "attracting high levels of foreign direct investment (FDI) was not a panacea for economic development, and countries like South Africa should rather concentrate on improving the environment for investment and functioning of markets" (Business Day, 6 February 2003). Abedian went on to say that " The conventional wisdom that countries needed FDI flows to augment national savings did not apply to South Africa, and the main impediment to investment seemed to be a dire shortage of skills, which recent debates on immigration law failed to address." FDI can generate domestic innovation and development, but it is dependent on an absorptive capacity existing within South Africa's people. It is the skilled individual, which is crucial to translating the knowledge that FDI brings into application appropriate to the local environment. There is a need for similarity in knowledge levels if FDI is to be an effective force in development. To these ends, developing South Africa's domestic skills capacity will both improve the environment for investment and allow a greater realisation of the potential benefits that FDI holds. Fundamentally increasing the number of skilled South Africans is crucial to increasing the rate of national economic growth.

There need to be more mechanisms in place to promote the development of high level research skills in key areas through the provision of scholarships for young researchers to study at institutions abroad on condition that they return and work in South Africa. These targeted areas of high skills need to be identified and reviewed on a continuous basis. There is a need for industry, government and higher education to cooperate to ensure returnees have posts to work at when they return. This must be placed within an assessment of the global role of South Africa in specific research fields. Questions need to be answered regarding these research fields, such as is the area worth developing, or is it a field whose capacity will be developed at too great a cost to another area, more pertinent to South Africa's interests? Again, these initiatives should be linked to centres of excellence programmes to build new capacity in the S&T system. South Africa also needs to take better advantage of the opportunities provided by its bilateral and multilateral science and technology cooperation agreements. The S&T co-operation agreement with the European Commission provides for a wide variety of two-way exchanges for mobile researchers, including postgraduate students.

South Africa needs to decide on the best mix between importing skills and growing local skills. Time will be needed to obtain the benefits of this mix. Foreign skills need to be harnessed to create more regional absorptive capacity. A focus on exogenous skills in the short term should be aimed at allowing endogenous capacity to be developed in the medium to long term. At the same time it is important to keep the development and equity agenda alive through importing skills that will assist in the growth and development of relevant expertise in the country.

Because of its racial and isolationist past South Africa appears to have been slow at taking advantage of the international opportunities available for study and development abroad (compared to other newly industrialising nations). Yet basic and advanced training in many fields is internationally comparable and at reasonable cost so there is migration to South Africa for training and research experience. There is a need to consider South Africa's placement as an educational hub for Africa and at the same time place it in the context of a nation of the South needing to use and fit into an international system of geographically diffused specialisations. The country has relatively few enabling mechanisms providing opportunities for international diversity in its research base in higher education and other research institutions, although other SADC countries appear to be catered for.

A study of South African research links with EU partners (Blankley, van Vliet and Basson, 1998) showed that informal collaboration between researchers in South Africa and colleagues in EU institutions was very strong. These informal links often result in more formal collaboration agreements as partners become accustomed to working together. Researchers from South Africa who undertook their postgraduate studies in institutions in Europe and elsewhere tend to maintain strong research links with the institutions where they studied. These links can also benefit students who get introduced to international networks through their supervisors.

There are well-intentioned policies, strategies, and intentions for high-level human resource development (including R&D workers) in South Africa. However, South Africa is operating within a strong resource constraint of skills regarding its industrial capacities for sectoral development. There appears to be a need for good

governance and review of policy. Policies are not reviewed on a systematic basis and this is a difficult task because of a complex policy environment. A government department such as Home Affairs which does not have a science, technology and innovation or
economic mission has to deal with an important aspect of S&T worker mobility through the Immigration Act. It is important that science, technology and education orientated government departments and other players communicate and negotiate with Home Affairs. Alternatively, the department could be given a specific mission and mandate regarding S&T and be held to account for this.

SETAs appear to be poorly understood, particularly by smaller firms, higher education institutions and even public bodies. Their importance and relevance needs to be explained and demonstrated. While currently focused at basic skills development, the SETAs provide a model and mechanism for higher-level skills development that is also potentially appropriate for the S&T and R&D workforces.

There is a critical and central issue of a bottleneck in the system regarding the supply of mathematics and physical science graduates from the school system. The number of African school leavers with higher grade passes in mathematics and physical science remains at about one fifth of the total school leavers with these qualifications. This is a critical area to address in the medium and long term if South Africa wants to grow the S&T base. Policy makers are keenly aware of this problem but improvement in the situation has been very slow.

