DISCUSSION DOCUMENT

SOUTH AFRICAN INNOVATION KEY FACTS AND FIGURES 2004

NATIONAL ADVISORY COUNCIL ON INNOVATION

SOUTH AFRICA

DEPARTMENT OF SCIENCE AND TECHNOLOGY

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DISCUSSION DOCUMENT

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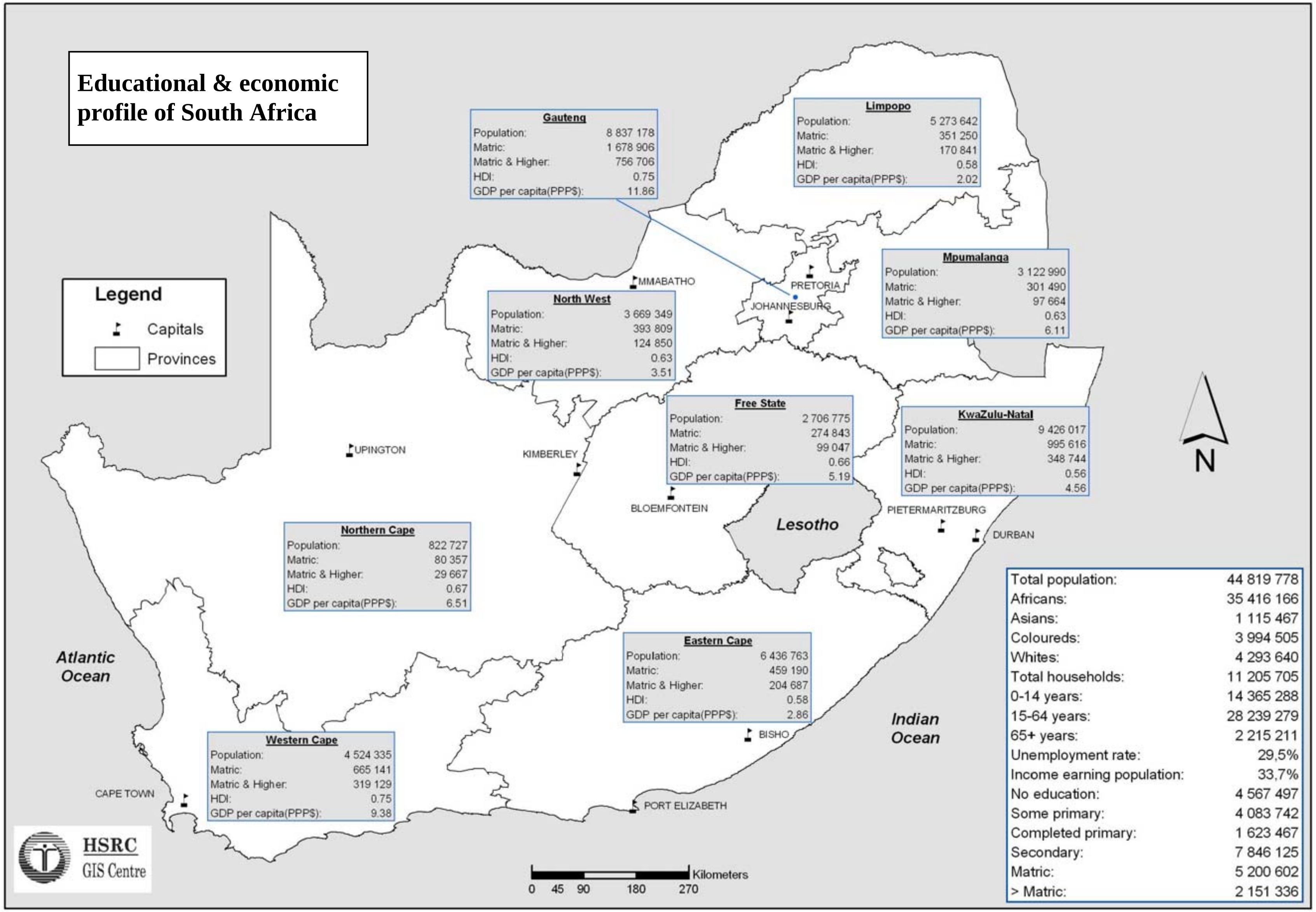


Educational & economic profile of South Africa
Legend
Capitals
Provinces
Gauteng
Population: 8 837 178
Matric: 1 678 906
Matric & Higher: 756 706
HDI: 0.75
GDP per capita(PPP$): 11.86
Limpopo
Population: 5 273 642
Matric: 351 250
Matric & Higher: 170 841
HDI: 0.58
GDP per capita(PPP$): 2.02
Mpumalanga
Population: 3 122 990
Matric: 301 490
Matric & Higher: 97 664
HDI: 0.63
GDP per capita(PPP$): 6.11
North West
Population: 3 669 349
Matric: 393 809
Matric & Higher: 124 850
HDI: 0.63
GDP per capita(PPP$): 3.51
Free State
Population: 2 706 775
Matric: 274 843
Matric & Higher: 99 047
HDI: 0.66
GDP per capita(PPP$): 5.19
KwaZulu-Natal
Population: 9 426 017
Matric: 995 616
Matric & Higher: 348 744
HDI: 0.56
GDP per capita(PPP$): 4.56
Northern Cape
Population: 822 727
Matric: 80 357
Matric & Higher: 29 667
HDI: 0.67
GDP per capita(PPP$): 6.51
Eastern Cape
Population: 6 436 763
Matric: 459 190
Matric & Higher: 204 687
HDI: 0.58
GDP per capita(PPP$): 2.86
Western Cape
Population: 4 524 335
Matric: 665 141
Matric & Higher: 319 129
HDI: 0.75
GDP per capita(PPP$): 9.38
MMABATHO
PRETORIA
JOHANNESBURG
UPINGTON
KIMBERLEY
BLOEMFONTEIN
PIETERMARITZBURG
DURBAN
Lesotho
BISHO
PORT ELIZABETH
CAPE TOWN
Atlantic Ocean
Indian Ocean
N
Total population: 44 819 778
Africans: 35 416 166
Asians: 1 115 467
Coloureds: 3 994 505
Whites: 4 293 640
Total households: 11 205 705
0-14 years: 14 365 288
15-64 years: 28 239 279
65+ years: 2 215 211
Unemployment rate: 29,5%
Income earning population: 33,7%
No education: 4 567 497
Some primary: 4 083 742
Completed primary: 1 623 467
Secondary: 7 846 125
Matric: 5 200 602
> Matric: 2 151 336
HSRC
GIS Centre
Kilometers
0 45 90 180 270

Foreword

Innovation is critical to our national participation in the global knowledge economy. Characterized by the introduction of new products and services and the use of new processes in our economy and, more broadly, in our society, innovation is very important for long-term economic sustainability and for improved quality of life. Innovation, in other words, involves harnessing new knowledge produced by researchers.

Investing in innovation is an economic choice made daily by firms, institutions, and government. Innovation spending competes with other investment domains, however. These daily choices require information on needs, outputs and impacts as basis for prioritization, in short: indicators of the performance of the system. This publication represents on overview of the current reality of the measurable parts of the innovation system. In any complex system, however, there are intangibles and ‘unmeasurables’: no set of indicators can tell the full story.

National innovation systems have characteristics in common, but notable differences exist among countries. The ‘pre-history’ of an innovation system can greatly influence current performance, for instance, and the exclusion of most of South Africa’s population from science, engineering and technology needs attention and focus.

The absolute size of the system is also a critical policy consideration. Benchmarking with other countries allows decision-makers to contextualize the significance and range of particular indicators. Time series over a number of years can also give an impression of the extent of change or stasis and the dynamics of the system overall. The perception is that South Africa is not as strategic or aggressive as some countries in mobilizing innovation for wealth creation and improved quality of life. Nevertheless, the facts and figures in this publication suggest that there are advantages in our current economy and we are in a position to make policy and strategy choices to strengthen our performance in the short, medium and long term. First, the insufficient numbers of engineers and scientists in South Africa and our low patenting rates need immediate attention. Second, the need to increase research and development (R&D) spending by government is already recognized. Third, the low tax incentives for R&D spending by businesses in South Africa, potentially reduces the attractiveness of South Africa as a ‘research and innovation’ destination, even though our absolute costs are still low.

This publication is not a policy document. It is intended to contribute the latest available reliable and valid information to the crucial debate about the value placed in our economy on knowledge and its appropriate use through innovation by the public and private sectors. It is a potentially valuable resource to enrich discussion and to assist South Africa to make better choices in the future.

Rob Adam
DG: DST & CEO: NACI

Section 1

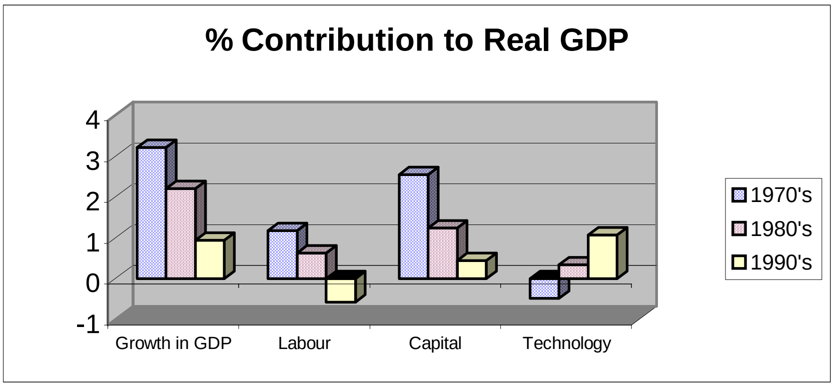
Introduction to innovation

Definitions of innovation

Innovation, and organisational changes associated with it, is a key determinant of economic growth over the long term. In the past, economic growth was thought to depend on inputs, such as labour and capital investment. Recent studies of economic growth show, however, that innovation and technology determine any economy's long-term growth prospects (NACI/NSTF, 2001).

The NACI/NSTF growth and innovation study of 2001 investigated the interactions between science and technology and economic growth in our setting. Figure 1.1 depicts the percentage contribution to South Africa's gross domestic product (GDP) by labour, capital investment, and technology efficiency over the past two decades. This study showed that, whereas in the 1970s growth in real GDP was attributed to capital and labour contributions, recent economic growth in South Africa could be attributed more to technological contributions than to those of labour and capital (NACI/NSTF, 2001).

Figure 1.1: Contribution of factor inputs to real GDP



Source: NACI/NSTF, 2001

Observed economic growth is related to 'technological innovation', that is, to technological advances that lead to improved products and more efficient processes.

The OECD's Guidelines for Collecting and Interpreting Technological Innovation Data (the Oslo Manual) define 'technological innovation' as follows:

A technological product innovation is the implementation/commercialisation of a product (goods and/or services) with improved performance characteristics such as to deliver objectively new or improved services to the consumer. A technological process innovation is the implementation/adoption of new or significantly improved production or delivery methods. It may involve changes in equipment, human resources, working methods or a combination of these.

Innovation should be distinguished from inventions and creations. Creativity is defined as the ability to make, form, produce, or constitute for the first time, or the ability to invent. Inventions and creations become innovations only once they yield market value. Innovation depends in essence on current levels of science and technology. To be innovative, individuals and businesses need to understand and master scientific and technological processes that underpin product and process development. Although innovation is normally associated more with technology than with science, the linkages between science and technology are critical for any innovation process.

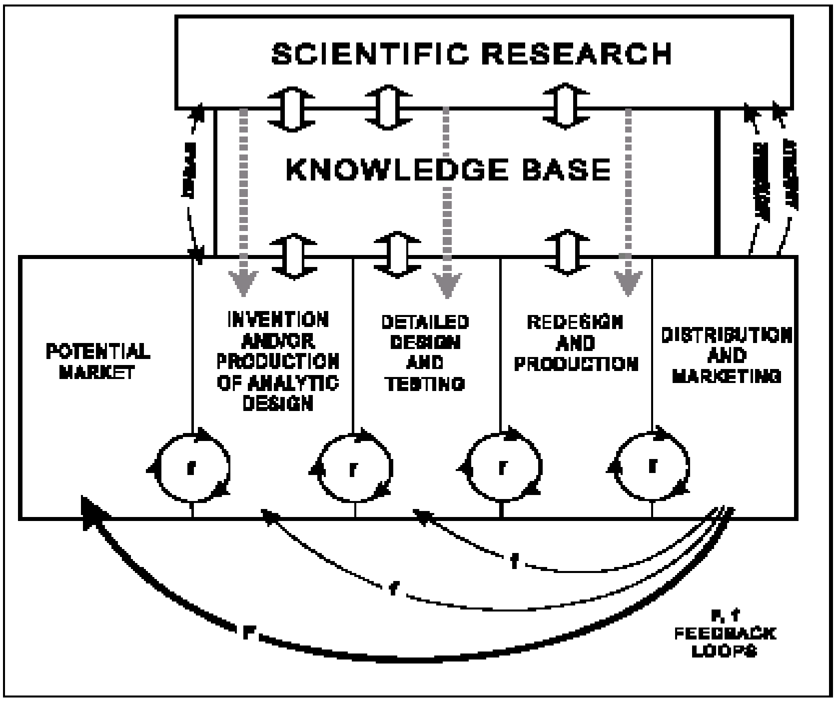
There is a clear distinction between science and technology. "*Science* is fundamentally about the pursuit of better understanding" while "*technology* is the development of practical devices or processes that operate reliably" (Commonwealth of Australia, 1988). Science and technology are both interdependent and cumulative. Newly developed technological devices, used in research, may lead to advances in scientific understanding. Similarly, advances in scientific understanding may lead to the development of new devices.

The process of innovation

Early models presented innovation as a linear process in which scientific research leads directly to technological improvement and, ultimately, the introduction of innovative products to the market. Recent developments in our understanding of the nature and inter-relationships of science, technology, and the process of innovation have generated a new model, which views innovation "as a series of changes in a complete system, not only 'hardware', but also of the market environment, production facilities and knowledge, and the social context of the innovative organization'(Kline and Rosenberg, 1986:275).

Figure 1.2 illustrates this model of innovation, aptly called the 'chain-linked' model.

Figure 1.2: Chain-linked model of innovation



Source: Adapted from Kline and Rosenberg (1986: 290)

A review of innovation undertaken in Australia made the following observations about this model. Figure 1.2 shows ideas and knowledge flowing in both directions — from scientific research to technology and from technological advances to science. Technology can provide useful devices and software that enhance scientific research, and signals from the market can suggest specific strategic directions where research is needed to support technological development that is commercially viable. Extensive feedback loops between all stages of the innovation and commercialization processes are the ‘chain links’ in the model (Commonwealth of Australia, 1988).

Innovative processes, therefore, involve complex interactions, which not only include research and development and new inventions, but also environmental factors that may involve a choice between the adoption or rejection of a new invention in the market place. The innovation process needs to be well coordinated, since sporadic innovations are not sustainable and will not ensure a competitive market edge. For competitiveness, an organization requires a consistent innovation strategy to be implemented over a period of time.

Mapping innovation and innovation activities

Innovation is an important determinant of economic growth and should be monitored by governments and other stakeholders so that long-term growth trends can be mapped. The ability to anticipate future trends enables governments to implement corrective policy measures for reducing the risk of market failure and enhancing the potential for economic growth.

'Innovation', unlike other terms such as 'distance' (measured in metres, for instance) or 'time' (that can be measured in seconds), is an abstract concept without physical properties that can be measured directly and accurately for further examination and analysis. In the absence of measurable physical properties, indicators are used as proxies to suggest or indicate the concept's attributes.

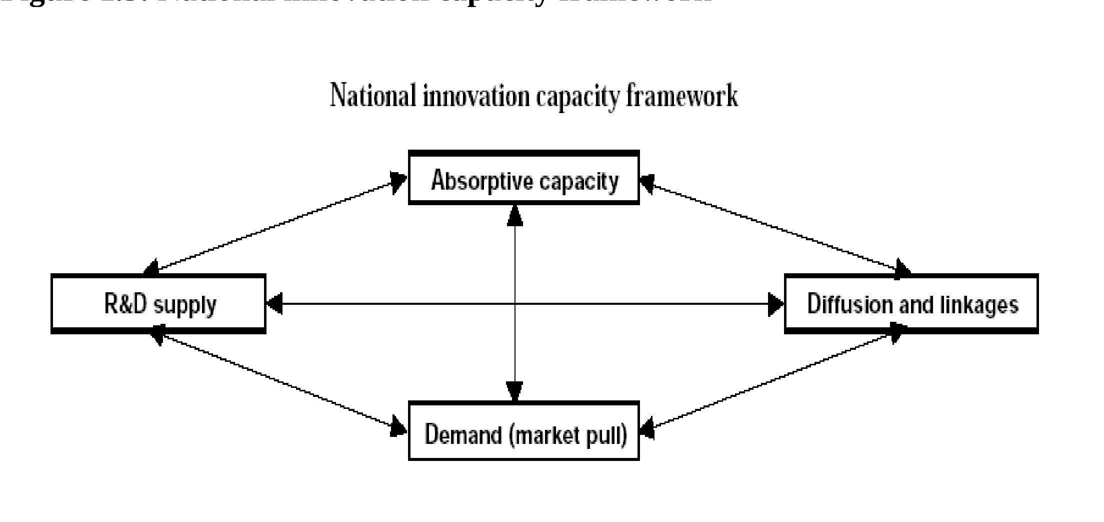
The successful choice of an indicator for a given abstract concept depends on how well the concept itself is understood. To choose appropriate indicators, we need to identify the attributes or properties of the concept, and define clearly their relationship to the desired concept. Based on these considerations, measurable properties of innovation have been derived so as to reflect South Africa's innovative capacity.

