THE PERFORMANCE OF SOUTH AFRICA'S HIGH TECHNOLOGY SECTOR – MACRO AND MICRO EVIDENCE: SOME POLICY IMPLICATIONS.

David Kaplan
Department of Economics and Graduate School of Business
University of Cape Town
dakaplan@gsb.uct.ac.za

MICRO EVIDENCE ON INNOVATION IN DEVELOPING ECONOMIES CONFERENCE

UNU-MERIT
MAASTRICHT

MAY 31-JUNE 1, 2007.

INTRODUCTION

"Innovation is the specific tool of entrepreneurs, the means by which they exploit change as an opportunity for a different business or a different service. It is capable of being presented as a discipline, capable of being learned, capable of being practiced." Drucker, P. Practice of Innovation in Innovation and Entrepreneurship.

It was Joseph Schumpeter who argued that change and disequilibrium were the 'natural state' of dynamic capitalist societies. Peter Drucker's conception of innovation as the action of entrepreneurs exploiting that change suggests too that innovation like change must similarly be ubiquitous and continuous. It is the continuous and ubiquitous presence of innovation that makes the discrete measurement of innovation over time so difficult and complex. Research and development expenditures, numbers of employees engaged in innovation and other measures of inputs are too narrow and they tell us nothing about the productivity of these inputs. Output measures are preferable. Patents are widely used, but have a number of limitations especially their very limited usage, if at all, in wide sectors of the economy. While they have their own limitations – and this can be the basis for further discussion- a better indicator might be to examine the growth over time of those sectors where innovation is so critical to firm and country level performance – the so-called high-technology sectors. In particular, an examination of a country's performance in the global market for high technology products provides a significant indication of innovation activity and the link between innovation and comparative economic performance.

At the same time, this macro level data is aggregative. This data therefore does not allow for indications of dispersal around the mean – there may be many firms that are performing well even if aggregate performance is low. This indeed, as we will show, is the situation that prevails in South Africa. In addition, the factors that allow some firms to perform well even if aggregate performance is low, can only be gathered at the micro i.e. firm level.

This paper examines South Africa's high technology sector. The macro evidence is drawn principally from global trade statistics, but also patents, while the micro data derives from an examination of a number of firms and detailed interviews with 20 firms.

The first part of the paper outlines South Africa's export performance in high technology products, in a global context. The second part of the paper looks at the micro or firm-level data – examples of South African firms producing and exporting high technology products. The two sets of data give contrasting pictures - what appears to be a paradox. The economy wide performance is weak, but there are simultaneously many examples of effective innovating high-technology firms. The third section addresses this paradox, and identifies the factors that allow many firms to succeed, but that simultaneously constrain economy wide performance. The final section proposes some policy directions.

1. SOUTH AFRICA'S TRADE IN HIGH TECHNOLOGY PRODUCTS: THE MACRO PICTURE

1.1 SOUTH AFRICA' S GLOBAL PERFORMANCE

This analysis utilises the classifications developed by Sanjaya Lall (Lall, 2000 and Lall, 2001) and employed by UNIDO (UNIDO, 2003).[1] Lall distinguishes between primary products and manufactured products and further breaks down the manufactured products into 4 categories – namely resource-based, low-technology, medium-technology and high-technology products. Standard International Trade Classifications (SITC) three-digit (rev. 2) codes yield a total of 239 product groups. 18 of these groups (7.6%) are classified as high technology. The high technology category is divided as between electrical and electronic (11 product groups) and other (7 product groups).

TABLE 1.HIGH TECHNOLOGY PRODUCTS

SITC code	Product Group Description
	High Technology 1: Electronic and Electrical
716	Rotating electric plant and parts
718	Other power generating machinery
751	Office machines
752	Automatic data processing machines
759	Parts of and accessories for ADP and office machines
761	Television receivers
764	Telecommunications equipment, parts and accessories
771	Electric power machinery and parts
774	Electric apparatus for medical purposes
776	Thermionic, cold & photo-cathode valves, tubes and parts
778	Electrical machinery and apparatus, n.e.s.
	High Technology 2: Other
524	Radio-active and associated materials
541	Medicinal and pharmaceutical products
712	Steam & other vapour power units, steam engines
792	Aircraft & associated equipment and parts
871	Optical instruments and apparatus
874	Measuring, checking, analysing, controlling instruments
881	Photographic apparatus and equipment, n.e.s.