The history of isolation in business, academia and research and its effects on South Africa's reintegration into the global economy has been more profound than most people think. There are serious challenges facing the country as it develops and builds a new viable international competitive, innovative and equitable research system as part of a more comprehensive economic and social approach to addressing global flows and forces. The high incidence of xenophobia in the population, particularly towards immigrants from other African countries, is worrying and a consequence of South Africa's isolated past. Other developing and newly industrialising nations appear to have been more proactive at pursuing solutions to these types of problems and taking advantage of new opportunities.

There is a legacy of scepticism in the business sector towards R&D, which appears to be a product of a historical focus on the physical and financial capital intensity of the economy. R&D is seen as a factor of uncertainty and not as a factor of enhanced competitiveness. We need to unpack how firms innovate. An important source of innovation occurs along the value chain i.e. the inputs of suppliers and the demands of clients or customers. Perhaps in South Africa our focus is too much on R&D and innovation within the firm and we are not looking closely enough at the human resource and technology transfer links within the value chain. Policy makers need to guard against judging R&D and innovation potential solely on the basis of in-firm activities from surveys such as the R&D survey that focus on the business entity. Innovation surveys provide better evidence of value chain based activities. South Africa is often described as an early adopter of imported technologies and perhaps there is merit in South Africa's abilities in this regard.

6.4 Recommendations for the long term

While in the modern economy we should no longer think of "one job for life" there is a demand by bright students for PhD enrolment in areas where there is no R&D capacity in South Africa to support later employment at the same level of interest. Policy makers and funders should address the question of how these needs for specialisation can be accommodated and usefully channelled in the absence of an appropriate or viable local industry sector.

The cultural and societal values of science, mathematics and engineering need to be popularly recognised. This is no easy task given the current low levels of education and particularly mathematics and physical science training in the general population (see Blankley and Arnold 2001).

Mechanisms and interventions need to be understood and introduced to encourage career trajectories that reward both a technical and management pathway

6.5 Key Issues

International competitiveness is fundamentally driven by innovation, for which R&D is a central and crucial driver. Ensuring a strong and vibrant R&D workforce is key to the national future.

Several key issues and findings emerged that have clear indications for policy makers. One of the most striking of these is the mismatch between the apparent good intentions of the Immigration Act regarding the generous quotas for entry of foreign academic researchers and other key professionals and the bureaucratic, complicated and costly procedures needed to be followed in order to bring these experts to South Africa. A key finding of a recent European Commission (EC) Seminar on mobility was that the main obstacles in countries ability to promote mobility are found in national barriers, not in higher education and research organisations and structures (EC 2001). Collaboration across key Ministries and government departments needs to be reinforced if obstacles to mobility are to be removed. In South Africa the strong need for inter-institutional cooperation has been expressed by experts in government, business and higher education.

One example from the seminar was the establishment of a specific office dealing with administrative assistance for incoming researchers at Barcelona University. The creation of such a "Bureau d'accueil" was seen as an excellent way to facilitate mobility because the office is able to specialise and provide clear and complete information. This may well be the solution required by certain South African higher education and other research institutions requiring better access to international researchers. The improvement of administrative administrative processes and a better organisation of hosting institutions can have a positive impact on the mobility of researchers. This should be something that the Department of Science and Technology attends to in partnership with other ministries, departments and relevant institutions. Mobility needs to be considered as an issue relevant to all government departments. Clarity in legislation is essential and speedy processes are needed to deal with applications for entry and stay or work permits.

The strengthening of South Africa's S&T and R&D infrastructure, including the establishment of centres of excellence is part of the National R&D Strategy. Centres of excellence are a step in the right direction if the country wants to retain its best researchers and also be a popular destination for visiting scientists. Centres of excellence are a basis to build capacity, but they should be interactive and their purposes and viabilty within the global value-chain need to clear.

The first survey of innovation in South Africa's manufacturing sector (Blankley and Kaplan, 1997) showed that the extent and success of co-operative R&D linkages between manufacturing firms and organisations such as universities and science councils leaves much room for further development of beneficial partnerships and co-operative relationships. Joint government-industry initiatives should be designed and introduced in order to enhance networking and the better integration of the different components of the NSI, with a strong emphasis on high level skills development for industrial sectors.