Innovation measures and indicators are implicit in the chain-link model, and a number of factors interact for successful innovation. To indicate a country's innovative capacity, four multi-factor indicators may be used: *absorptive capacity*, *R&D capacity*, *diffusion and linkages* and *demand capacity.*

Absorptive capacity is the ability to absorb new knowledge and adapt imported technologies. This capability is essential for catch-up and emerging economies to grow and innovate. *R&D capability* is important not only to generate new knowledge but also as mechanism to absorb it. *Diffusion* essentially measures the widespread adoption of technology by users other than the original innovator. It is key to reaping economic benefits from own investment in R&D as well as to employ absorptive capacities. *Demand* for R&D and innovation is the key economic mechanism, which initiates wealth generation processes in R&D, absorption and diffusion activities. (Radosevic)

Figure 1.3 shows the framework used for the structuring of this publication. Implicit in this framework is the fact that none of these components can lead to a productive innovation system in isolation, they are interdependent and interacting elements.

Figure 1.3: National innovation capacity framework



Source: Radosevic

The success of any innovation system depends on how well these four components are individually optimised and collectively implemented.

The indicators for each component in Figure 1.3, as suggested by Radosevic, are listed below.

Absorptive capacity

- Expenditures in education as % of GDP
- S&E graduates
- Population with 3rd level education
- Participation in life-long learning
- Employment high-tech manufacturing
- Employment high-tech services

R&D supply

- Public R&D expenditures (% GDP)
- Business R&D expenditures (% GDP)
- R&D personnel per labour force
- EPO high-tech patents (per million of the population)
- USPTO high-tech patents (per million of the pop)
- Resident patents per capita

Diffusion and linkages

- Training enterprises as % of all enterprises
- CVT as % of labour costs of all enterprises
- ISO 900 certifications per capita
- Internet users per 10 000 inhabitants
- PC per 100 inhabitants
- ICT expenditures (% GDP)

Innovation demand (market pull)

- Stock market capitalization in % GDP
- Domestic credit provided by banking sector (%GDP)
- Share of FDI in GDP
- Share of trade in GDP
- Index of patent rights

The specific indicators used in this publication were selected in terms of their relevance and according to the availability of data. This list is by no means exhaustive, but it summarizes in part the indicators deemed important in a developing country such as South Africa.

Section 2

Absorptive capacity

Introduction

Absorptive capacity indicates the ability of South Africa, as a developing country, to adapt and use new technologies developed elsewhere. It requires the ability to identify, acquire, and quickly understand new developments, so as to use them profitably. This section reviews the country's absorptive capacity by using as indicators the level of human development, expenditure on education, and the availability of engineers and technologists in South Africa. Key observations from this chapter are that:

- Using the Human Development Index (HDI) as a proxy, South Africa may be considered to have a medium level of development
- Although the education expenditure as a percentage of GDP is higher than the OECD mean, this should be viewed in the context of the educational backlog created by educational policies under apartheid and against the backdrop of the country's current levels of human development
- Although South Africa continues to register new professional engineers each year, the rate at which it introduces new engineers is exceeded by the rate at which engineers are lost to the system. The overall number of professionally registered engineers is low and continues to decline
- The number of registered engineering technologists is increasing slowly, albeit at a lower rate.

Education and unemployment

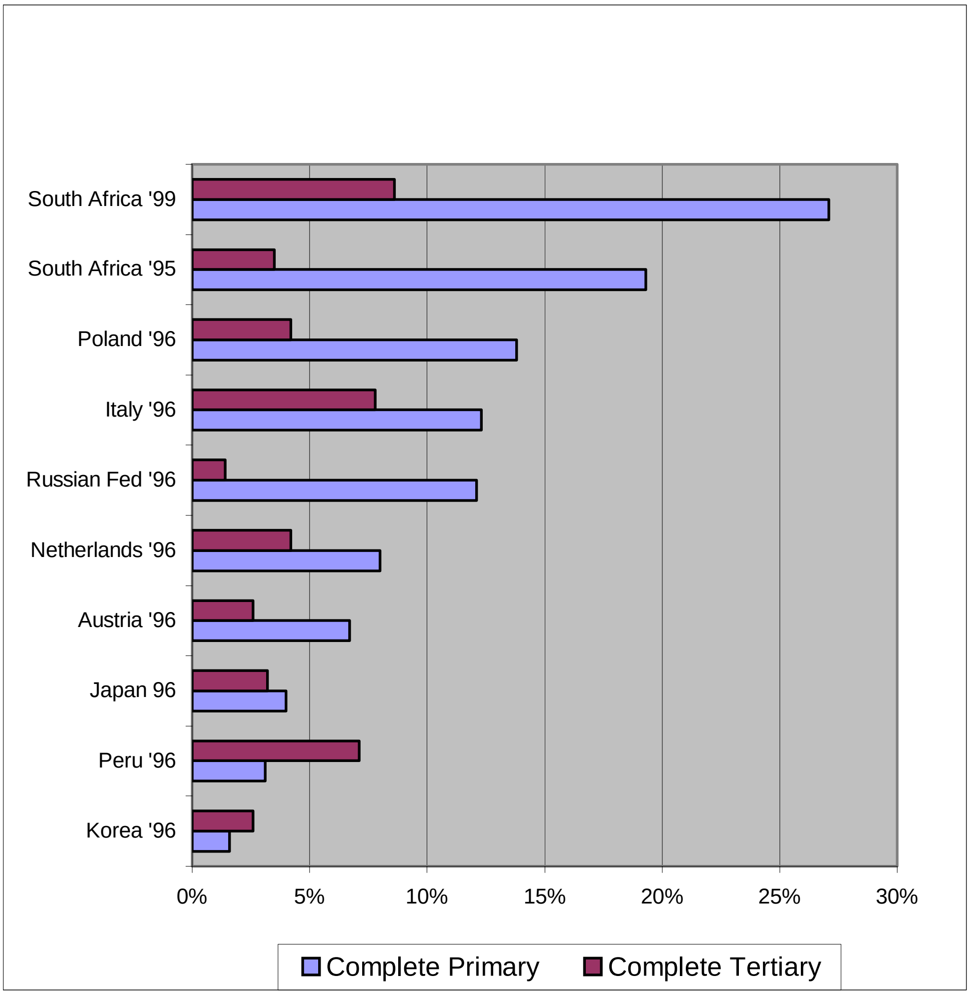
Most South Africans in the age group 20 and higher have achieved only Grade 12 and lower, and only 8.4 percent have a qualification higher than Grade 12/Std 10.

Figure 2.1: Highest level of education amongst those aged 20 and older (2001)

Level of Education	Number	% of total
No schooling	4 567 497	17.9
Some primary schooling	4 083 742	16.0
Completed primary	1 623 467	6.4
Some secondary	7 846 125	30.8
Grade 12/Std 10	5 200 602	20.4
Tertiary	2 151 336	8.4
Total	25 472 769	100

Source Statistics South Africa, 2003

Figure 2.2: Unemployment rate by education attainment in selected countries

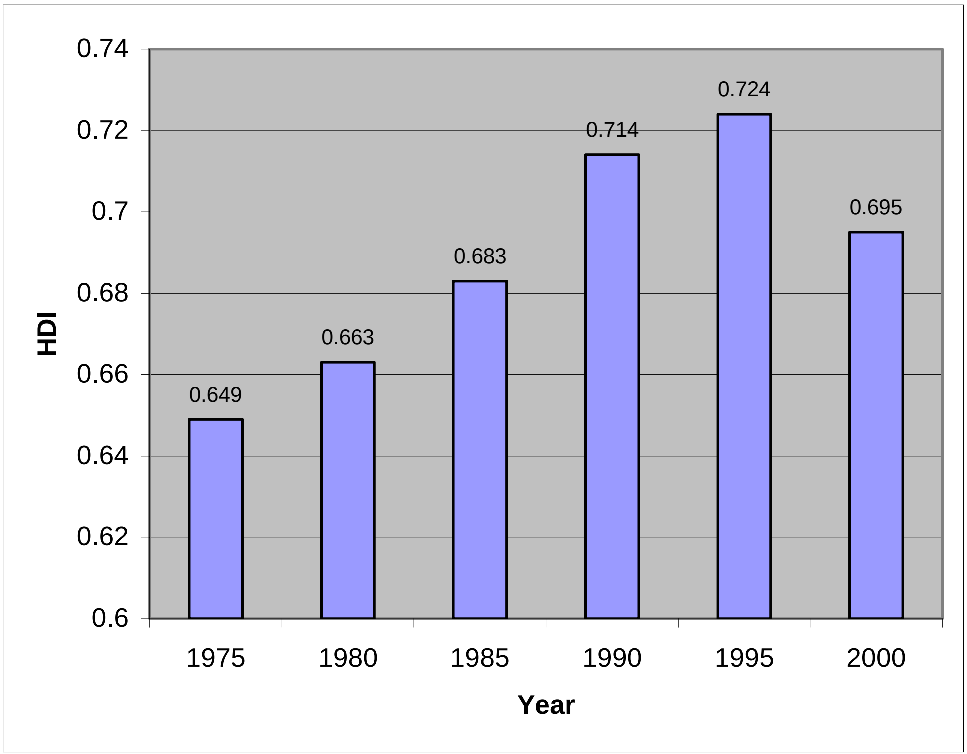


Source: Statistics South Africa, 2002a

Education is one of the most important factors — as a lagging indicator — of a country's level of employment and productivity. In general, the level of unemployment is higher for people with primary education only than for those with tertiary education: "The depicted unemployment rate for South Africa is a little higher [than the figures suggest] since 'complete tertiary' in this case actually includes people who have completed secondary education and hold a certificate or a diploma. The true figures of unemployment for people holding degrees (i.e. undergraduate and/or postgraduate) is 2.1 percent in 1995 and 4.6 percent in 1999.'(Statistics South Africa, 2002a)

Human development

Figure 2.3: South African Human Development Index (HDI) (1975–2000)



Source: UNDP, 2002

The Human Development Index is a composite indicator, using basic indicators to measure a country's level of development. The three basic indicators are: a long and healthy life as measured by life expectancy at birth; knowledge as measured by the adult literacy rate and combined primary, secondary, and tertiary gross enrolment; and a decent standard of living as measured by GDP per capita. South Africa experienced positive growth until 1995, after which it experienced a slight decrease.

Figure 2.4: South African knowledge trends

	1990–91	2000–1
Adult Literacy	81.2	85.6
Net Primary Enrolment Ratio(%)	103.0	89.0
Net Secondary Enrolment Ratio	…	57.0

Source: UNDP, 2002

Note: The figures for adult literacy rates are for 1990 and 2001, respectively.

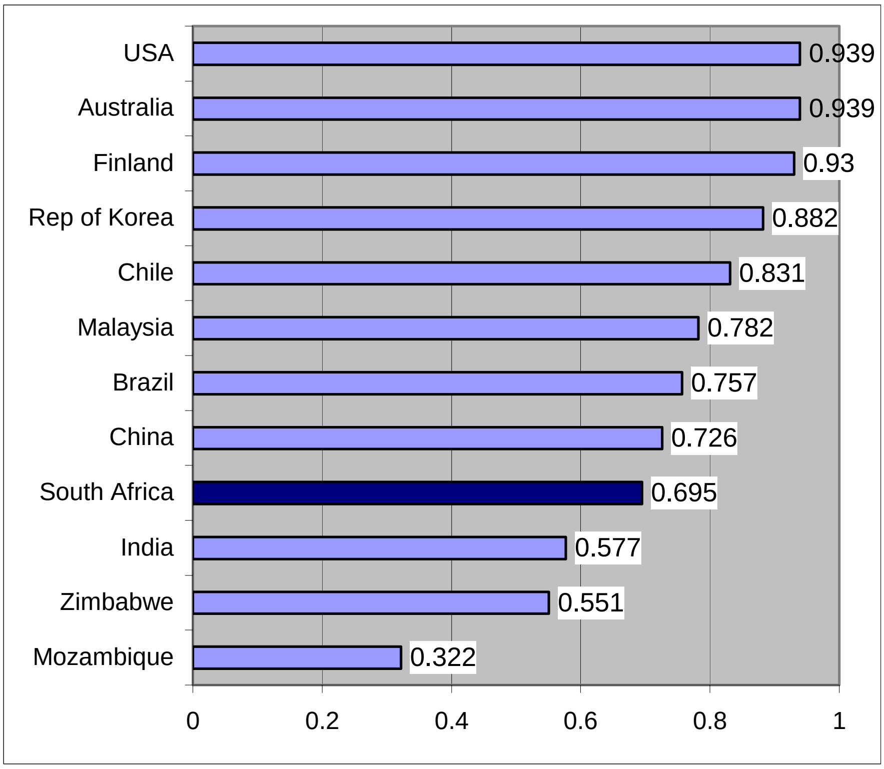
Figure 2.5: South African long and healthy life trend as measured by life expectancy at birth

	1970–75	2000–05
Life Expectancy at Birth	53.7	47.7

Source: UNDP, 2002

Figures 2.4 and 2.5 show that, whereas South Africa's adult literacy rate has increased, there has been a reduction in life expectancy and in the net primary school enrolment ratio. This situation could be related to the effect of HIV/AIDS on life expectancy and might have let to the overall reduction in the Human Development Index (Figure 2.3).

Figure 2.6: International HDI comparisons (2000)

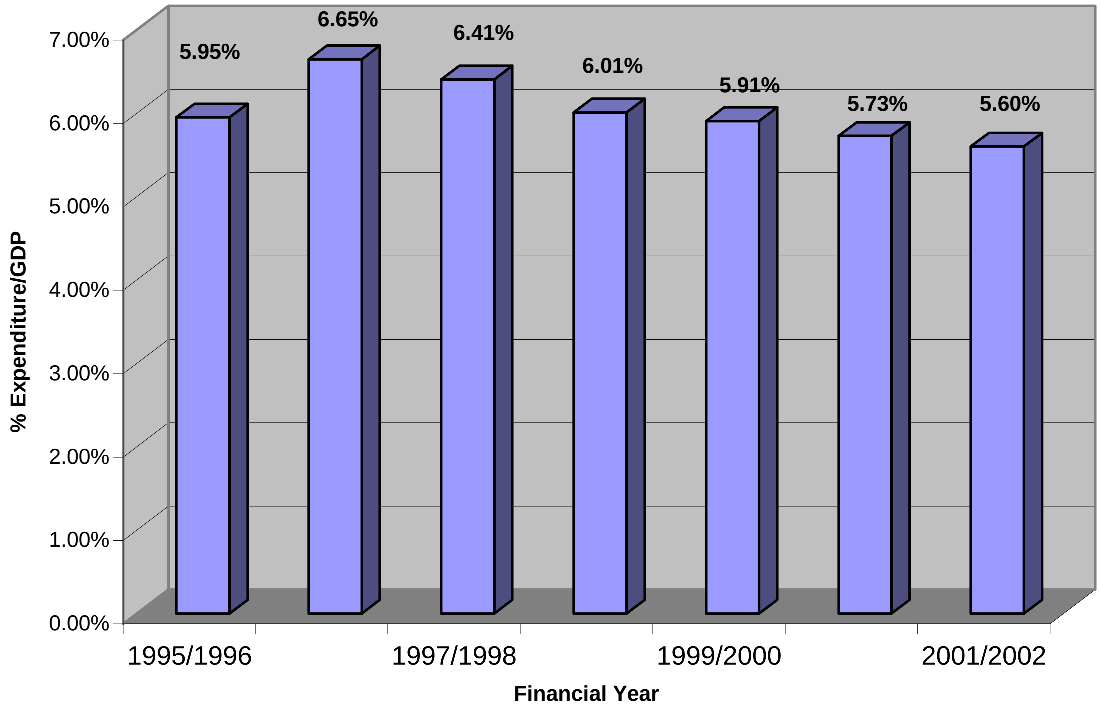


Source: UNDP, 2002

Using the Human Development Index as a reference (figure 2.6), South Africa's development is rated as medium. This means that, to be competitive in global markets, South Africa needs aggressively to accelerate its development of human capacity.