Source: Lall (2000)

Currently these 18 high-technology manufactured products constitute about one-quarter of global exports and one-fifth of developing country exports. South Africa's high-technology manufactured products at about $1.25billion constitute approximately 2.5% of South Africa's exports.

Over the period 1992-2005, South Africa's high technology exports increased significantly, by 9.5%. But this was somewhat below the global increase and substantially below the increase for developing countries.

TABLE 2.GROWTH RATES OF HIGH-TECHNOLOGY EXPORTS, 1992-2005 (average annual %)

	South Africa	World	China	Developing Countries	High income OECD
Total HT exports	9.53	11.09	31.55	20.86	8.74

Source: COMTRADE, TIPS data.

As a result, South Africa’s share of global high technology exports has declined. South Africa’s share of global trade in high-technology manufactured goods was 0.07% in 2005 – the same level as in 1992, and down from a high in 1998 of 0.09.

TABLE 3.SOUTH AFRICA’S PERCENTAGE SHARES OF GLOBAL EXPORTS, 1992-2005: TOTAL AND HIGH-TECHNOLOGY

	1992	1994	1996	1998	2000	2002	2003	2004	2005	Growth
Total exports	0.69	0.69	0.57	0.51	0.56	0.51	0.48	0.50	0.50	-2.45
Total HT exports	0.07	0.04	0.07	0.09	0.06	0.06	0.06	0.07	0.07	-0.41

Source: COMTRADE, TIPS, SA DTI, Mineral Production and Sales Statistics, and WTO data, and own calculations

Note: South Africa’s share of total world exports for 1992-2002 are based on calculations using COMTRADE, TIPS, DTI, and Minerals Production and Sales Statistics data. These appear to be the most accurate data, particularly as regards the export of primary products. However, replicating the figures for 2003-05 proved impossible due to discontinued access to certain data. South Africa’s share of total world exports from 2003-2005 is therefore taken from *International Trade Statistics 2006* (WTO, 2006). Hence there may be some inaccuracy in the time-series, but this is unlikely to be significant.

Few products show significant increases in export – and these are all off a very low base.

TABLE 4.SOUTH AFRICA’S EXPORTS OF HIGH-TECHNOLOGY PRODUCTS – 1992-2005 (Current US dollars, millions, and %)

		1992	1994	1996	1998	2000	2002	2003	2004	2005	Growth
Total HT exports		383.7	322.3	672	916.7	825.4	734.5	897.6	1175.5	1253.2	9.53
Total HT1		169.8	172.3	384.4	508.2	478.2	446.2	169.8	558.8	769.8	12.20
	716	13	12.2	16.6	19.6	19.8	31.7	39.2	72.2	63.6	12.97
	718	0.6	10.1	2.5	1.7	2	6.3	4.6	4.9	5.1	17.66
	751	5.1	3.3	7.1	8.6	5	5.9	5.4	6.4	5.0	-0.26
	752	17	9.9	31.9	44.3	31.3	29.2	48.6	48.3	66.4	11.07
	759	32.2	11.7	74	82.1	60	43.7	41.5	47.7	59.4	4.81
	761	2.2	1.3	13.2	11.3	15	9	16.6	31.3	25.0	20.63
	764	45.6	39.8	93.9	177.7	161.7	126.9	167.6	246.7	204.6	12.24
	771	9	16	19	26.5	52.7	29.5	32.0	44.9	50.9	14.23
	774	2.7	2.9	8	25.3	9.2	8.5	10.1	12.4	14.2	13.48
	776	3.1	13.3	17.9	13.8	21.2	56	72.0	104.6	125.5	32.81
	778	39.2	51.8	100.2	97.4	100.2	99.5	121.2	150.3	138.5	10.20
Total HT2		213.8	150	287.6	408.5	347.2	288.2	338.8	405.7	495.1	6.67
	524	98.5	43.1	65.4	59.5	31.8	32.6	42.9	52.5	76.6	-1.92
	541	36.6	34.3	58	84.2	106.5	91.4	101.9	119.7	130.5	10.28
	712	1.2	7.8	1.5	3.6	0.8	5.4	1.0	1.8	0.4	-7.88
	792	45.2	29.5	80.7	174.1	130.1	80.9	45.2	80.5	102.6	9.21
	871	1.3	2	6.2	6	9.6	6.8	1.3	6.6	8.8	19.65
	874	27.4	31.4	70.7	77.6	63.9	57.3	27.4	94.2	111.7	11.93
	881	3.7	2.1	5	3.5	4.6	13.7	3.7	11.8	8.6	10.57