The age distribution of research staff from the 2001/2002 R&D Survey (at least from the science council sector) shows that there is a more normal distribution of young and old workers than expected. Studies by the Centre for Interdisciplinary Studies at the University of Stellenbosch have indicated that only 15% of research outputs recorded in the SAKnowledgebase are produced by researchers less than 40 years old and nearly 50% are produced by researchers older than 50 years old. These findings led to the conclusion by policy makers that the R&D workforce is ageing and in dire need of replenishment because of a severe lack of young researchers in the system. From the data obtained from science councils for the 2001/2002 R&D Survey it appears that 50% of researchers employed in the sector are less than 40 years old and only about 23% are older than 50. The publications recorded in SAKnowledgebase are mostly produced by academic researchers (relatively few come from the private sector and science councils) and the age profiles of R&D workers in the higher education sector are still being recorded in the R&D survey. However, from the science council data it appears that there may be more young researchers in the system than previously thought. The reasons why these young researchers do not appear to be publishing as prolifically as their counterparts some 10 years ago needs to be carefully investigated. South Africa needs to pay close attention to the dynamics affecting young, and especially young black and young women, researchers if it is to regenerate its R&D workforce. Signs that young researchers are not publishing their research could indicate tensions and problems in the system that are also not making attractive careers for people.

South Africa's human resources in science and technology are growing and appear to have increased by about 7% (according to qualifications of the population) between 1997 and 2002. If this growth is looked at in terms of occupations the growth is nearly 30%. The large gaps in these two estimates illustrate the crudeness of the data that we have in South Africa to measure the S&T workforce. There is a strong need for a proper survey along Canberra Manual lines. The R&D Survey of 2002 will provide a more accurate picture of the number of researchers and other research staff. The number of researchers working in the science councils is about 2090. This figure compares favourably with the 2297 researchers recorded for the services sector (including science councils and government) in the 1997/98 survey. However it is clear that the number of people in South Africa with S&T qualifications

capable of working in the S&T and R&D system is inadequate for a competitive and dynamic economy although the percentage of the population employed in the S&T sector grew from 3.3% in 1997 to 4.2% in 2002, reflecting a world wide trend. Racial and gender biases are still strong and the 1.7% of the African population employed in S&T in 1997 grew from this small base to 2.3% in 2002 while white participation in the sector grew from 14.9% in 1997 to 18.0% in 2002. Female participation in the S&T workforce grew from 42.1% in 1997 to 48.3% in 2002. However female educational attainments remain low and in 1996 they only held 26.7% of doctorates and 30.8% of masters degrees. This means that women employed in the S&T sector are likely to hold lesser positions than males because of their lower qualification profile. The importance of a balanced and equitable S&T and R&D workforce with highly developed skills to achieve sustainable economic growth rates cannot be overemphasised.

Official immigration to South Africa dropped from 20 972 in the period 1994-1997 to 15 925 between 1998 and 2001. The percentage of HRST immigrants dropped from 15.7% in 1994-1997 to 10.6% in 1998-2001 and this is worrying. It is difficult to say whether foreigners with S&T qualifications see South Africa as a less favourable destination or whether the rules governing immigration have become stricter and led to a fall in inflows. The main countries of origin of immigrants in 1997-2001 were the UK (13.4%), India (9.1%), Zimbabwe (5.9%), Germany (5.4%), China (5.3%) and Taiwan (5.1%). In contrast the top destinations of the 40 040 emigrating South Africans in the same period were the UK (27.7%), Australia (16.2%), New Zealand (10.1%) and the USA (9.8%). Of these 4 040 emigrants 23% were with HRST qualifications which was up from the 20% recorded for the period 1994-1997.

This study has shown some of the difficulties that are encountered when working with data and information on the mobility of R&D workers. Only when proper surveys and data sources are in place that we will be able to have a better understanding of the mobility flows in the country. The study has not seen evidence of a "brain drain" crisis although it did not look at specific health employment sectors such as doctors and nurses working in the public sector where problems might be more critical. The "brain drain" may be overestimated where return rates are not clear. South Africans have only really been welcome to travel and work freely in other countries since 1994 and many of those currently abroad may return one day. Even if they do not they still have links with the country and mechanisms such as SANSA and the UCT GSB World Bank Diaspora network attempt to support and develop these links for development in South Africa. One thing is clear though. If South Africa's public research system is perceived to be weak or eroding in that there are few job opportunities or resources available this will encourage national researchers, especially the young, to seek positions in other countries. Likewise a weak S&T system will not attract the flows of skilled foreigners required to stimulate the S&T system. Fortunately, government seems dedicated to growing and strengthening the R&D and S&T system and also realises the importance of international links and mobility in this process. However these objectives will not be obtained unless there is greater collaboration between the government ministries and departments concerned.

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