Expenditure on education

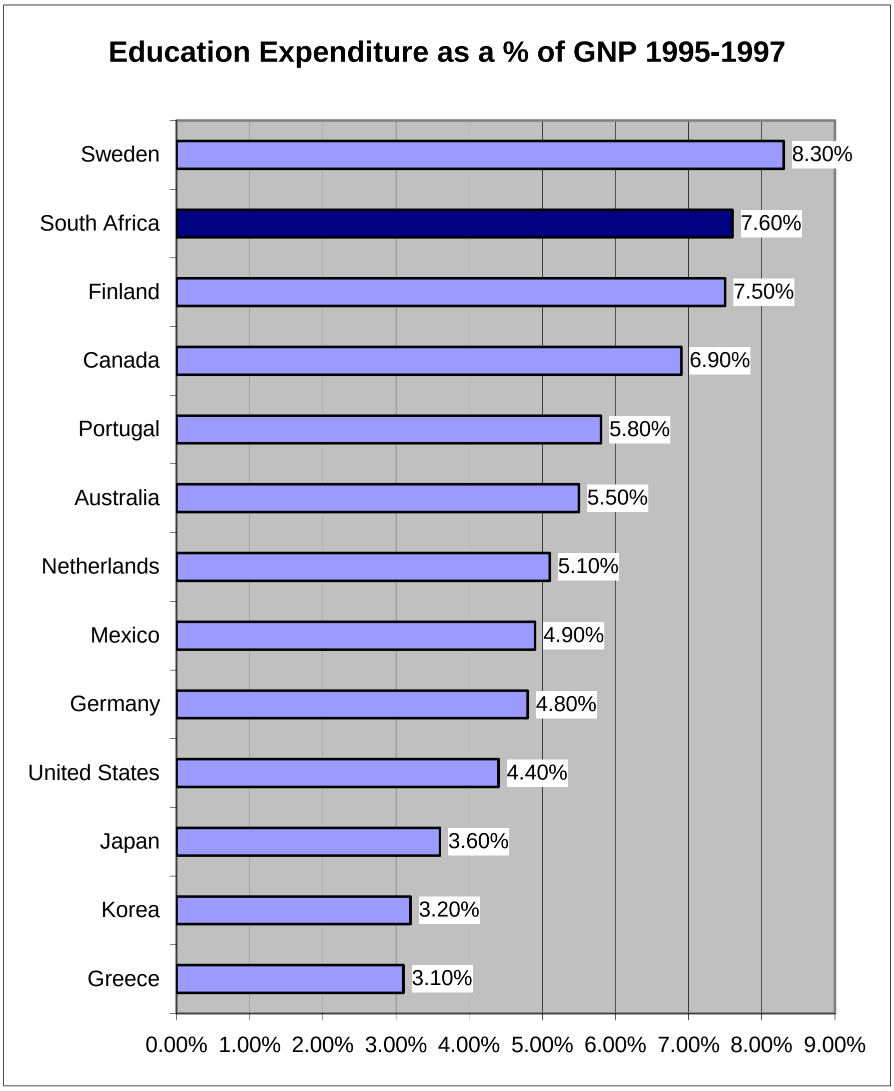
Figure 2.7: South Africa's expenditure on education



Source: DoE website

A country's ability to innovate depends upon the speed at which it can develop and maintain a high level of human skills, largely determined by the education attainment of its citizens. An indicator normally used to assess the national commitment to achieve high levels of intellectual capital is the expenditure on education. Figure 2.7 shows a decrease over the past five years in the expenditure on education as a percentage of GDP.

Figure 2.8: International expenditure on education as a percentage of GNP (1995–1997)

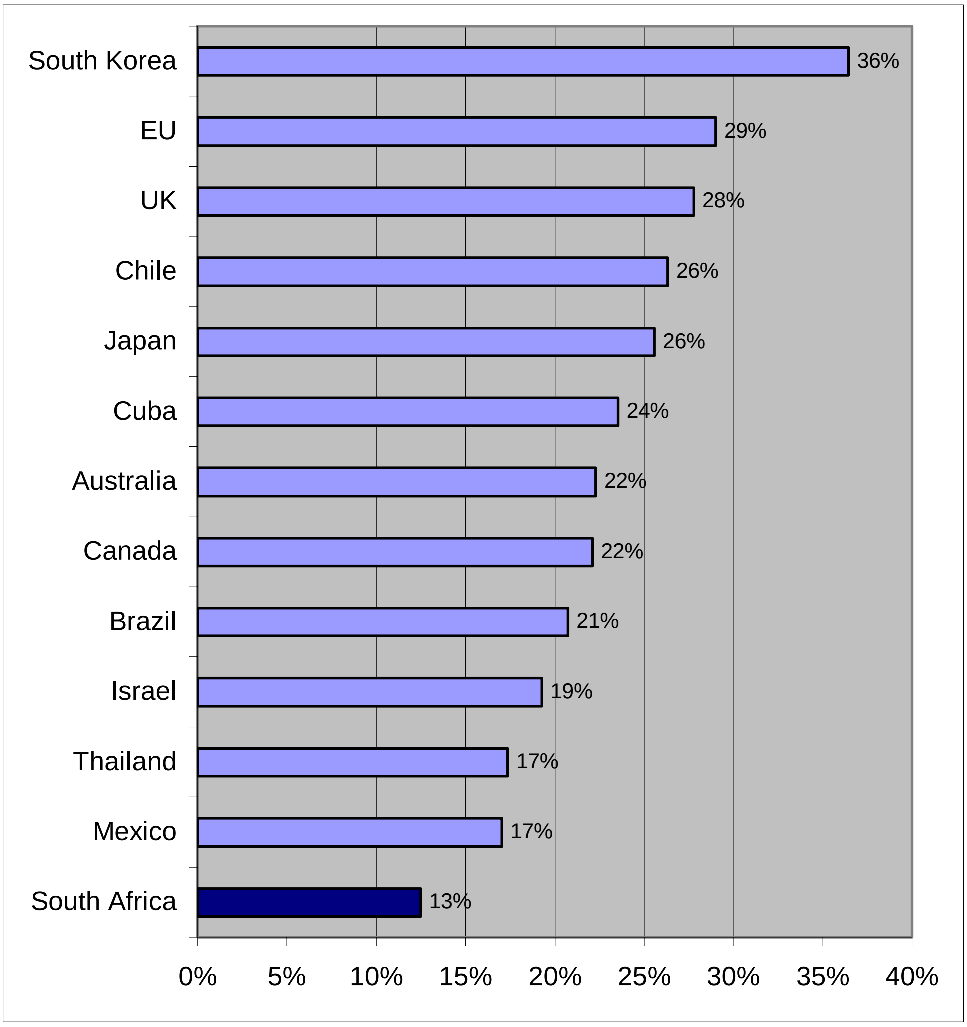


Source: UNDP, 2002

Although South Africa's expenditure on education as a percentage of GDP has been decreasing over the last few years (Figure 2.7), it remains above the 1995 OECD mean of 5.6 percent (Statistics Finland). Figure 2.8 above shows South Africa spending more on education as a percentage of GNP compared to most upper income and upper-middle income countries, which has led to the increase in adult literacy (Figure 2.4). This expenditure is further justified by the fact that South Africa still has comparatively low levels of human development (Figure 2.6).

Engineers and technologists

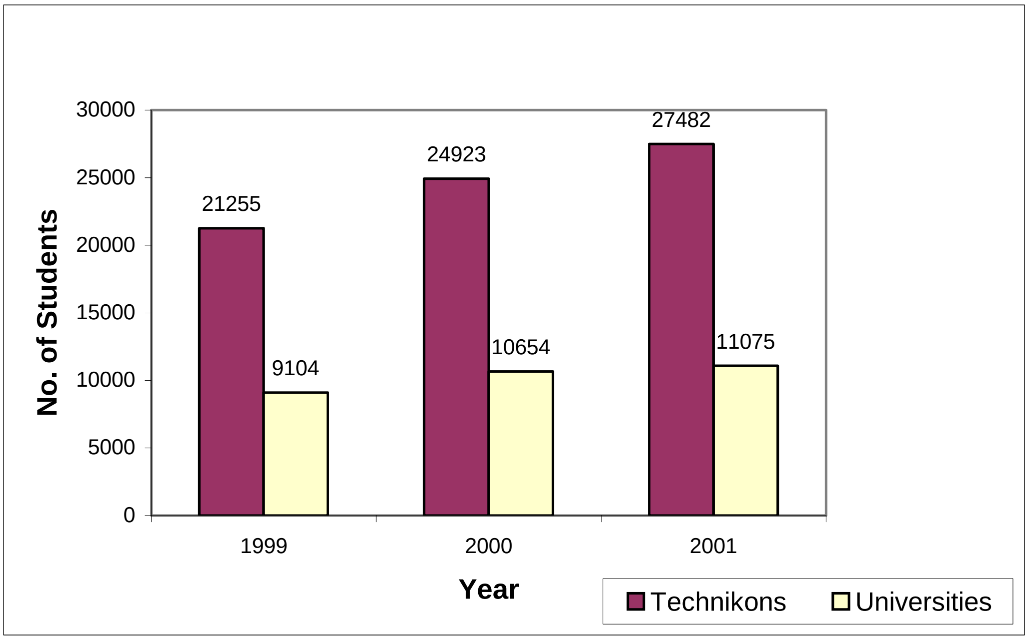
Figure 2.9: Ratio of natural sciences and engineering graduates to all university graduates in the 24 years age cohort



Source: Unesco

Scientists and engineers are key to the innovative capacity of a country. A snapshot of the number of natural scientists and engineering graduates as a percentage of all South African graduates shows that South African universities lack capacity in natural sciences and engineering disciplines. The ratio of completed undergraduate degrees in natural sciences and engineering to the 24-year old population is also substantially lower than that of selected other countries.

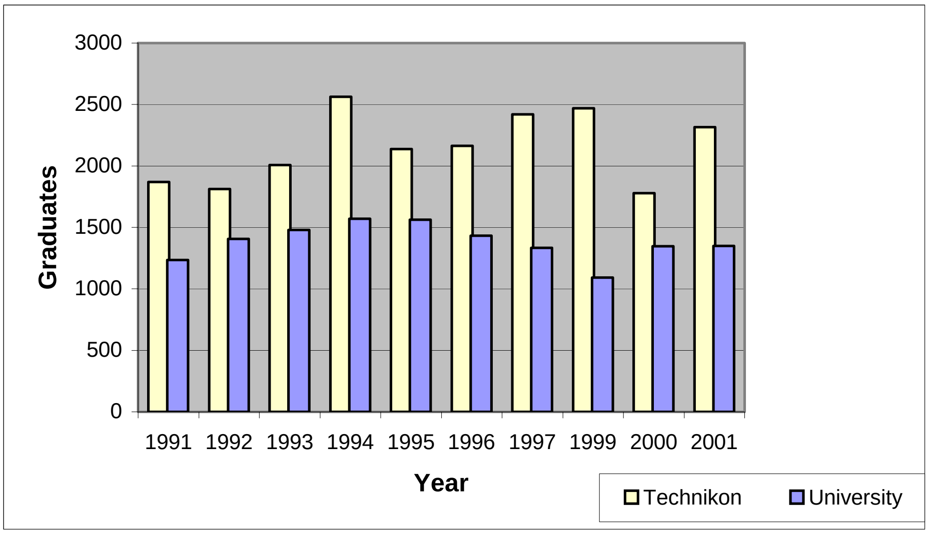
Figure 2.10: Enrolments at South African universities and technikons (1999–2001)



DoE database

Note: 'Enrolments' refers to all engineering faculties and all categories of qualifications.

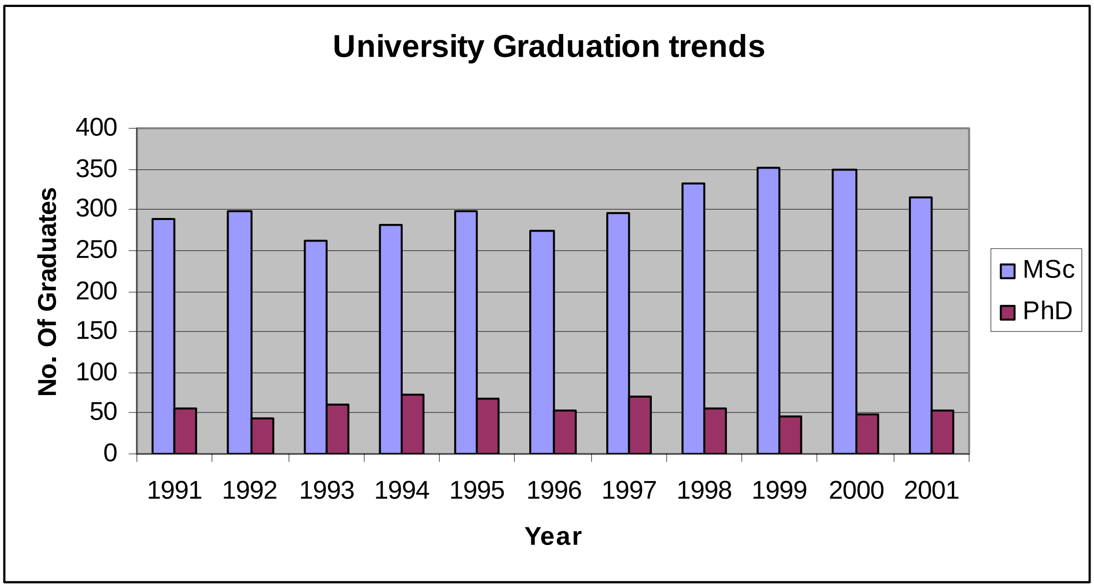
Figure 2.11: South African university and technikon engineering graduates



Note: Figures for 1999–2001 include national diploma and B.Tech. graduates

'University graduates' include all first time degrees. 'Technikon graduates' from 1991 to 1997 refer to graduates with national diplomas, while data from 1999 to 2001 includes both national diplomas and B.Tech. degrees. The number of South African technikon graduates (in all categories) has fluctuated over the past few years, whereas the number of university engineering graduates has been a declining.

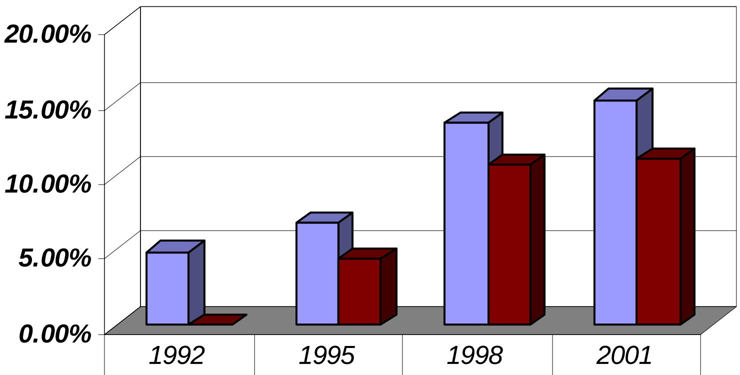
Figure 2.12: Graduates in South Africa who fulfilled the requirements for M Sc and PhD in engineering (1991–2001)



Source: DoE database

The number of postgraduate students graduating with a master's or a doctoral degree in engineering has started to decline.

Figure 2.13: Percentage of women graduating with M Sc and Ph D in engineering and Engineering Technology (1992–2001)

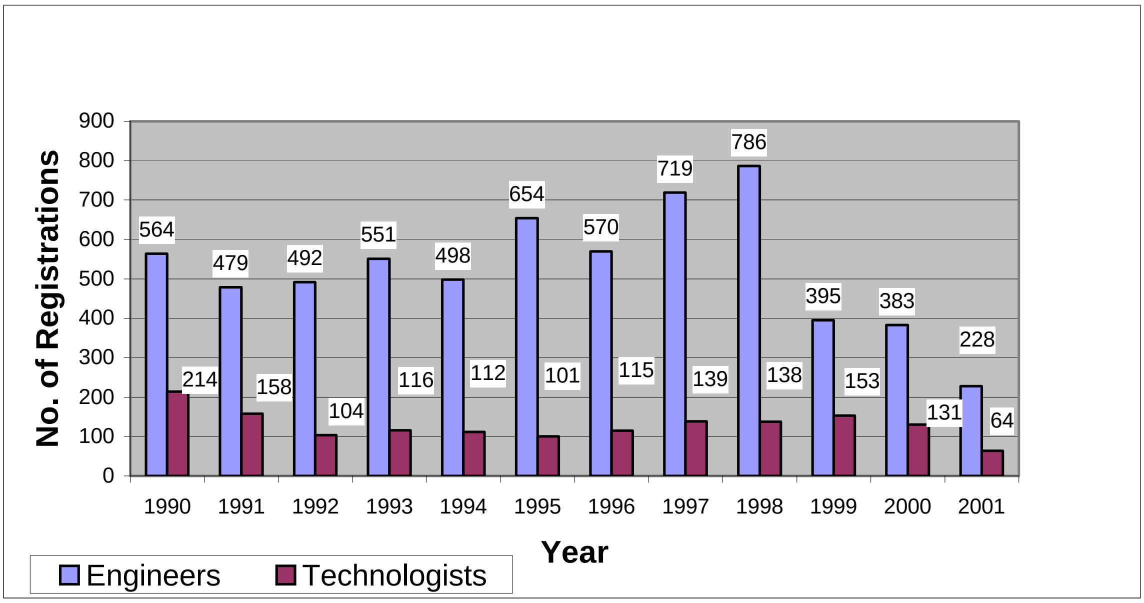


	1992	1995	1998	2001
MSc	4.90%	6.83%	13.56%	15.11%
PhD	0.00%	4.41%	10.71%	11.11%

Source: CENIS and DoE database

On the other hand, enrolment by women in Engineering and engineering technology has being on the increase.