Source: COMTRADE, TIPS and own calculations

South Africa’s poor performance is evident in respect of almost all of the different products. In only one high technology product group, namely 524, radio-active and associated materials, does South Africa’s share of world exports exceed South Africa’s overall share of global product exports (0.46%).[2] 524, is accordingly the only high technology product group for which South Africa’s revealed comparative advantage (RCA)[3] in 2005 is greater than 1 – at 2.5. In all the other products South Africa’s RCA is below 0.4.

South Africa has very large and rapidly growing adverse balance of trade in regard to all high-technology products (SA exports of the product less SA imports of the product). Again, the lone exception is radio-active and associated materials (524). In 2005, 524 had a favourable balance of trade of just over $68million.

However, 524 represents only a small share of South Africa’ high-technology exports – 6% in 2005. Moreover, 524 has been amongst the slowest growing product in global high-technology trade.

In summary, in high-technology products, in total, and with respect to almost all of the 18 individual high-technology product categories, South Africa’s performance, over the period 1992-2005 has been weak. Radio-active and associated materials, 524, is the only high-technology product group in which South Africa holds a positive trade balance and an RCA greater than one. However, 524 represent only a very small share of South Africa’s high-technology product exports and has been growing only slowly in global trade.

A further indication of South Africa’s weak performance in high technology products is the output of patents registered abroad. While there has been some increase in the number of South African patents registered since 1993, there is no clearly discernible trend. Indeed, the indications are that South Africa’s output of patents registered in the United States has been declining over the last five years.

TABLE 5. PATENTS OF SOUTH AFRICAN ORIGIN GRANTED BY THE UNITED STATES PATENT AND TRADEMARK OFFICE, 1994-2006.

	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06
Utility Patents	101	123	111	101	115	110	111	120	113	112	100	87	109
All Patents	109	127	116	114	132	127	125	137	123	131	115	108	127

Source:
USPTO, 2005(a); USPTO, 2005(b).
Data for 2006 supplied by Paul Harrison of the USPTO, 19/01/2007

South Africa’s share of all foreign patents registered in the USPTO to 1992 was 0.28%. In the period to 2005, this share had declined to 0.21%. For utility patents, South Africa’s share to 1992 was 0.3%. This declined to 0.23% in the period to 2005.[4]

There is a similar lack of a discernible trend in respect of domestic patents. The number of domestically registered patents generally fluctuates between 10,500 -11,000.

1.2 SOUTH AFRICA’S PERFORMANCE BY COMPARISON WITH OTHER COMMODITY EXPORTERS

To what extent is South Africa’s weak performance in high technology exports a reflection of its reliance on the production and export of raw materials? How does South Africa’s performance compare to that of other commodity exporters? South Africa is compared here with two other commodity exporters – Brazil and Argentina, as well as China. The share of primary products and resource based manufactures in exports for Brazil (54.7%) is slightly lower than that for South Africa (64%) while for Argentina the share is slightly higher (72%).[5]

Table 6 shows the very rapid rate of increase in China's global exports shares, particularly in Electrical and Electronic High Technology Products (HT1) and especially in the period 1992-2003. Brazil's share of global exports also increased, especially in Other High Technology Products (HT2), albeit much more slowly by comparison with China. Argentina's global share, by contrast with Brazil, showed a slight decline. South Africa's performance was similar to that of Argentina

TABLE 6.GLOBAL SHARE OF HIGH TECHNOLOGY EXPORTS – CHINA, BRAZIL, ARGENTINA AND SOUTH AFRICA, 1992-2005 (%s)

	1992	2003	2004	2005
CHINA				
HT1	1.61	10.71	12.91	15.35
HT2	1.22	3.35	4.28	5.64
TOTAL	1.49	9.26	11.21	13.43
BRAZIL				
HT1	0.26	0.26	0.23	0.35
HT2	0.37	0.84	1.13	1.03
TOTAL	0.29	0.37	0.40	0.49
ARGENTINA				
HT1	0.05	0.01	0.01	0.02
HT2	0.05	0.11	0.06	0.07
TOTAL	0.05	0.03	0.02	0.03
SOUTH AFRICA				
HT1	0.05	0.05	0.06	0.05
HT2	0.15	0.12	0.12	0.13
TOTAL	0.07	0.06	0.06	0.07

Source: COMTRADE, TIPS and own calculations

The share of high technology products in South Africa's total exports is much lower than that of Brazil and marginally lower than Argentina.