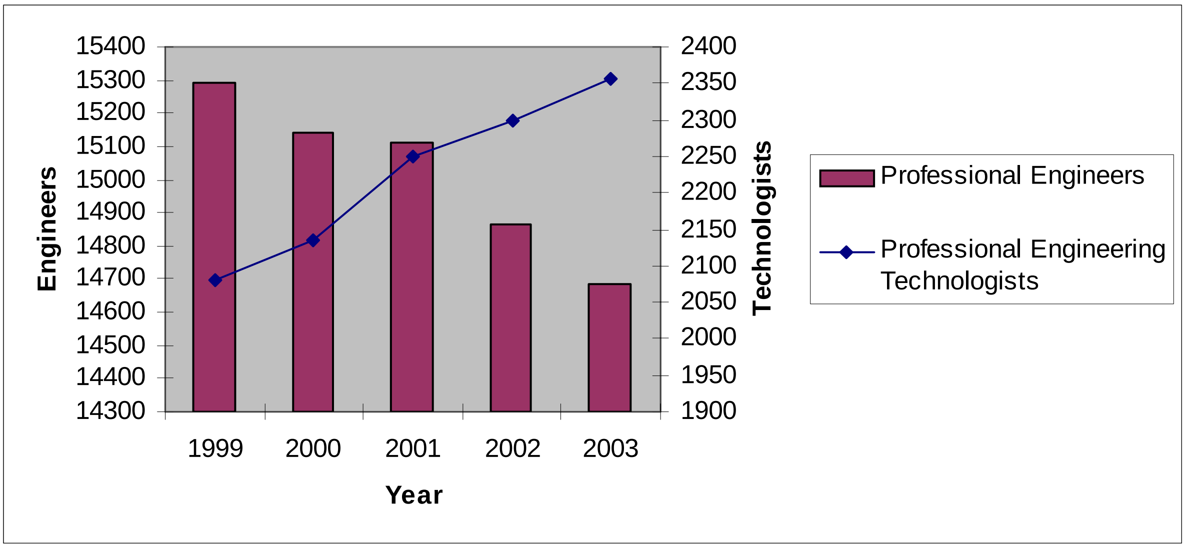
Figure 2.14: New professional registrations of engineers and engineering technologists (1990–2001)



Source: ECSA

The number of professional registrations of engineers and technologists has been decreasing. Engineering registration dropped by 60 percent from 564 in 1990 to 228 in 2001 (with fluctuating figures in between), whilst registration by technologists dropped by 70 percent from a high of 214 in 1990 to a new low of 64 in 2001.

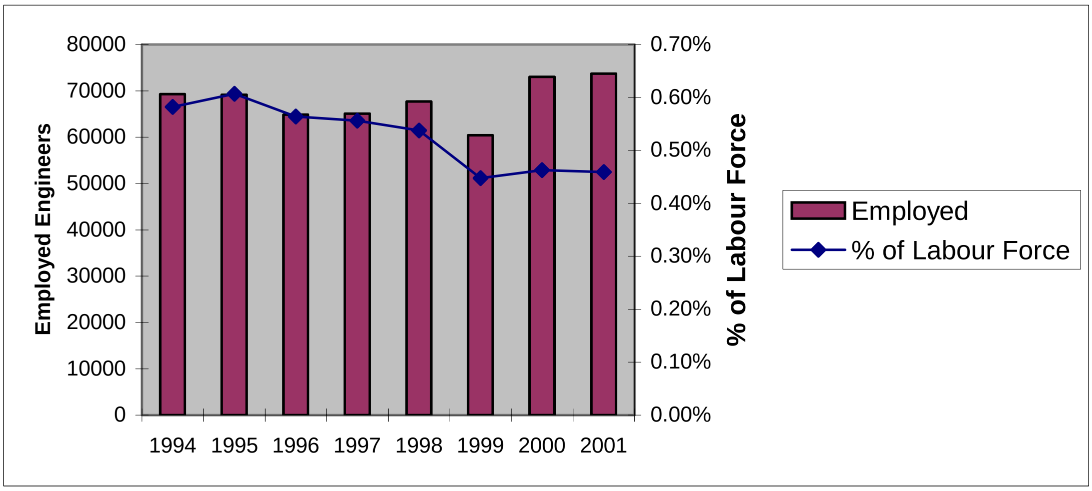
Figure 2.15: Numbers of professionally registered engineers and engineering technologists in South Africa (1999–2003)



Source: ECSA

As at 31 March 2003, the number of registered professional engineers has been on the decline, while that of professional engineering technologists has been increasing, although at a slower rate and off a moderately lower base.

Figure 2.16: Employed engineers as a percentage of the total South African labour force



Source: Manpower Survey, OHS95-99, LFS2000-2001

Despite the decline in the number of registered professional engineers, the number of employed engineers increased in the years 2000 and 2001. The number of engineers as a percentage of the total labour force has, however, remained stable since 1999. The 2001 census reported that 14 percent of the working population aged between 15 and 65 years were employed as professionals and technicians (Statistics South Africa, 2003).

Figure 2.17: Number of engineers expressed as a percentage of the total number of engineers in the United Kingdom and Europe

Country	Engineers as a % of the total number of engineers in the UK and Europe
United Kingdom	19.3
Spain	4.7
Finland	4.3
Norway	4.0
Denmark	3.3
Netherlands	3.3
Switzerland	1.6
South Africa	**1.1**
Ireland	0.7

Source: Consultants for Institutes and Societies www.e-engineeringonline.com (12 June 2003)

South Africa's ranking is comparable to Spain's. With 7.5 percent of the population of the UK and Europe, Spain has 4.72 percent of the total number of engineers in the area. South Africa, with 8.13 percent of the population of the UK and Europe, has only 1.08 percent of the total number of engineers in the UK and Europe.

Section 3

Research and development supply

Introduction

South Africa's National Research and Development Strategy (RSA, 2002) is based on the understanding that research and development is the foundation for innovation and technology. Investing in R&D has two main benefits: first, the continuous generation of a knowledgeable and competent workforce; second, the economic rewards associated with firm product and process developments and the intellectual property and licences fees that they generate. Indicators such as the level of investment in R&D, the availability of researchers, and number of patents and publications generated, are widely used and accepted as measures of the status of systems of innovation.

This section uses four broad classes of indicators to define South Africa's research and development capacity:

- Expenditure on R&D
- Availability of researchers in the workforce
- Availability of innovating firms in the country
- Number of patents issued and the proceeds from royalties and license fees.

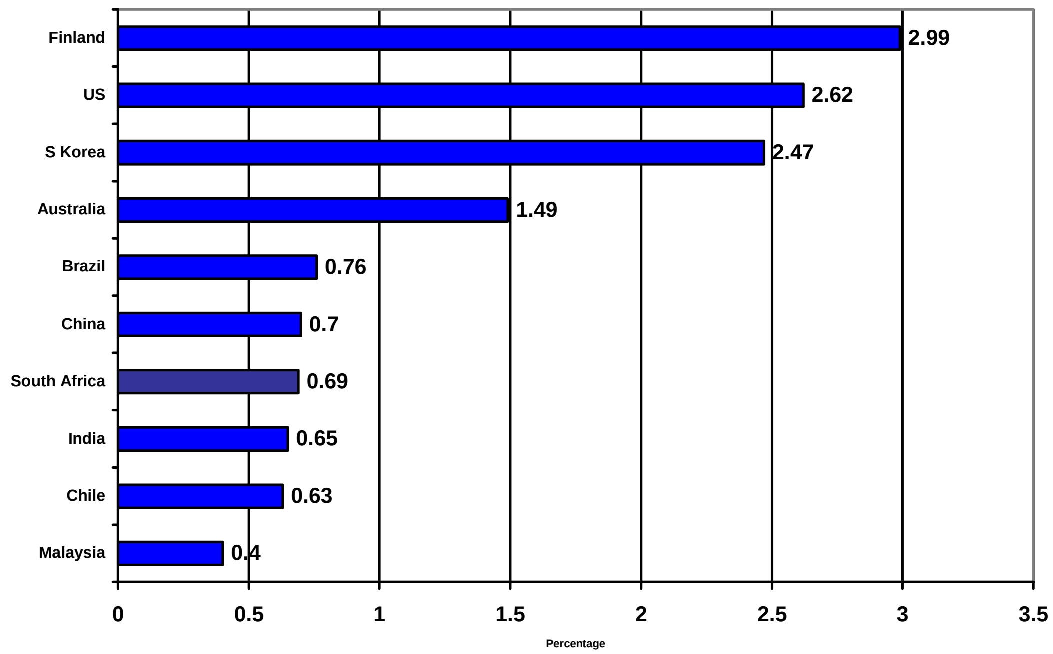
Expenditure on research and development

Figure 3.1: Total expenditure on R&D in South Africa (1997/1998)

Sector	Total expenditure(R million)	% of total
Industry	2 052	50
Government (including science councils)	1 354	33
Higher education	410	10
Research income from abroad	287	7
Total	4 103	100

Source: DACST, 2000

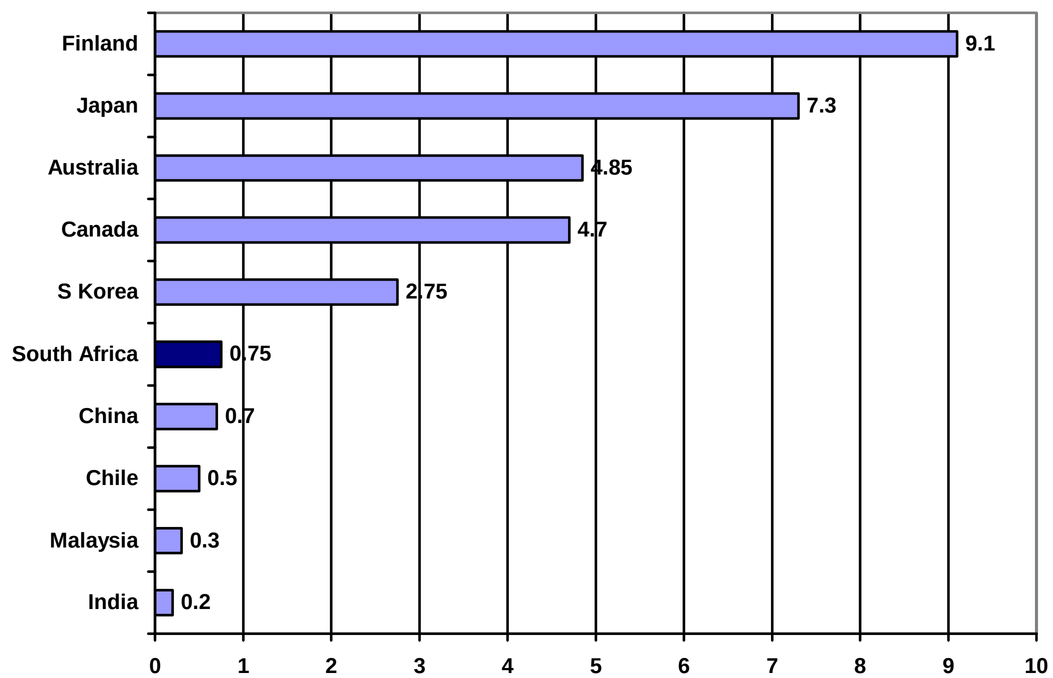
Figure 3.2: Gross expenditure on R&D as a percentage of GDP



Source: WCY 2001/OECD/R&D Survey

South African expenditure on R&D as a percentage of GDP is a low 0.69 percent and substantially below the internationally recognized ideal 'minimum norm' of 1 percent.

Figure 3.3: Number of researchers per 1000 of the labour force



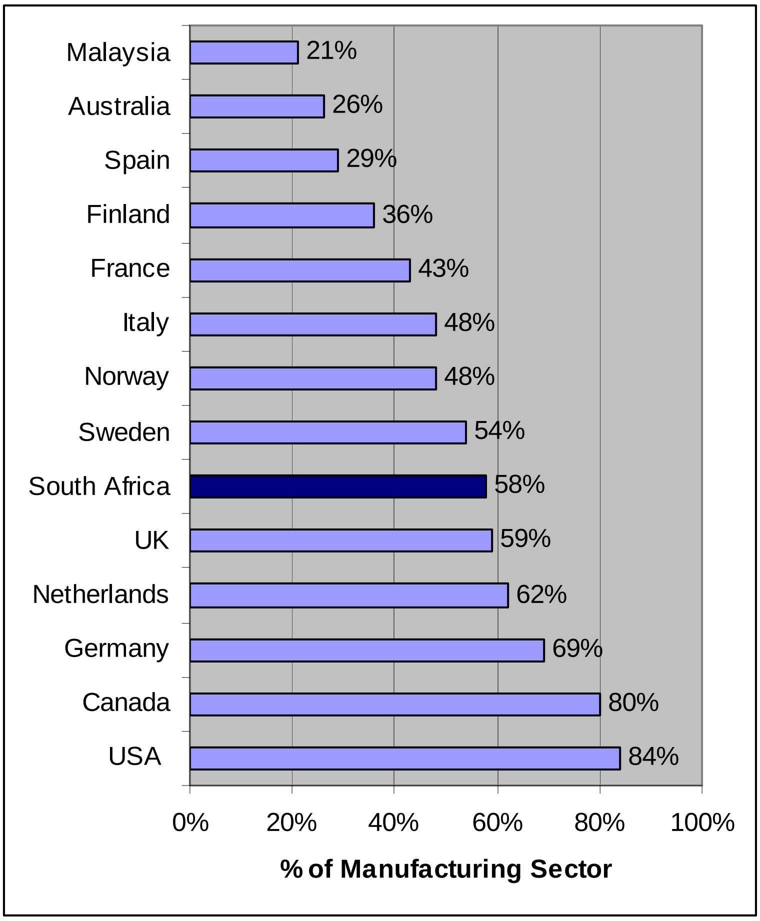
Source: WCY 2001/OECD/R&D Survey

Innovating firms

Innovation within a single firm can be defined as the successful incorporation of knowledge and technology that is new to the firm by way of products, processes, services, organization, management, or marketing.

In the 2001 South African Innovation Survey conducted by the University of Pretoria (SAIS, 2001), an 'innovation' was defined as a "new or substantially improved service, product or process for the firm". The distinguishing characteristic is that of 'new or significantly improved' in relation to the essential characteristics of comparable, earlier services, products, or processes. A service/product innovation, for example, might imply a wider range of uses than before, while a process innovation might result in significantly lower costs and/or increased output. For the purposes of the survey, innovative firms were defined as firms that answered 'yes' to the question: "Did your firm have technological innovation in the period 1998–2000?"

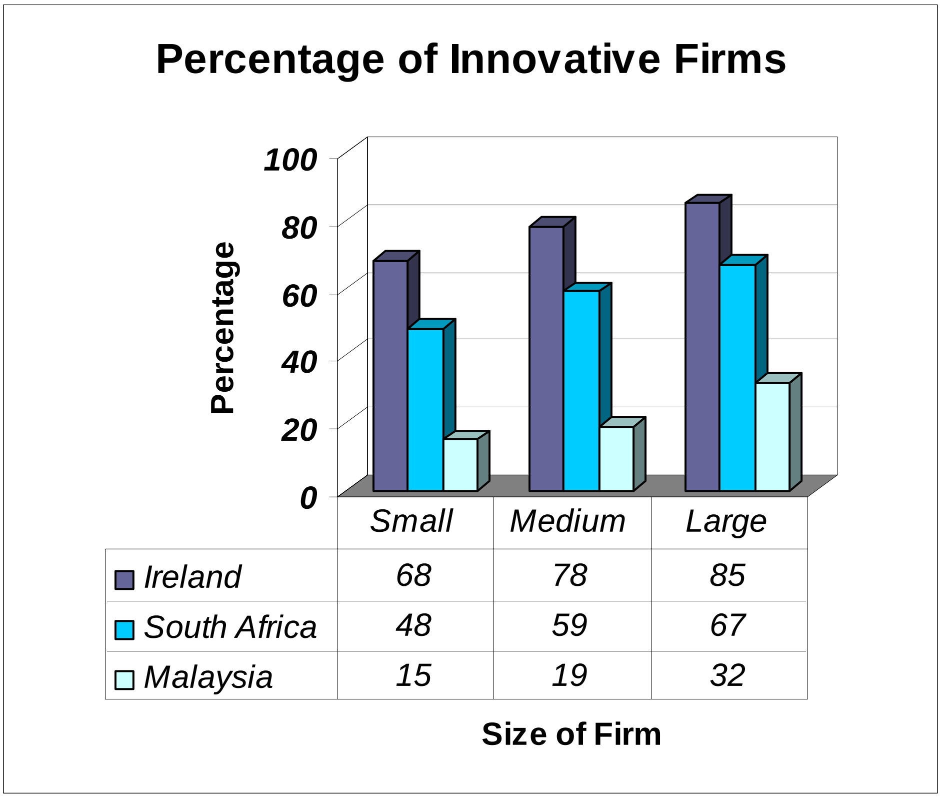
Figure 3.4 Innovating firms as a percentage of the total manufacturing sector



Source: SAIS2001

The South African data (Figure 3.4) are from a survey of the South African industry that was conducted in accordance with the Oslo Manual.

Figure 3.5: Percentage of innovative firms



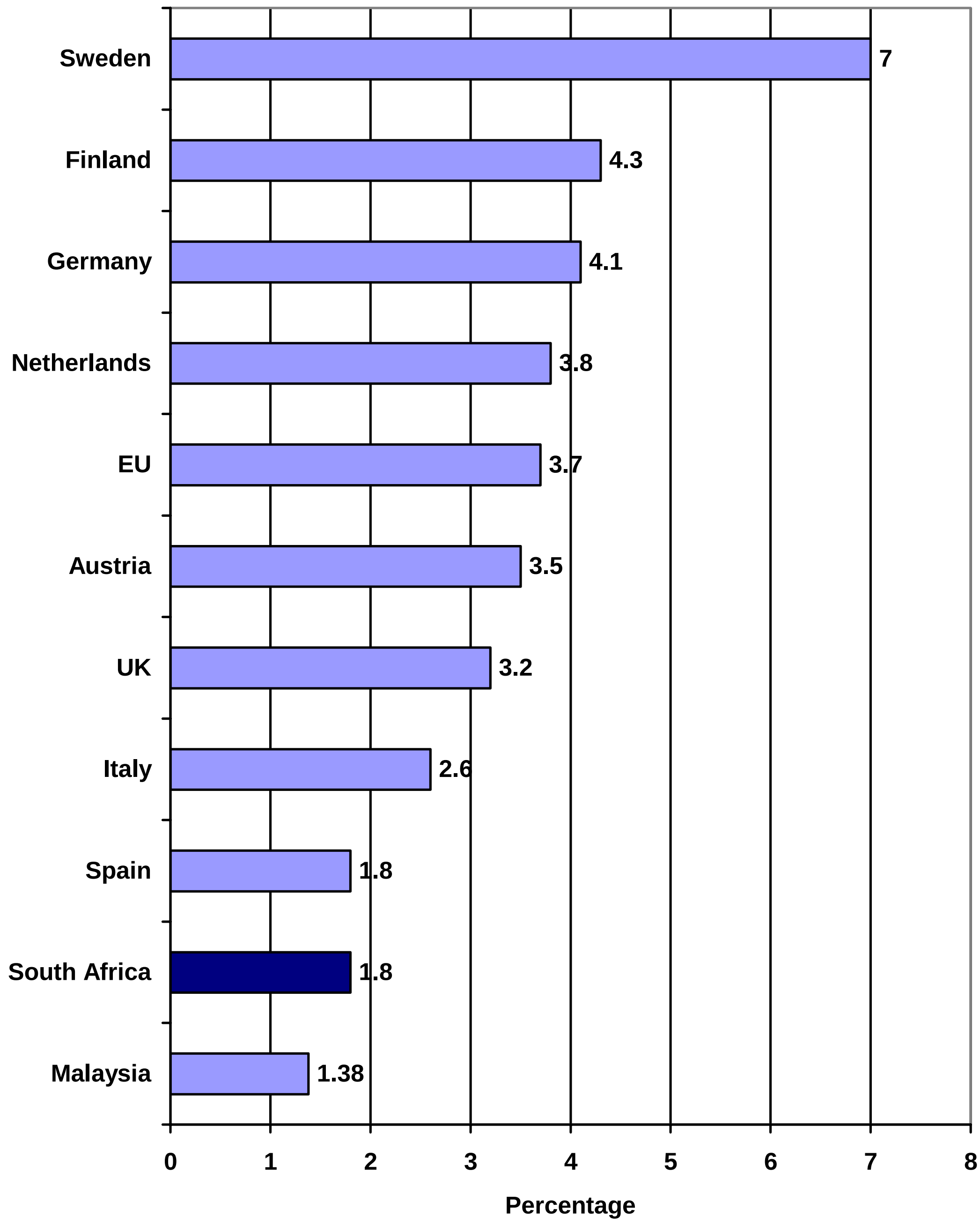
Sources: SAIS2001, MASTIC[3]

Note: The following definitions were used for the size of the firm: 'large' manufacturing firms are firms with more than 250 employees, 'medium' sized manufacturing firms are firms employing between 50 and 249 people, and 'small' manufacturing firms are those employing between 20 and 49 people.

Innovation costs

Total innovation costs include R&D as well as non-R&D investments such as purchase of machinery, equipment or computer hardware, outsourced research, industrial design and innovation implementation, licenses/advices, and marketing and training costs that were specifically incurred for innovation purposes.

Figure 3.6: Innovation costs as a percentage of sales



Sources: SAIS2001, Arundel [2], MASTIC [3]

Factors affecting innovative activities

Technological activities are defined as all research, development and other activities aimed at providing products, services or processes with significantly improved or completely new technical features when compared with the older, comparable products or processes of the firm. Technological activities do NOT include research and development activities in the fields of human resources, organization and/or marketing, nor do they include routine variations on an already existing product or service, or 'face lifts' to an already existing product, such as, for example, the substitution of a new brand name for an old one.

Figures 3.7, 3.8, 3.9, and 3.10 give the reasons that companies gave for their non-involvement in innovative activities between the years 1998 and 2000. Figure 3.7 gives typical reasons for lack of participation in innovative activities; Figure 3.8 summarizes the results of the SAIS20002 survey; Figure 3.9 reports the main reasons identified; and Figure 3.10 gives the main reasons according to the companies' differing sizes.

Figure 3.7: Explanation of reasons for lack of technological innovation activities

Reason	Explanation
Economic risks	Cost-benefit analyses had too many uncertainties
Costs too high	Estimated innovation costs too high for our firm
Short of staff	Lack of qualified personnel
No time	No time within the firm for innovative activities
Time to market	Could not meet required market introduction
Short of finance	Lack of appropriate external financial resources
Demand risks	Too many uncertainties (future) product markets
Third party already innovated	A third party (parent, licensor) already generated innovations
Market reasons	Our market is too small or signals no new needs

Source:SAIS2002

Figure 3.8: Reasons given by firms for not engaging in technological innovation activities 1998–2000

Reasons	Firms with no technological activities
Economic risks	41%
Costs too high	52%
Short of staff	38%
No time	46%
Time to market	15%
Short of finance	45%
Demand risks	40%

Source:SAIS2002

Figure 3.9: Main reasons per sector for not engaging in technological innovation activities: 1998–2000

Sector	Main reasons
Manufacturing of food, beverages, tobacco	short of finance; costs too high; short of staff
Manufacturing of textiles, clothing, leather products	costs too high; economic risks; demand risks
Manufacturing wood, paper and publishing	short of staff; demand risks; costs too high
Manufacturing of chemicals, rubber and plastic	costs too high; short of finance; demand risks
Manufacturing of metal product, machinery, and equipment	costs too high; short of finance; short of staff
Manufacturing of electrical and optical equipment	short of staff; demand risks; economic risks
Manufacturing of transport equipment	short of staff; short of finance; economic risks
Manufacturing of furniture, and n.e.c.	no time; short of finance
Wholesale	no time
Transport and communication	short of staff; costs too high, economic risks
Financial intermediation	economic risks; costs too high; demand risks
Business services	costs too high; short of finance

Source:SAIS2002

Figure 3.10: Two most important reasons for not engaging in technological innovation activities 1998–2000 according to the size of firm

Size of firm	Two most important reasons
< 50 employees	costs too high; no time
50 to 250 employees	costs too high; short of staff
250 to 500 employees	costs too high, no time
> 500 employees	costs too high, demand risks

Source:SAIS2002

Key factors hampering innovation

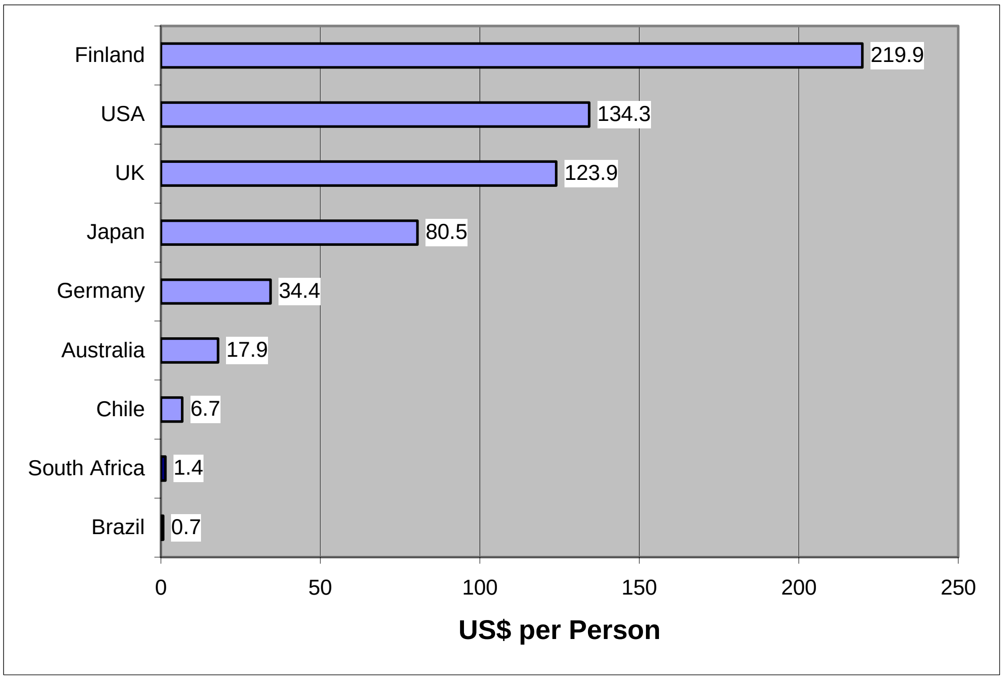
Figure 3.11 lists the major causes of bottlenecks as reported by companies trying to implement previously planned projects. It presents the effects of each identified bottleneck on the implementation of the project. The column ‘Experienced no bottleneck’ gives the proportion of projects that continued successfully without any problems, while the other columns report the consequences of the identified bottleneck on the project.

Figure 3.11: Factors hampering innovation and their consequences

Bottleneck	Experienced no bottleneck %	Experienced a bottleneck and as a result innovation projects were:		
		% not started	% abandoned	% seriously delayed
Economic risks	37	22	4	36
Short of staff	30	14	3	53
Knowledge gap	47	11	3	39
Costs too high	43	11	11	34
Short of finance	41	15	11	33
Time to market	50	6	7	36
Partnership	70	6	7	17
Demand risks	41	19	10	30
Regulations	62	12	7	20
Rigidities	66	4	4	26
Other bottlenecks	21	54	6	19

Source:SAIS2002

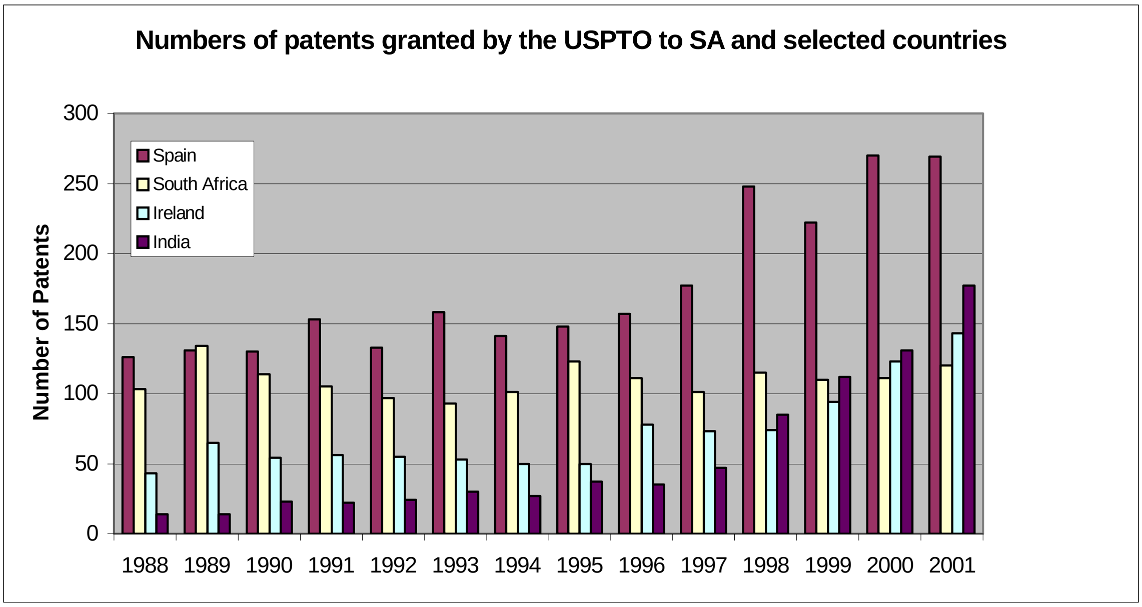
Figure 3.12: Royalties and license fees



Source: UNDP, 2002

There is a positive correlation between earnings from royalties and licence fees and the number of researchers per 1000 of the labour force. In general, the higher the proportion of researchers in a given country, the higher the proceeds from royalties and licence fees. South Africa is under-performing with regard to the proceeds received from royalties and licence fees.

Figure 3.13: Patents granted by the USPTO to South Africa and selected other countries



Source: USPTO

Numbers of patents granted by the USPTO														
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
South Korea	97	159	225	405	538	779	943	1161	1493	1891	3259	3562	3314	3538
Spain	126	131	130	153	133	158	141	148	157	177	248	222	270	269
South Africa	103	134	114	105	97	93	101	123	111	101	115	110	111	120
Ireland	43	65	54	56	55	53	50	50	78	73	74	94	123	143
India	14	14	23	22	24	30	27	37	35	47	85	112	131	177

Source: USPTO

Figure 3.13 and the table that follows show that, in the late 1989s, South Africa registered more patents than South Korea, Ireland, and India. The number of patents has grown very slowly since then, and, by 2001, South Africa had been overtaken by these three countries.

Figure 3.14: Patents granted by the USPTO (1999)

Patents granted by the USPTO in 1999	
Country	**No. of Patents**
Japan	31 104
Germany	9 337
United Kingdom	3 572
South Korea	3 562
Italy	1 492
Switzerland	1 280
Australia	707
Finland	649
Spain	222
Russian Federation	181
New Zealand	114
India	112
South Africa	110
Ireland	94
Brazil	91
Mexico	76
Malaysia	30
Czech Rep	24

Source: USPTO

Figure 3.15: South Africa's technology indicators (1993–2002)

Technology Indicators: South Africa 1993-2002		
Year	**Current Impact Index**	**Science Linkage**
1993	0.64	0.80
1994	0.60	0.30
1995	0.70	1.10
1996	0.58	0.50
1997	0.62	0.90
1998	0.55	1.40
1999	0.55	1.40
2000	0.52	1.50
2001	0.51	1.80
2002	0.51	1.10

The *Current Impact Index* examines the quality of patents registered by the country over the previous five years. It is estimated as the number of times that patents registered over the previous five years are cited in the current year relative to the entire patent database. A value of 1 indicates that the citation frequency is average; a value of 0.8 represents 80 percent of average citation frequency. Because the current impact index looks back just five years, it falls quickly when a country is no longer registering new inventions.

Science Linkage indicates the extent to which a country's technology can be classified as 'leading edge'. It is defined as the average number of science papers referenced on the front page of the country's patents. A high science linkage rating indicates that a country is building its technology base on advances in science. Countries at the forefront of technology tend to have a higher science linkage than their competitors.

There has been a decline in the international recognition of the quality of the South African patents, shown by a consistent drop in their current impact index. On the other hand, most of the patents that are filed by South African companies are increasingly based on the latest advances in science and technology.