TABLE 7.GLOBAL SHARE OF TOTAL AND HIGH TECH. EXPORTS, 1992-2002:, BRAZIL, ARGENTINA AND SOUTH AFRICA (%)

	Brazil	**Argentina**	**South Africa**
Share of high tech. in total exports 1992	3.9	2.1	1.63
Share of high tech. in total exports 2002	10.5	2.6	2.51

Source: COMTRADE, TIPS and own calculations

In terms of the Revealed Comparative Advantage (RCA), all three countries score much lower in, Electronic and Electrical than in the other category, HT2. In all of the countries, electronics and electrical exports are very limited. It is only Brazil that has any electronic and electrical products where the RCA is above 0.5. The RCA measures for Brazil are significantly higher than for South Africa. South Africa's RCA measures are, in turn, very similar to those for Argentina.

TABLE 8: REVEALED COMPARATIVE ADVANTAGE IN HIGH TECH. EXPORTS: BRAZIL, ARGENTINA AND SOUTH AFRICA, 2002

	Brazil	**Argentina**	**South Africa**
HT1+HT2	0.47	0.12	0.13
HT1	0.32	0.05	0.11
HT2	0.83	0.26	0.16
HT1 products > 0.5	3	1	0
HT2 products > 0.5	1	0	1
HTI products > 1	1	1	0
HT2 products > 1	1	0	1

Source: COMTRADE, TIPS, and own calculations

A more detailed examination of the different product groups reveals that Brazil has a very high RCA (2.42) in respect of one of the product lines, namely 792 aircraft and associated equipment and parts. This product represents almost 50% of Brazil's high technology exports and has been expanding rapidly. Global exports of this product have been growing at 4% per annum.

Thus, while Brazil has a very limited export exposure over most of the high technology product spectrum, particularly in regard to Electronic and Electrical Products, it has developed a particular focus and a growing competitive edge within high technology products – notably aircraft. This product is likely to see continuing rapid growth in global demand. As outlined above, South Africa has a high RCA with respect to one high technology product group (radio-active and associated materials – 524). But, by contrast, this group constitutes a very small and declining share of South Africa's high technology exports. Moreover, it is experiencing a significant decline in global demand.

2.3 CONCLUSIONS

Viewed from a comparative perspective, three overall conclusions regarding South Africa's high technology exports can be drawn:

1. South Africa's performance in high technology exports and patent outputs over the period 1992-2005, has been weak. Of particular note, South Africa's share of global high technology exports has declined and there is a growing adverse balance of trade in respect of high technology products.
2. South Africa's performance has been comparable to that of Argentina, a country which has suffered a series of economic crises in this period. By comparison with Brazil, South Africa's performance was significantly weaker; high technology products are a lower share of exports and its overall competitive position in high technology products is much lower.
3. By contrast with Brazil, South Africa has not developed a high technology export focus in products which constitute a significant share of its high technology exports and which have the potential to expand significantly on the back of rapidly growing global demand.

2. SOUTH AFRICA’S PERFORMANCE IN HIGH TECHNOLOGY PRODUCTS: THE MICRO PICTURE

At the micro-level, a number of South African entities principally private sector firms, but also organisations in the public sector, possess very strong competencies in highly complex technologies. Some of them have been able to profitably exploit this expertise in global markets. A few concrete examples are illustrative.

Perhaps the most outstanding example is SASOL. SASOL, one of South Africa’s largest companies with a turnover of R69billion and direct employment in excess of 30,000, is the global leader in gas to liquid (GTL) fuel conversion technology. Utilising natural gas, this technology has the potential to produce more than 10% of the world’s diesel fuel. SASOL is commercialising this technology in a joint venture with Chevron. It has a very large plant due to come on stream in Qatar and plants are likely to be commissioned in a number of other countries including Iran, China, Australia and Nigeria. SASOL is the largest single performer of R&D in South Africa – probably responsible for some 10% of total business sector R&D. The company is currently spending about R500million on R&D and employing some 350 researchers full-time. 100 of the researchers have doctorates.

What is perhaps most surprising about SASOL’s R&D activity is not its scale but its location. While there are inevitably linkages with research centres and universities abroad, with the exception of a small research activity at a university in Scotland, SASOL has chosen to locate its large scale and highly-sophisticated R&D programme almost entirely within South Africa. As would be the general pattern for trans-national corporations headquartered in a developed country, SASOL retains its R&D and new product and technology development in its home country and commercialises this globally.

South Africa is a potential world leader in nuclear power generation. The Pebble Bed Modular Reactor (PBMR), a small scale high temperature nuclear reactor has a number of very attractive features including safety and small scale is currently under development. This is a leading edge technology which has attracted considerable international attention. It has significant commercial potential – once the product has been developed, the projections are for annual sales in excess of $3billion per annum.[6] The programme receives major support from government with R15billion having already been spent or allocated to the project.[7] The PBMR is currently South Africa's largest single employer of highly skilled scientists and engineers.[8]

Thawte is a company which specialised in secure digital certificates. Exploiting the restrictions imposed by the United States government on the export of cryptography, Thawte became a leading producer and exporter of this technology. It was acquired by its only major competitor, Verisign in 1999 for a sum of $575million. While Thawte is the major success story, there are a number of South African based companies, located broadly in software, that have managed to penetrate export markets.

The three examples outlined here are merely indicative. There are a number of South African companies, over a wide range of other technologically sophisticated product areas that are succeeding in export markets on the basis of their technological expertise. These include medical devices, electronics such as radar and antennas, fine chemicals and aerospace. The recently completed Innovation Survey found that nearly 52% of South African firms had technological innovation activities and that South Africa compared favourably with other countries such as Sweden, the UK and Portugal (DST, 2007:8).

Thus, while the overall trade data suggest a poor performance in high-technology based exports, at a micro level, there are many examples of successful high-technology firms spread over a broad range of products. How can this paradox be explained?

3 EXPLAINING THE PARADOX

At one level, the paradox is easily explained. While there are successful South African high-technology companies in a wide range of sectors, the overall number of firms is limited As a result, the overall levels of output and exports are low. But, this only suggests a recasting of the paradox. Why do only a few firms succeed? Why is the success of the few firms not emulated by a larger number of firms?

What is it that restrains new entrants from following the lead of the successful firms?

A recent study of a number of high technology based firms suggests some answers to this paradox (Breitenbach et al, 2006).

This study selected a total of twenty firms, chosen randomly from listings of high technology firms drawn from various sources. [9] All of the firms were intensively engaged in product innovation. The firms varied in size and were drawn from a wide variety of product areas – ICT, Aerospace, Bio-pharmaceuticals (including medical devices), Chemicals and Electronics. Data was gathered from extensive interviews with senior executives.

The central focus of the study was to determine how effectively the system overall and government policies in particular currently support the development of technological capacities in the high-technology firms. South Africa has built an elaborate structure for support for R&D and innovation. A number of government programmes support R&D and innovation within firms while others facilitate and support interaction between firms and the tertiary education institutions and science councils. Measures have been taken to encourage universities to engage with firms in research endeavours and the science councils have been restructured so as to promote a deeper engagement with local firms. A tax allowance for firm level R&D expenditures has recently been introduced. There are other supports for exporting and capital investment. All of these measures are designed to ensure a cohesive national system of innovation that is supportive of technological advance.

A number of deficiencies in the government support programmes, largely relating to the efficiency of their administration, lack of information, ease of access and multiplicity of programmes, were identified by those interviewed. However, in broad summary, most government supports functioned fairly effectively and the firms interviewed made extensive usage of governmental programmes and supports for innovation and R&D.

Some deficiencies that impact on a range of high-technology sectors were identified. The absence of an examining patent office is important and the perceived weaknesses in the national standards and accreditation systems is a concern for a number of firms (Breitembach et al, 2006:11). There are also some deficiencies that constrain further technological development in particular sectors – the absence of legislation and regulations governing the medical device industry and weak regulations governing clinical drug trials, for example.

But the major systemic weakness, and one that impacts negatively on all of the firms, relates to high skilled human resources, specifically well-trained scientists and engineers. All of the firms rely very heavily on highly skilled graduates from local higher education institutions (HEIs). They regard the supply of graduates as far more critical to their performance and future prospects than any government support or output of the national system of innovation. The quality of the best local graduates is perceived to be very high and comparable to the best internationally. Indeed, the firms identified the high quality of some of the local graduates as the most important factor underpinning their success.