Figure 3.16: Technology indicators for South Africa by technology area

Technology Area	% Patents in area	Current Impact Index	Science Linkage
Agriculture	3.80	0.24	3.90
Oil & Gas, Mining	3.90	0.28	0.10
Power Generation & Distribution	1.40	0.81	2.00
Food & Tobacco	2.10	0.21	0.00
Textiles & Apparel	1.10	0.68	0.30
Wood & Paper	1.90	0.47	0.20
Chemicals	8.80	0.27	2.10
Pharmaceuticals	3.00	0.34	10.80
Biotechnology	2.10	0.63	21.80
Medical Equipment	6.20	0.78	1.80
Medical Electronics	0.30	0.85	0.00
Plastics, Polymers & Rubber	2.20	0.44	0.40
Glass, Clay & Cement	0.80	0.40	0.00
Primary Metals	2.80	0.47	0.00
Fabricated Metals	1.10	0.30	0.00
Industrial Machinery & Tools	4.90	0.46	0.00
Industrial Process Equipment	5.80	0.38	0.20
Office Equipment & Cameras	1.10	0.80	0.00
Heating, Ventilation, Refrigeration	0.80	0.61	0.00
Misc. Machinery	6.80	0.46	0.00
Computers & Peripherals	1.90	n/a	0.40
Telecommunications	3.30	1.15	0.30
Semiconductors & Electronics	1.40	0.53	4.60
Measurement & Control Equipment	2.10	0.48	0.10
Electrical Appliances & Components	4.40	0.57	0.90
Motor Vehicles & Parts	2.50	0.50	0.00
Aerospace & Parts	0.30	0.37	2.00
Other Transport	2.10	0.46	0.00
Misc Manufacturing	14.80	0.66	0.30
Other Transport	6.30	0.61	0.10

Figure 3.17: South Africa's patent growth by technology area: 1993–1997 to 1997–2002

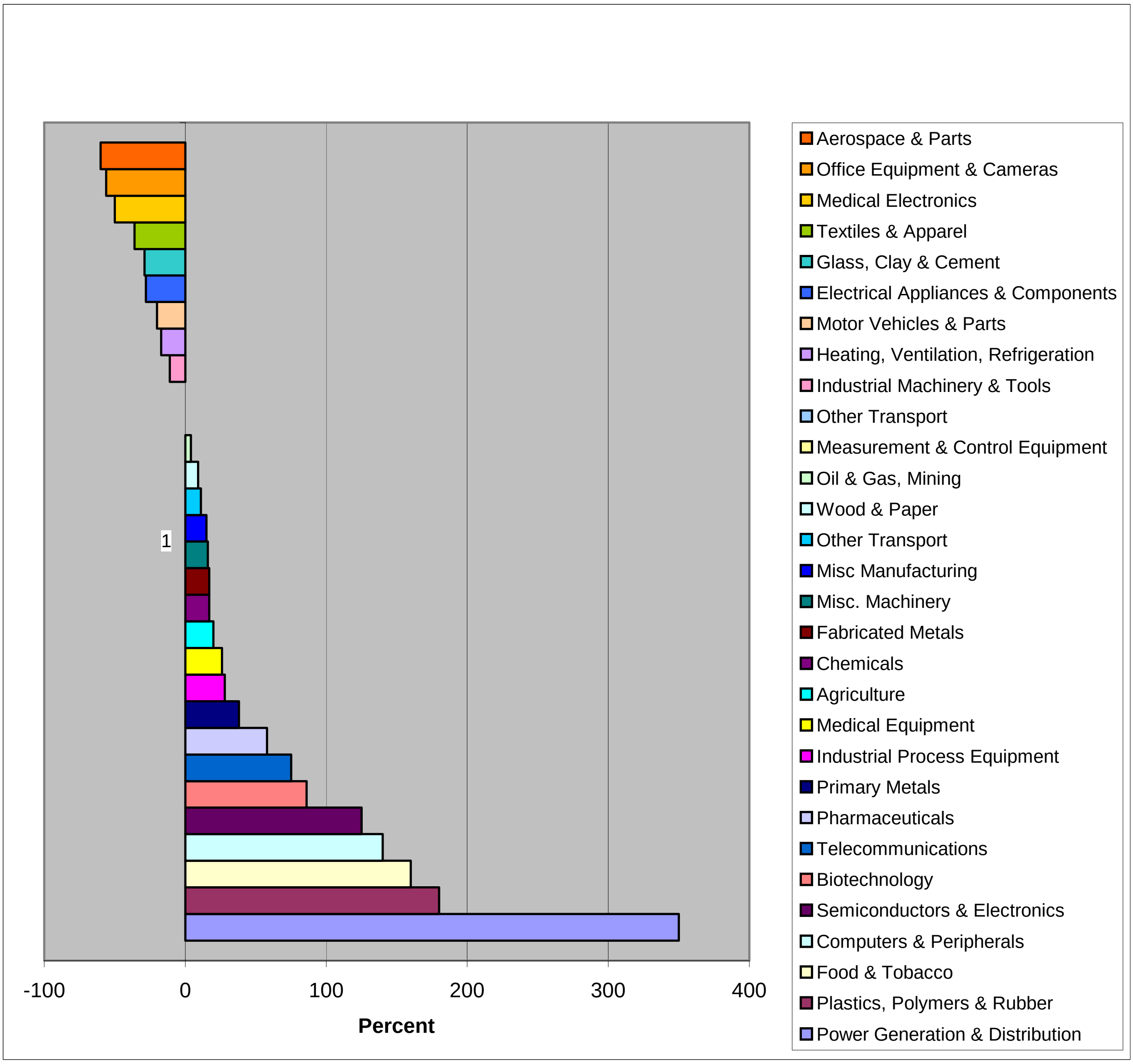
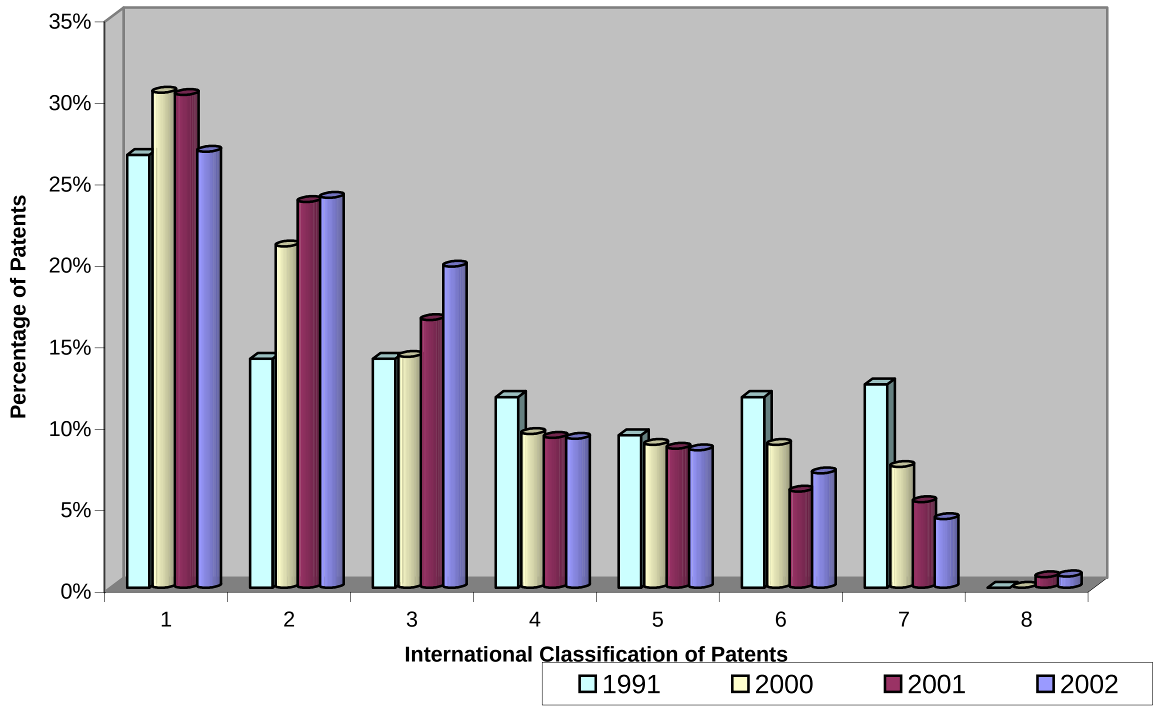


Figure 3.18: South Africa's patent distribution by standard industrial classification for the years 1991, 2000, 2001 and 2002



Source: USPTO

In the four years under consideration, more than 55 percent of South Africa's patenting activity was in the human necessities, performing operations, and chemistry and metallurgy groups. The number of patents registered in the mechanical engineering group is dropping whereas human necessities and chemistry and metallurgy are on the increase.

No.	International Classification Code	Description
1	Section B	Performing operations; Transporting
2	Section A	Human Necessities
3	Section C	Chemistry; Metallurgy
4	Section G	Physics
5	Section H	Electricity
6	Section E	Fixed Constructions
7	Section F	Mechanical Engineering; lighting, Heating, Weapons; Blasting
8	Section D	Textiles; Paper

Section 4

Diffusion and linkages

Introduction

Technology diffusion measures the adoption of technology by users other than the original innovator. Evidence indicates that company performance, including productivity and job creation, is affected by the ability to identify, absorb, and implement technology. Diffusion is also important for ensuring that a country maximizes its returns on investments in R&D.

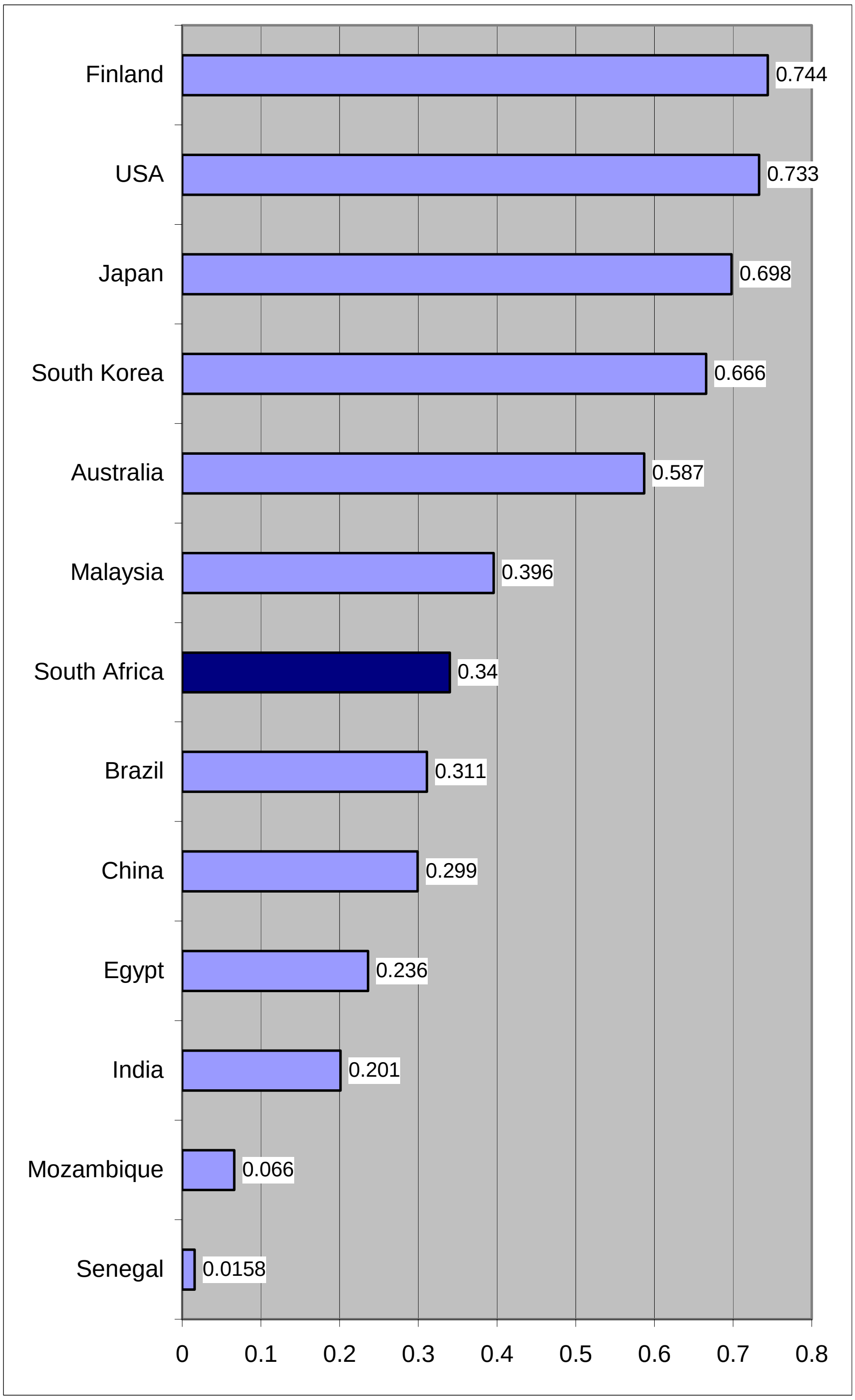
The creation and level of diffusion of new technologies is embodied in the Technology Achievement Index (TAI), which measures a country's ability to create and diffuse new technologies. This is a composite index, comprising eight indicators categorized into four groups:

- The level of technology creation which is proxied by the number of patents granted and by the revenue received from royalties and licence fees
- Diffusion of recent technologies measured by the number of internet connections and by the level of high and medium technology exports
- Diffusion of old technologies as measured by electricity consumption and by access to telephone lines
- Human skills as measured by the mean years of schooling and the gross enrolment ratio of tertiary education students enrolled in science, mathematics, and engineering.

This section considers the TAI and the individual indicators of which it is composed.

Technology Achievement Index

Figure 4.1: International Technology Achievement Index comparisons(2002)

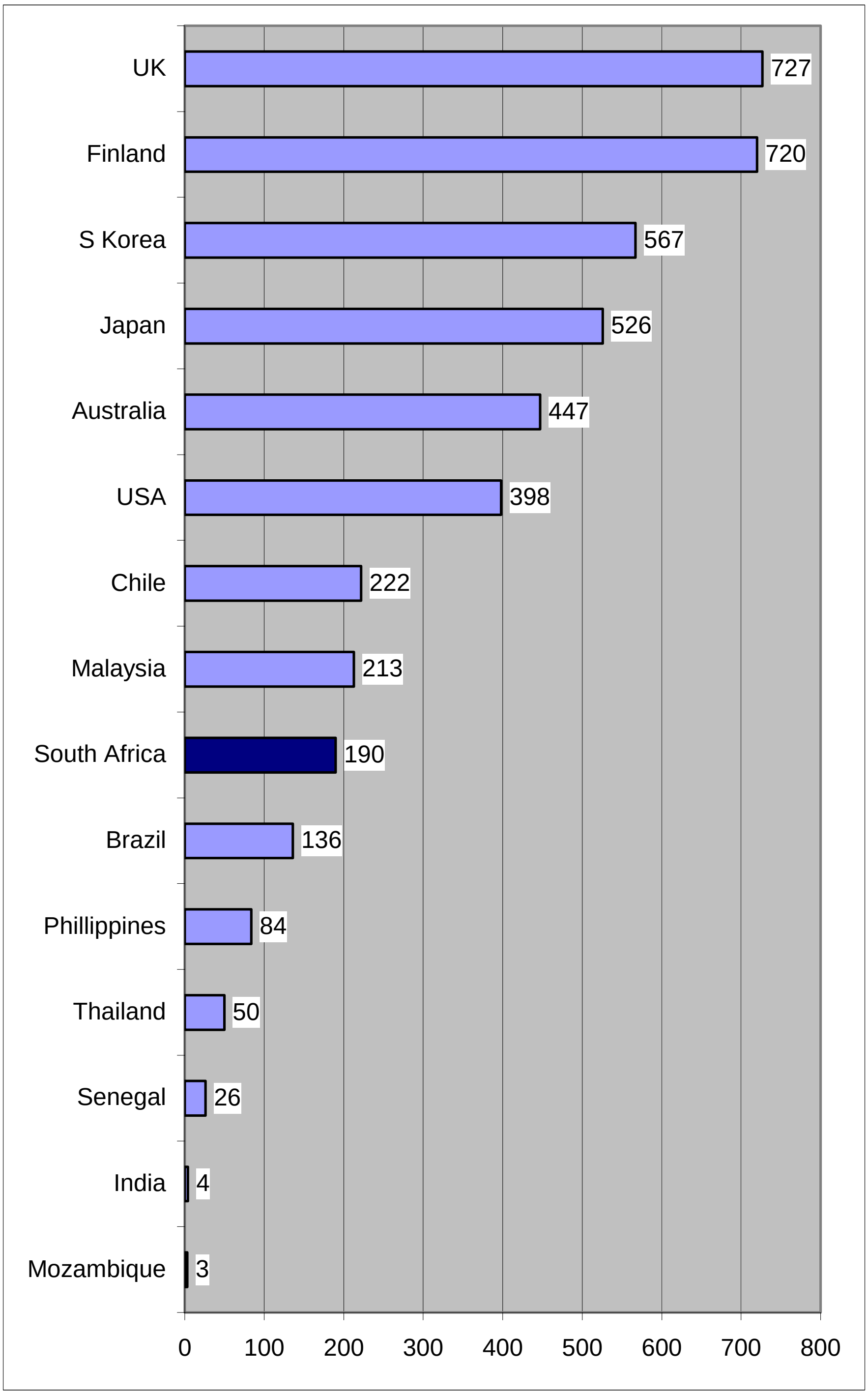


Source: UNDP, 2002

There is a positive correlation between the value of proceeds from royalties and licence fees (Figure 3.12) and the TAI. Countries with a high TAI realise more returns from royalties and licence fees.