However, there are two major concerns. First, some firms are worried that the quality is declining. Secondly, and most critically, all of the firms experience such high-level skills as being in very short supply. They are particularly constrained by shortages in the supply of specific high-level skills, leading some of them to source needed skills from abroad (Breitenbach et al, 2006:11-12). What emerges very clearly from the interviews, is that the short supply of locally-trained skilled personnel, particularly in the context where immigration laws make it very difficult to import needed skills, is the major factor constraining the further development of existent high technology firms in South Africa. Existent firms have pronounced difficulties in this regard, but the constraining impact will be felt even more acutely by any potential new entrants.

R&D in the South African business sector is heavily concentrated. Just four firms constitute 40% of total business sector R&D spending (Kahn and Blankley, 2006:280). A high proportion of the local supply of skills is similarly concentrated. The dominance of well-entrenched large firms renders it even more difficult for new start-ups to secure the necessary skills.

The root of the paradox therefore is the following: in the context of a reasonably supportive national system of innovation, the availability of well-trained skilled personnel allows for the development of a number of leading-edge firms that can engage effectively in global markets. At the same time, a pronounced scarcity of supply of such personnel, acts as the major restraint on the further development of existent firms while simultaneously even more severely constraining the entry of new firms, despite the visible success of some existent firms.

It is very evident that despite the progress that has been made in developing a set of programmes and institutions that support innovation in South African firms, very little progress has been made in respect of the supply of high-level skills. The number of students graduating in high level mathematics and science declined in the late 1990s and it has been increasing only slowly since then. South Africa exhibits a wider distribution of mathematics and science scores than do other countries – reflecting the very poor overall standard, and at the same time, the presence of high standards in a small minority of schools (Reddy, 2006:399). The number of full-time equivalent researchers in South Africa has also been increasing only very slowly (Kahn and Blankley, 2006:282-28). [10]

There are two other systemic constraints that are of a lesser order than the short supply of skills, but that particularly impact on new entrants. The first constraint is the limited development of venture capital in South Africa. New start-ups find it very difficult to attract early stage investors. The shortage of start-up capital has been identified as a particularly important constraint on the development of new companies in software development (African Analysis Team, 2004:101-102).

The second constraint relates to marketing. A number of South African firms have succeeded admirably in developing technologically sophisticated products, but have had great difficulties when it comes to marketing the products on the global market. This is particularly evident in software, but it is also true of other product areas, such as wine, where South African producers have developed excellent products but, due to marketing difficulties, have failed to secure prices commensurate with the quality of the product (Wood and Kaplan, 2006). In common with other latecomer firms, South African firms have had major problems in marketing their high-technology products, particularly in the industrialised countries. There are major gaps in the information and knowledge that firms possess of export markets. Entry into export markets necessitates high start-up costs and ongoing marketing costs are also high. This is particularly daunting where, as in the South African context, there have been significant exchange rate fluctuations.

In software development, many of the firms that have succeeded in export markets have done so through selling via the world wide web. The case of Thawte, outlined above, is instructive. Thawte’s secure digital certificates were marketed through the web. For companies able to market their products through a web portal, the marketing costs were very limited. Other software products cannot be sold off the shelf and particularly where back up and support are required, marketing costs are very high. For a number of software firms, the key constraint on their performance in export markets is posed by marketing rather than technology.[11]

4. CONCLUSION: POLICY PRIORITIES

After 1994, South Africa embarked on a number of new policy measures to develop the national system of innovation (NSI). These measures borrowed extensively from perceived global best practice (Kaplan, 2003). Two key macro level indicators of output, namely patent activity and particularly high technology exports, suggest that, despite these measures, there has not been a significant improvement in the performance of the NSI.

At the micro level, evidence gathered from interviewing the high technology firms suggests that the policy measures and the overall environment generally are broadly supportive of innovation. There is certainly room for policy improvement, notably in implementation. There is also a need for institutional development, particularly in regard to IPR and standards and accreditation. Nevertheless, highly innovative companies can and do function very effectively within this system.

Bringing together both macro and micro evidence, suggests that the main and immediate focus of government policy should be to address the systemic constraints identified that curtail the expansion of existent innovative companies and particularly impose major barriers to new entrants. Enhancing the supply of high skilled labour, without lowering its quality, will be key.