Diffusion of new technologies

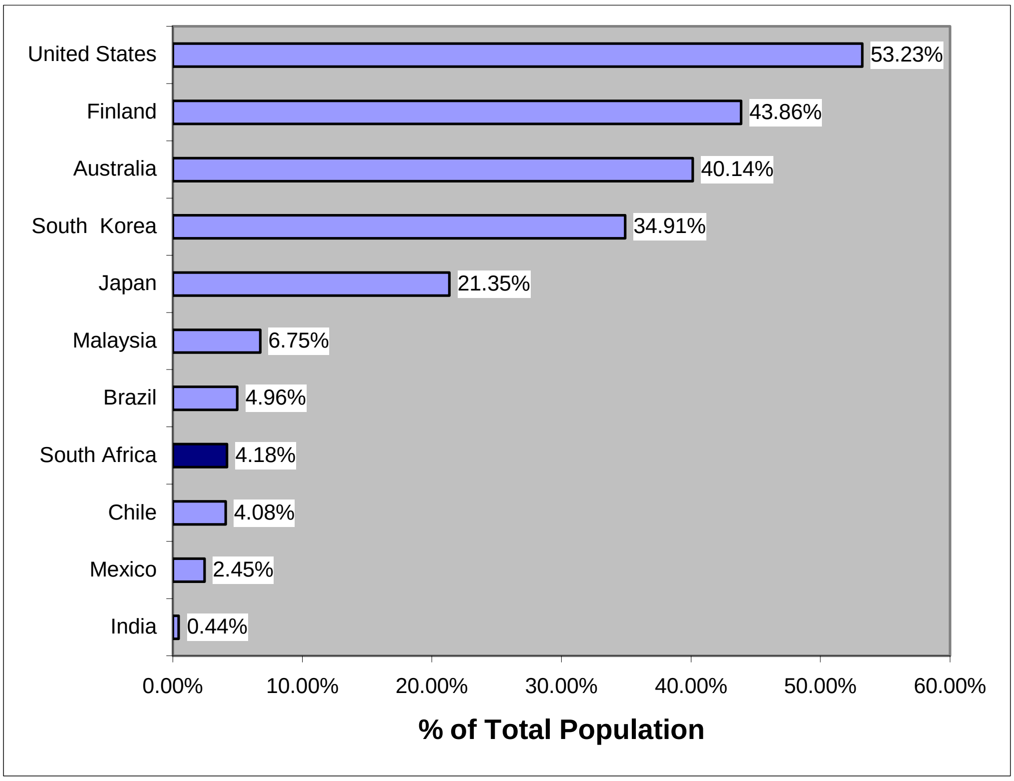
Figure 4.2: Cellular/mobile telephone subscribers per 1000 people (2000)



Source: UNDP, 2002

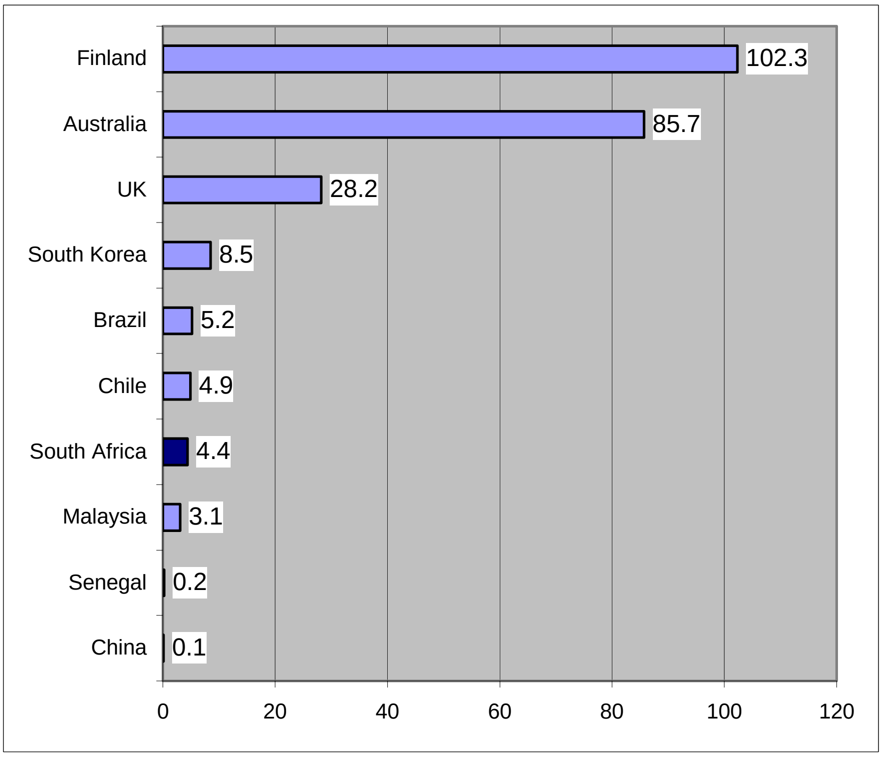
The penetration of cellular/mobile telephones (in terms of subscribers per 1000 of the population) indicates the adoption of new technologies within a country. (See also Figure 4.6 below.)

Figure 4.3: Internet users



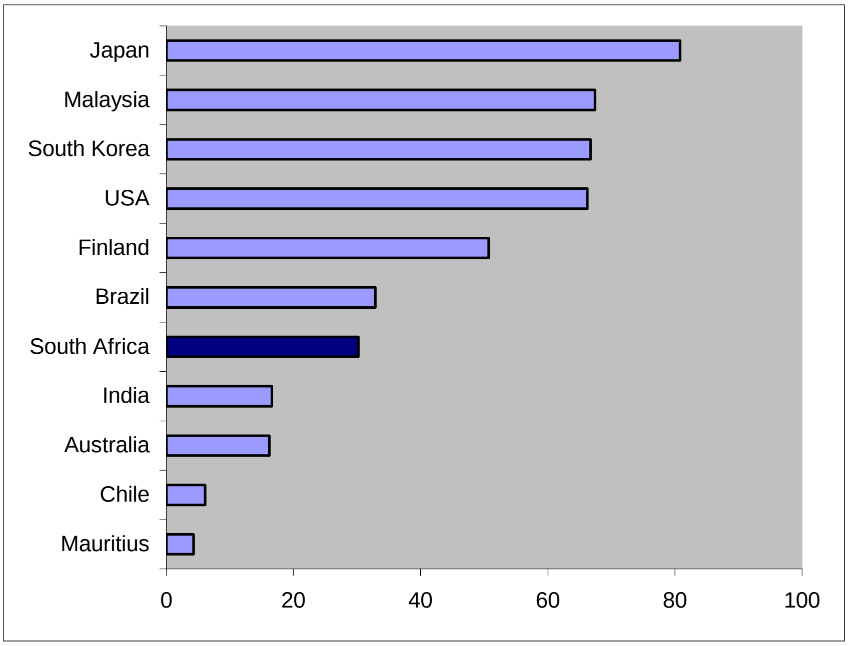
Source: UNDP, 2002

Figure 4.4: Internet hosts per 1000 people (2000)



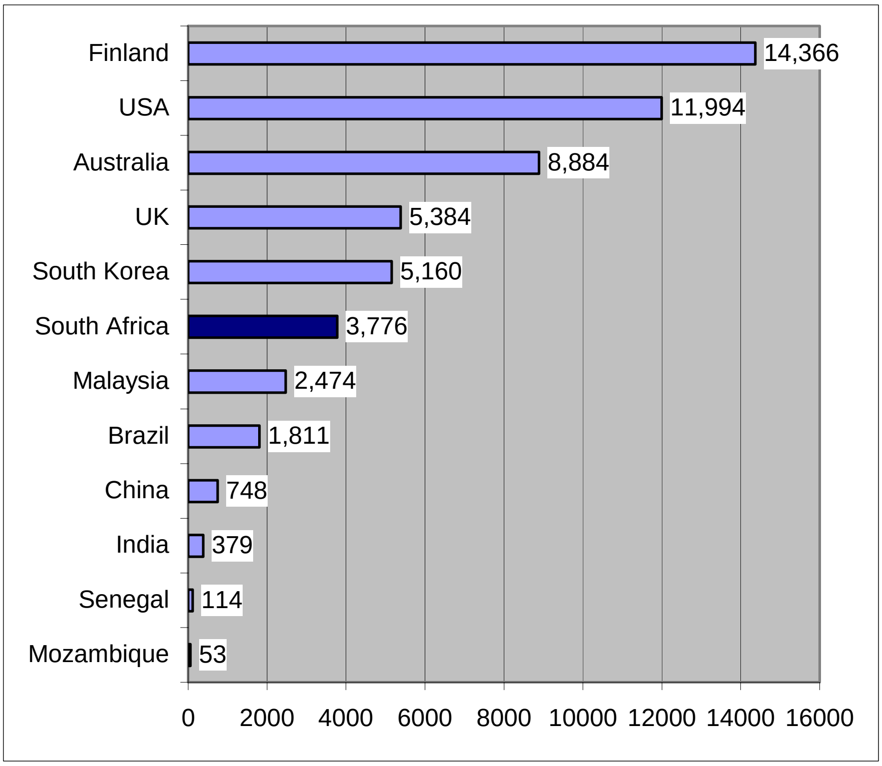
Source: UNDP, 2002

Figure 4.5: High and medium technology exports as a percentage of total goods exported



Source: Unido

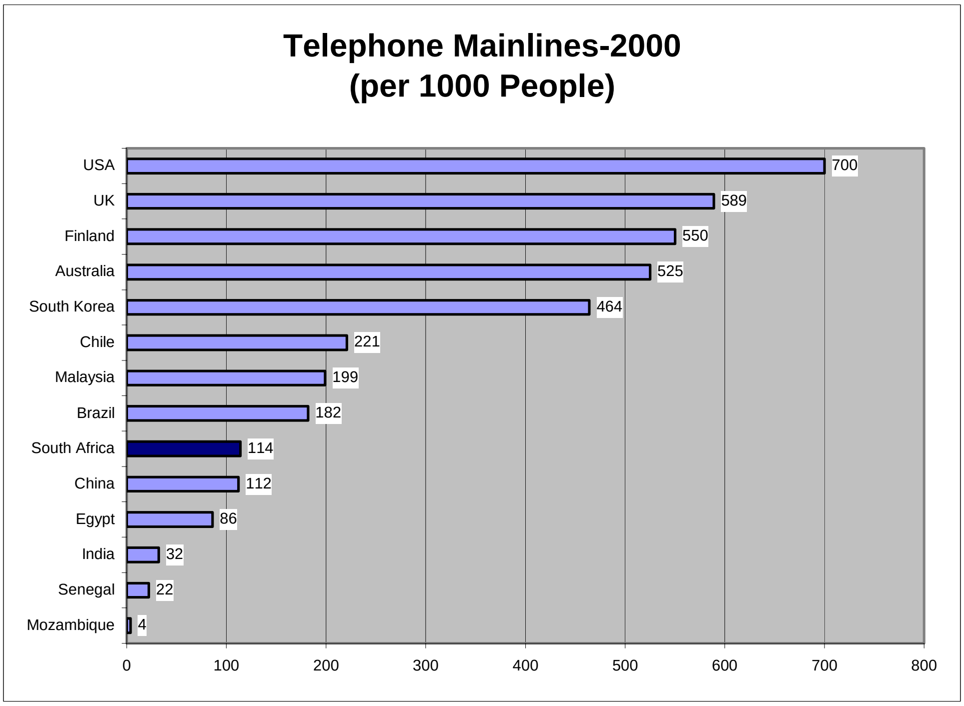
Figure 4.6: Electricity consumption per capita (kilowatt hours) in 1999



Source: UNDP, 2002

Diffusion of old technologies

Figure 4.7: Telephone mainlines per 1000 people (2000)



Source: UNDP, 2002

The use of mainline telephone lines indicates the accessibility of old technologies within a country. The figures from South Africa's most recent census show that, by 2001, 42 percent of households in South Africa had access to landline or cellular telephones (Statistics South Africa, 2003).

Section 5

Demand

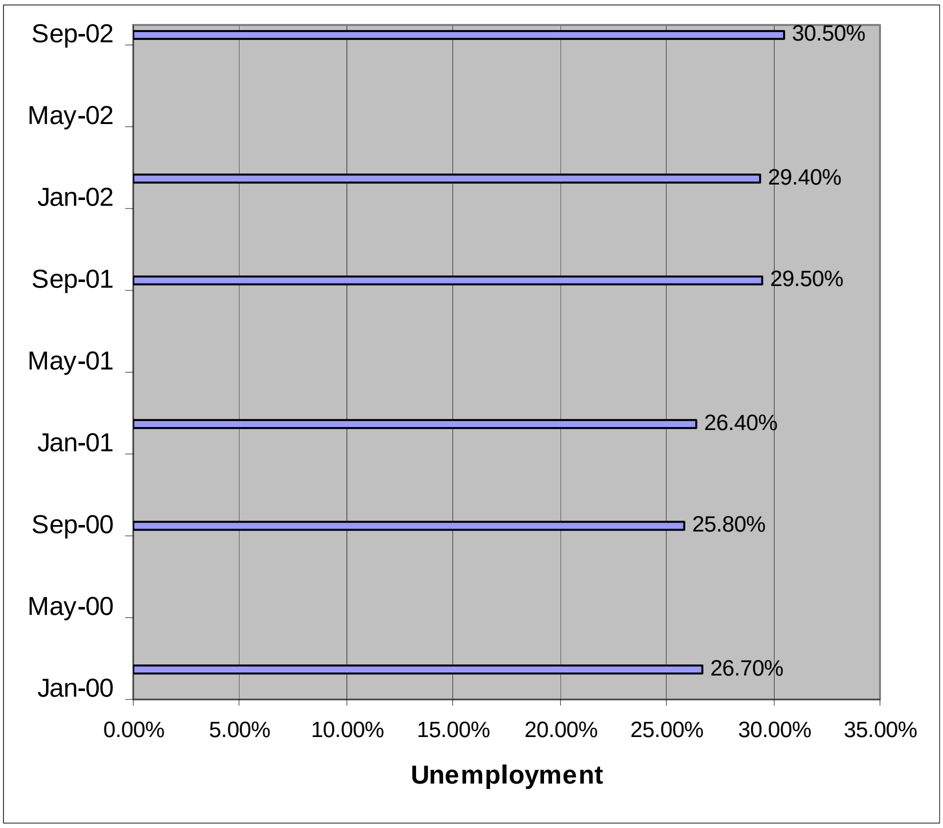
Introduction

This section measures the extent to which the South African market forces are conducive to innovation. Indicators used are:

- Unemployment trends, which are used to indicate the level of economic growth within the country
- The availability of venture capital
- The level of protection provided for patents
- The use of fiscal incentives (such as tax) to encourage R&D, and other trade related indicators such as technology intensity, technology balance of payments, and foreign direct investment.

Unemployment

Figure 5.1: South African unemployment trends by official definition



Source: Statistics South Africa

GDP growth can be indicated by growth in the employment rate and growth in labour productivity. The former indicator may be shown as trends of working age population in employment; the latter is measured in terms of the average output per employed person, and it captures the impact variables other than employment growth, such as capital investment, technological progress, or increases in human capital on the output growth of the country. According to the Labour Force Survey, the unemployment rate for South Africa as a whole in September 2001was 29.5 percent.

Official definition of unemployment: According to the official or strict definition, the unemployed are those people within the economically active population who (a) did not work in the seven days prior to census night, (b) wanted to work and were available to start work within a week of census night, and (c) had taken active steps to look for work or to start some form of self-employment in the four weeks prior to census night (Statistics South Africa, 2003).

Venture capital

Access to finance is one of the crucial elements in the innovation process for deriving commercial value out from the results of R&D. Innovation activities have a high element of risk and are difficult for large firms to undertake; they have the greatest chance of survival when undertaken in small technology-based firms.

Venture capital (also referred to as 'early stage' capital) is a specific kind of funding used to finance high-risk innovative activities. Large firms or financial institutions invest alongside management in young companies that are not quoted on the stock market. Venture capital investments normally involve a long time-frame, an element of risk, a partnership with management, and returns in the form of capital gains rather than dividends.

Figures 5.2 and 5.3 compare the relative sizes of the private equity markets in South Africa and those in selected other countries. Private equity markets play an important role in innovation, supporting among other things the establishment of new ideas and firms. South Africa appears to have a relatively sizeable private equity market in comparison with European countries but a relatively small one in comparison with the UK and the USA. (It should be emphasised that suspicions exist that certain players in the field of private equity may have overstated their relative involvement in South Africa.)

Figure 5.2: International private equity markets (measured by investments)

Country	Amount $US billion	% of GDP
USA	400.00	4.0
UK	34.80	2.5
Netherlands	6.00	1.6
Sweden	5.00	2.2
South Africa	3.70	2.9

Source: KPMG and SAVC, 2003

Figure 5.3: International equity in terms of funds raised as well as funds invested ($US billion) (2001/2002)

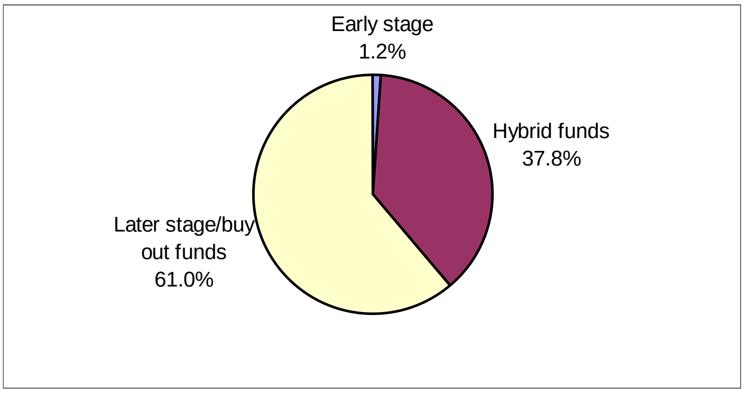
Country	Invested US$ billion	Funds raised US$ billion
US	59.70	99.60
UK	6.20	18.40
Germany	4.00	3.30
Canada	3.20	3.00
France	3.00	4.90
Sweden	1.80	1.60
Netherlands	1.70	0.06
South Africa	0.50	0.10

Source: KPMG and SAVC, 2003

Note: The figures for South Africa are for 2002; the figures for the other countries are for 2001.

Figure 5.4 shows the distribution of private equity investments according to purpose of funds. Only 1.2 percent of the total amount was directed for 'early stage' business. 'Early stage' or venture capital is used for research evaluation and the development of a concept or business before the business starts, and/or for funding for new companies being set up, or for the development of those that have been in business for a short term (from 1 to 3 years). 'Early stage' funds in the USA normally constitute between 2 and 4 percent of the funds disbursed by private equity investors. Struggling investors or entrepreneurs in South Africa find it difficult to secure such seed funding.