The major effort needs to be made in regard to improving the education and training system. There is also a strong case for encouraging skill immigration. Currently, South African remuneration levels are higher than those for competing industrialising countries with the gap increasing the higher the level of skills (Clarke, et al 2005). The wage gap is indicative of the short supply of high level professional and managerial skills. Enhancing the inflow of skills is the best mechanism of enhancing supply in the short term.

Apart from expanding the supply of high level skills, government should ensure that the country's existing skills are deployed most effectively. This raises an important question about current policies. As noted above, the PBMR is highly skill intensive and probably is the largest employer of high level skills in the country. The armaments industry is another large scale high skill intensive industry. Both receive lavish and direct state funding. A serious concern should be raised about the social opportunity costs of such state support, particularly in the light of the severe constraints on high level skills.

Attention needs to be given to support for new technology based start-ups. In developing countries, the development of new products and technologies is subject to information failure since the underlying costs structures and possibilities remain hidden. The new start-ups are a critical part of the so-called "voyages of discovery" – demonstrating hitherto unknown possibilities that can be taken advantage of by other follower firms.

Finally, innovation and technological capacity building must be complemented by the development of marketing capacities. Latecomer firms are behind the technology frontier. But they are also far from the market – not merely in distance but in their practices and in their capacity to acquire the necessary knowledge. In some countries foreign direct investment (FDI) has provided channels for learning – both technological and also marketing. However, in South Africa, such FDI, apart from a few sectors such as autos, has been limited. South Africa has many local firms that are highly technologically innovative, but that lack an effective marketing channel.

Firm level micro evidence suggests that, in addition to programmes and policies to support innovation and technological enhancement, government should give attention to providing support that would allow local firms, particularly but not exclusively high technology firms, to develop the marketing capacities that are a necessary complement to their innovative capacities and that are essential for their success in global markets.

REFERENCES

AFRICAN ANALYSIS TEAM (2004) *Research study into the South African software market*. Report prepared for Gerhard Fourie, Trade and Investment South Africa. Mimeo (May), Pretoria

BREITENBACH, P. KAPLAN, D. & WOOD, E. (2006) *The Influence of Publicly Funded R&D on National Development.* Report for the National Advisory Council on Innovation (Mimeo). Center for Innovation and Entrepreneurship, Graduate School of Business, University of Cape Town.

CLARKE, G.R.G., EIFERT, B., HABAYARIMANA, J., INGRAM, I., KAPERY, W., KAPLAN, D., SCHWARTZ, M. and RAMACHANDRAN, V. (2005) *South Africa: An Assessment of Investment Climate*. World Bank, Washington D.C.
http://www1.worldbank.org/rped/documents/ICA008.pdf
(Accessed 25 February 2007)

DEPARTMENT OF SCIENCE AND TECHNOLOGY (DST) (2007) South African Innovation Survey, 2005. Highlights. DST, Pretoria.

DRUCKER, P. F. (1995) Innovation and Entrepreneurship. Harper Business, New York.

KAHN, M. and BLANKLEY, W (2006) "The state of research and experimental development: moving to a higher gear." In BUHLUNGU, S., DANIEL, J., SOUTHALL, R. and LUTCHMAN, J. (eds.) *State of the Nation. South Africa 2005-6.* HSRC Press, Cape Town.

KAPLAN, D. (2004) "South Africa's National Research and Development Strategy: A Review". *Science, Technology and Society,* 9:2. 273-294. Sage Publications India

LALL, S. (2000) *The Technological Structure and Performance of Developing Country Manufactured Exports, 1985-1998*. QEH

Working Paper 44, Queen Elizabeth House Working Paper Series, Oxford University.

LALL, S. (2001) "National Strategies for Technology Adoption in the Industrial Sector: Lessons of Recent Experience in the Developing Regions." Background paper for the UNDP's Human Development Report, 2001: *Harnessing Technology for Human Development*. UNDP, Washington

Mani, S. (2000) "Exports of High Technology Products from Developing Countries: Is it Real or a Statistical Artifact?." *United Nations University Institute for New Technologies, Discussion Paper Series 2000-1*. Maastricht. The Netherlands.

MANI, S (2002) "The South African Experience since 1994." In MANI, S. (ed.) *Government, innovation and technology policy*. Edward Elgar Publishing, Cheltenham UK:

NATIONAL TREASURY (2006) *Medium Term Budget Policy Statement and Adjusted Estimates of National Expenditure, 2006*. http://www.treasury.gov.za/documents/mtbps/2006/default.html. (Accessed 18 December 2006)

REDDY, V. (2006) "The state of mathematics and science education: schools are not equal." In BUHLUNGU, S, DANIEL, J., SOUTHALL, R. and LUTCHMAN, J. (eds.) *State of the Nation. South Africa 2005-6.* HSRC Press, Cape Town

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT (UNCTAD) (2002) *Trade and Development Report, 2002. Developing Countries in World Trade*. United Nations Conference on Trade and Development, Geneva.

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT (UNCTAD) (2003) "Investment and Technology Policies for Competitiveness: Review of successful country experiences." *Technology for Development Series*, United Nations Conference on Trade and Development, Geneva

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT (UNCTAD) (2004) *UNCTAD X1, Colloquium on Assuring Development Gains from Trade. Outcome/Summary*. Rio de Janeiro (June 7)
http://www.unctadxi.org/templates/Event
(Accessed 4 November 2005)

UNITED NATIONS INDUSTRIAL ORGANISATION (UNIDO) (2003). *Industrial Development Report, 2002-2003.* UNIDO, Vienna

UNITED STATES PATENT AND TRADEMARK OFFICE (USPTO) (2005) *Patents by Country, State and Year – All Patent Types (December 2005*). USPTO Electronic Information Products Division Patent Technology Monitoring Branch (PTMB)
http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_all.htm.
(Accessed 4 February 2007)

UNITED STATES PATENT AND TRADEMARK OFFICE (USPTO) (2005) *Patents by Country, State and Year – Utility Patents (December 2005)*. USPTO Electronic Information Products Division Patent Technology Monitoring Branch (PTMB)
http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_utl.htm
(Accessed 4 February 2007)

WOOD, E. and KAPLAN, D. (2005) "Innovation and performance improvement in the South African wine industry" *International Journal of Technology and Globalisation*, vol. 1, Nos. 3/4: 381-399.

WORLD TRADE ORGANISATION (WTO) (2006) *International Trade Statistics, 2006.* World Trade Organisation, Geneva.
http://www.wto.org/english/res-e/statis_e/its2006_e/its2006_e.pdf
(Accessed 7 February 2007)

ENDNOTES

---

1. Analyses of high technology trade rely on the COMTRADE database of the United Nations Statistics Division since this is by far the most comprehensive source of comparative trade statistics and COMTRADE utilises Standard International Trade Classification (SITC) codes. Classification of high technology products is accordingly generally based on SITC product categories (Mani 2000:16). In addition to the COMTRADE data, this article utilises the Trade and Industrial Policies (TIPS) trade database.

2. It is also the only high-technology product group in which South Africa's share of developing country exports exceeded South Africa's overall share of developing country exports (1.89%). South Africa's share of developing country trade in (524) radio-active and associated materials was 7.16% in 2002.

3. $RCA_{i,k} = \dfrac{X_{i,k}}{\sum_k X_{i,k}} \Bigg/ \dfrac{\sum_i X_{i,k}}{\sum_i \sum_k X_{i,k}}$, where $X_{i.k}$ is the export of country *i* in product *k*.

4. Own calculations from USPTO, 2005(a) and USPTO, 2005 (b)

.

5. Data are for 2002. Own calculations from the COMTRADE data base

6. "Why PBMR Technology?" http://www.pbmr.com/index.asp?content=3. (Accessed 22 January 2007)

7. The PBMR received an allocation in excess of R1billion in 2006 with R580 million being allocated in the 2006 Budget and a further allocation of R462 million made in October (National Treasury, 2006).

8. Precise employment figures are not known. The web site states that there are 550 are employees. This excludes development work being contracted elsewhere. http://www.pbmr.com/index.asp?content=1. (Accessed 22 January 2007)

9. Sources included the Technology Top 100 and the firms receiving support from a variety of government programmes for R&D. Breitenbach et al, 2006:14.

10. As a result, a number of writers have seen the lack of skills as the key constraint on the development of the Science and Technology system (Mani, 2002:210; Kahn and Blankley, 2006:282)

11. One example is the former Mosaic Software. The company developed highly innovative software for the ATMs and inter-bank transfers. Difficulties in marketing and supporting the product abroad, led the firm to relocate its Head Office abroad and ultimately the firm was acquired by SI Corporation