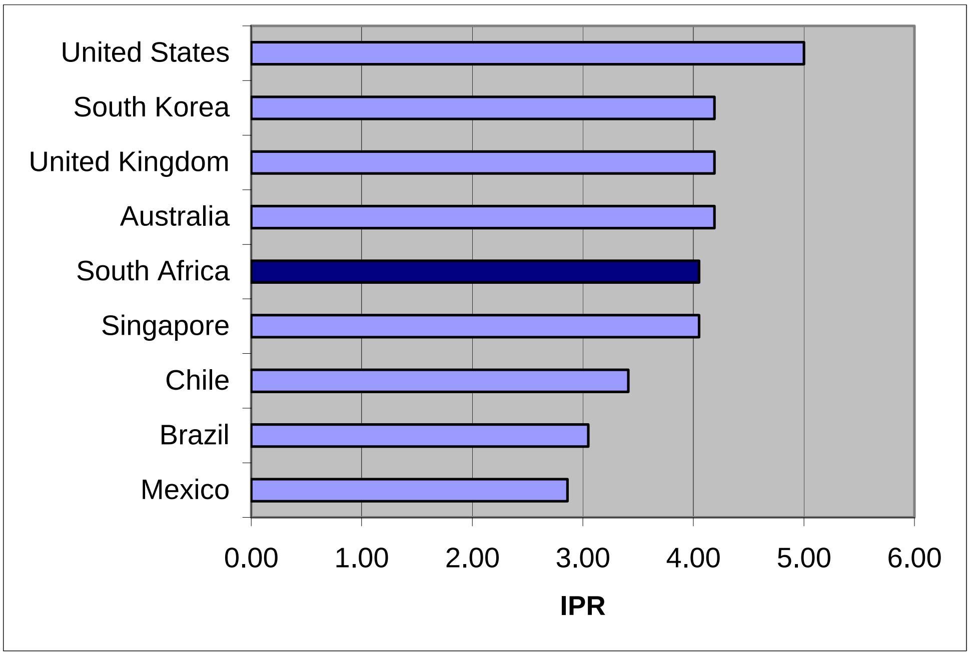
Figure 5.4: Distribution of private equity investment according to purpose of funds (2002)



Source: Science Consultancy Enterprises with data from SAVCA & NSF

Index of patent rights

Figure 5.5: International index of patent rights (2000)



Source: Economic Freedom of the World

The index of patent rights is constructed by examining national patent laws so as to determine the level of protection offered for patentees. It ranges from 0 to 5, with higher numbers reflecting stronger protection levels.

The value of the index is obtained by aggregating scores in five equally-weighted categories: (1) extent of coverage, (2) membership in international patent agreements, (3) provisions against loss of protection, (4) enforcement mechanisms, and (5) duration. The score in each category ranges from 0 to 1, and reflects the extent of legal features in that category available in a particular country at a particular time. For example, a higher score for enforcement indicates that a country has more mechanisms for enforcing patent laws.

Figure 5.6: South Africa's performance in the different categories

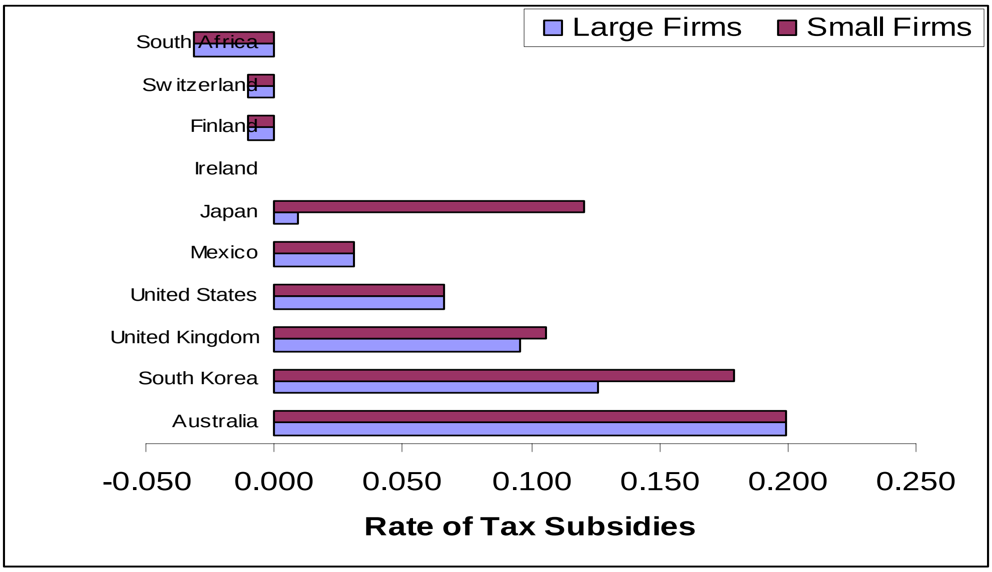
Coverage	Duration	Enforcement	Membership of International Treaties	Protection from Restriction on Patent Rights	Total
0.71	1.00	0.67	1.00	0.67	4.05

Source: Economic Freedom of the World

Figure 5.4 shows the index of patent rights for high income and medium income countries. Korea and South Africa are medium income countries but offer protection comparable to high-income countries. As shown in Figure 5.5, South Africa performs well in the categories of duration and membership of international treaties.

Indicators of tax treatment of R&D

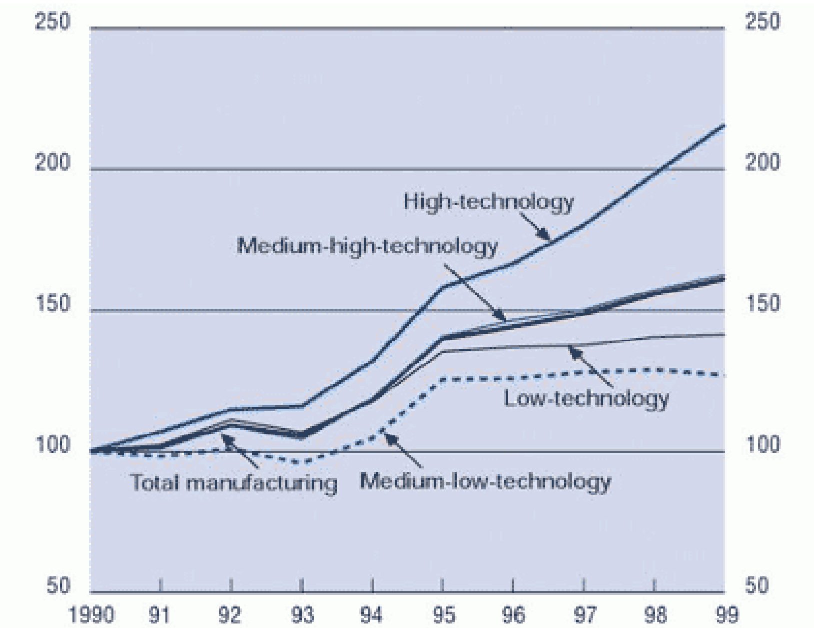
Figure 5.7: Rate of tax subsidies for US$1 of R&D for small and large firms 2001–2002 (or more recent years)



The amount of tax subsidies is calculated as 1 minus the B-Index. The B-Index is defined as the present value of before-tax income that is needed to cover the initial cost of R&D investment and to pay corporate income tax and make it profitable to perform research activities. In Spain, for example, US$1 of R&D expenditure by large firms results in 44 cents of tax relief.

International trade

Figure 5.8: International trade by technology intensity



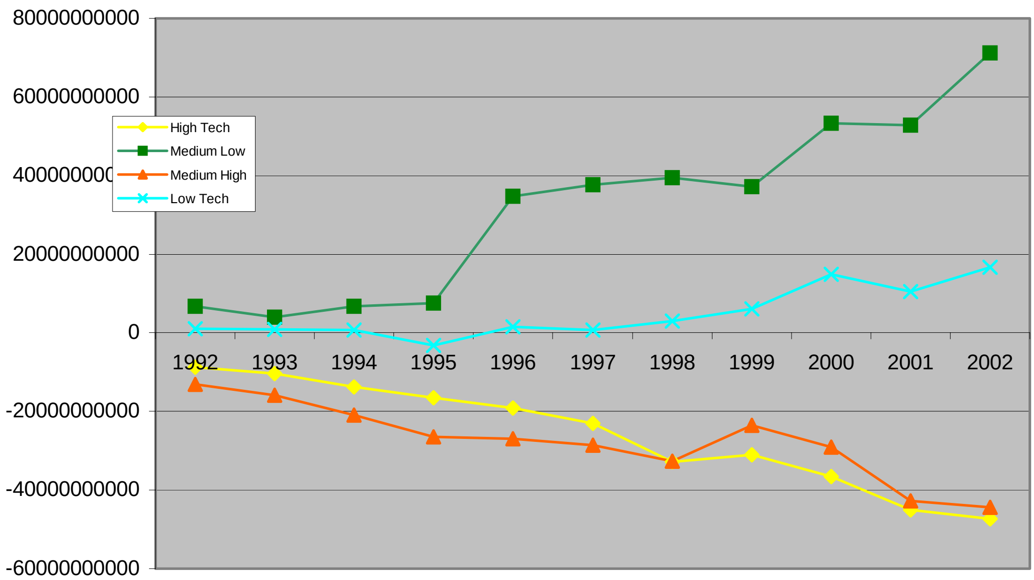
Source: Science Consultancy Enterprises

High technology and medium-high technology industries dominate international trade. In 1999 they constituted 64 percent of all trade.

The three industries with the highest growth rates in OECD manufacturing trade during the last decade are all classified as high technology industries: pharmaceuticals; radio, television and communication equipment; and computers.

The following figure (5.9) shows the trade balance of payments (exports–imports) of South Africa, according to research intensity, of different industries for the period 1992-2002.

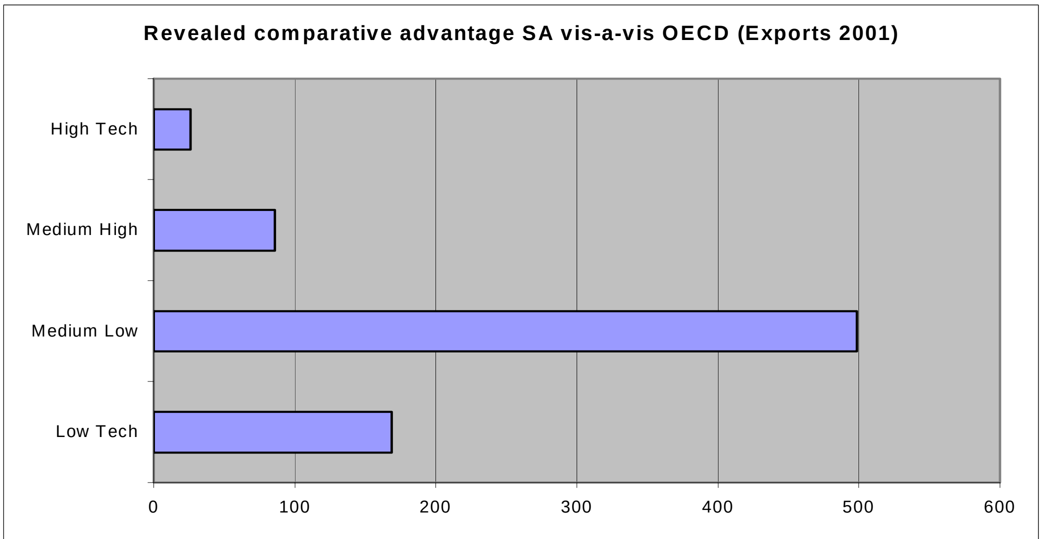
Figure 5.9: Trade balance of payments (1992–2002)



Source: Science Consultancy Enterprises

South Africa presents a substantial deficit in high technology and medium high technology and a surplus in the trade of medium-low technology products.

Figure 5.10: Revealed comparative advantage



The revealed comparative advantage or export specialization (see Figure 5.10 above) shows the extent to which a country's exports are specialized in a particular industry grouping relative to the OECD average. Values greater than 100 indicate that the country's exports are relatively specialized in that industry.

Figure 5.11: Foreign Direct Investment inflows

Foreign Direct Investment inflows 1997–2001 (US$ million)					
	1997	**1998**	**1999**	**2000**	**2001**
South Africa	3 817	561	1 502	888	6 653*
Morocco	1 079	333	850	201	2 658
Nigeria	1 539	1 051	1 005	930	1 104
Africa	10 744	9 021	12 821	8 694	17 165
Developing Countries	191 022	187 611	225 140	237 894	204 801
World	478 082	694 457	1 088 263	1 491 934	735 146

Note: The South African increase in 2001 is mainly due to the unbundling of cross-share holdings involving London listings of Anglo-American and DeBeers of South Africa.

Figure 5.12: Foreign Direct Investment as a percentage of fixed capital formation

Foreign Direct Investment inflows 1997–2000 as % of gross fixed capital formation				
	1997	**1998**	**1999**	**2000**
South Africa	15.80	2.50	7.60	4.70
Morocco	15.60	4.20	10.20	2.50
Nigeria	13.50	11.90	12.40	10.00
Africa	10.00	8.30	11.90	8.10
Developing Countries	11.10	11.40	13.40	13.40
World	7.40	11.00	16.50	22.00

Section 6

Summary Comments

The information in *South African Innovation: Key Facts and Figures 2004* is a collection of data that indicates the condition of South Africa's System of Innovation. This document is by no means a comprehensive representation of all figures, and the data used were selected on the basis of relevance and availability.

Certain key issues arose, as the data were being collected and analyzed, that warrant further attention.

- The Human Development Index (HDI) data gave rise to the following observations:
    - South Africa is a medium development country with historically low levels of human development
    - There has been consistent growth in the HDI level: a sudden drop was noted, which is related to a reduction in the infant mortality rate rather than to the literacy rate
    - Education expenditure as a percentage of GDP is higher than the OECD country mean, but this level of spending needs to be sustained to ensure that the level of human development continues to increase.
- The number of registered professional engineers in South Africa continues to decline. The cause of this decline is insufficiently understood and needs further investigation.
- South Africa's gross expenditure on R&D as a percentage of GDP, at 0.69 percent, is very low. It is not surprising, therefore, that although the population of South Africa is eight times that of Europe, South Africa has only one percent of Europe's total number of scientists and engineers, and, as a result, a relatively low number of researchers per 1000 of the labour force.
- South Africa's Innovation Survey is a valuable tool for examining South Africa's competitiveness and should be continued.
- South Africa has sizeable private equity markets compared with those of European countries. Most of South Africa's funds are, however, earmarked for later stage/buy-out funds and hybrid funds, and very little is available as 'early stage' venture capital.
- Although South Africa is a middle income country, it provides patent protection comparable to high income countries.
- Fiscal incentives for encouraging research and development in the country are not well developed and should be investigated further.

Appendix

Definitions of Innovation

Innovation is the process of transforming an idea, normally generated through R&D, into a new or improved product, process or approach, which relates to the real needs of society, which involves scientific, technological, organizational or commercial activities or services, and which has market value.
Technological Product and Process (TPP) innovations comprise implemented technologically new products and processes and significant technological improvements in products and processes. A TPP innovation has been **implemented** if it has been introduced on the market (product innovation) or used within a production process (process innovation). TPP innovations involve a series of scientific, technological, organisational, financial and commercial activities.

A TPP innovating firm is one that has implemented technologically new or significantly technologically improved products or processes during a specified period under review.
A technologically new product is a product whose technological characteristics or intended uses differ significantly from those of previously produced products. Such innovations can involve radically new technologies, or they can be based on combining existing technologies in new uses, or they can be derived from the use of new knowledge.
A technologically improved product is an existing product whose performance has been significantly enhanced or upgraded. A simple product may be improved (in terms of better performance or lower cost) through use of higher-performance components or materials, or a complex product consisting of a number of integrated technical subsystems may be improved by partial changes to one of the subsystems.
Technological process innovation is the adoption of technologically new or significantly improved production methods, including methods of product delivery. These methods may involve changes in equipment, or in production organisation, or in a combination of such changes, and may derive from the use of knew knowledge. The methods may be intended to produce or deliver technologically new or improved products, which cannot be produced or delivered using conventional production methods, or to increase the production or delivery efficiency of existing products.
NOTE: These concepts of innovation, as defined in the Oslo Manual, are challenging when applied to developing country situations where minor innovation, adaptations, and assimilation of existing technologies is often more common than major innovations. This suggests that the process of technological development and innovative activity in developing countries is essentially different from that in developed countries. This difference needs to be reflected in innovation indicators.

The following innovation variables are therefore vital for the development of appropriate indicators:

- Types of innovation
- Forces behind innovative activities
- Effects of innovative activities on particular economic and social development objectives.

List of abbreviations

GDP	Gross domestic product
GNP	Gross national product
HDI	Human Development Index
HSRC	Human Sciences Research Council
NACI	National Advisory Council on Innovation
NSTF	National Science and Technology Forum
OECD	Organization for Economic Cooperation and Development
R&D	Research and development
TAI	Technology Achievement Index
USPTO	United States Patent and Trademark Office

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