

TECHNOLOGY INTENSIVE MANUFACTURING AND INNOVATION IN SOUTH AFRICA: A COMPARISON WITH THE BRIC COUNTRIES AND AN EMPIRICAL EXAMINATION OF TECHNOLOGY BASED FIRMS

David Kaplan

Abstract

There is considerable interest in the economic progress of the BRICS and in their capacity to enter into more technologically demanding activities. But, there is considerable variation in the rate of innovation as between the BRICS.

This paper focuses on South Africa. The first part of the paper examines South Africa's poor performance by comparison with other BRIC countries over the past two decades in respect of innovation and the development of high technology manufacturing sectors and activities.

The second part of the paper examines a number of technology and innovation indices, both on the input and on the output side, to show that while in the mid-1990s, South Africa led the BRIC countries in terms of innovation, it has now fallen significantly behind.

Brazil has many similarities with South Africa particularly in relation to the manufacturing sector – *inter alia* share in the economy and long term growth rates as between the two countries are similar. Accordingly, particular attention is paid to comparing South Africa with Brazil.

While comparative statistical data are lacking, South Africa is developing comparatively few new technology based firms. The third part of the paper accordingly examines a number of high technology firms and sectors in South Africa. Utilising extensive interviews and case study material, supplemented where available by statistical data, the concern is to map the nature of the technology or innovation undertaken by South African firms; the constraints under which they operate and the extent to which current government policy addresses these constraints.

The conclusion draws some broad implications of the analysis for government's current industrial strategy.

Introduction

A key contrast between South Africa and the other BRIC countries is South Africa's comparatively poor performance over the past two decades in respect of innovation and the development of high technology manufacturing sectors and activities. This is briefly outlined in the first part of the paper.

The second part of the paper examines a number of technology and innovation indices to show that while in the mid-1990s, South Africa led the BRIC countries in terms of innovation, it has now fallen significantly behind.

Particular attention is paid to comparing South Africa with Brazil.¹

While comparative data are lacking, South Africa is developing comparatively few new technology based firms. The third part of the paper accordingly examines a number of high technology firms and sectors in South Africa. Utilising extensive case study material, supplemented where available by statistical data, the concern is to map the nature of the technology or innovation; the constraints under which South African firms operate and the extent to which current policy addresses these constraints.

The further development of manufacturing is currently at the center of South African government policy to raise aggregate output and enhance economy-wide employment. The implications of this analysis for the broad strategic direction of government's industrial policy are outlined in the conclusion.

1. Manufacturing Performance

Over the period 1995 – 2010, measured in constant \$US, by comparison with China and India, South Africa performs poorly in growth in manufacturing value added (MVA). However, South Africa outperforms Brazil: the annual growth rate of MVA in South Africa 1995 – 2010 was 2.4 percent whereas it was 1.7 percent in Brazil.

¹ Brazil has many similarities with South Africa particularly in relation to the manufacturing sector – *inter alia* share in the economy and long term growth rates as between the two countries are similar.

Table 1. Manufacturing Value Added. BRICS (excluding Russia). 1995 – 2010 (constant \$US (millions))

	1995	2000	2005	2010	% change 1995 - 2010	CAGR 1995- 2010	% change 2000- 2010	CAGR 2000 – 2010
Brazil	94987	96165	110966	122633	29	1.7	27.5	2.5
China	241973	384942	630818	1115271	361	11	190	11.2
India	52325	65753	91869	142305	172	6.9	116	8
Russia	---	---	----	---	---	--	---	--
South Africa	20300	22926	26678	28850	42	2.4	26	2.3

Source: World Development Indicators

In terms of growth in manufacturing exports, South Africa has performed poorly by comparison with China and India. South Africa has performed less well than Brazil, but the difference between the two countries is marginal. South Africa has also performed better than Russia.

Table 2. Manufacturing Exports, Trade Value. BRICS, 1995 - 2010 (current \$US millions)

	1995	2000	2005	2010	% change 1995 - 2010
Brazil	24703	31987	62534	72467	193
China	125168	219841	700075	1476007	1979
India	23277	32970	71319	140471	503
Russia	23061	24323	45278	58696	154
South Africa	12200	14149	26435	33169	171

Source: COMTRADE

It is in respect of high technology exports that South Africa performs particularly poorly – by comparison with all of the BRIC countries, including Russia. Brazil’s growth rate is almost six times that of South Africa.

Table 3. High Technology Exports. BRICS, 1995-2009 (current \$US millions)

	1995	2000	2005	2009	% change 1995-2009
Brazil	1,197	5,738	8,028	8,316	595
India	1,001	1,569	3,383	10,143	913
China	13,175	40,837	214,246	348,294	2543
Russia	2,162+	4,191	3,690	4,576	112
South Africa	692	986	1,739	1,418	104

+Data for 1996

Source: World Development Indicators.

Currently, high technology exports are a far smaller share of manufactured exports in South Africa than in any of the other BRIC countries. In 2010, the latest year available, high technology exports were 7.2 percent for India; 8.85 percent for Russia; 11.4 percent for Brazil and only 4.28 percent for South Africa. Moreover, high technology exports as a share of manufactured exports in South Africa have been declining.

Table 4. High Technology Exports as a Percentage of Manufactured Exports

	1992 -1995	1996 – 2000	2001 - 2005	2006 - 2010
Brazil	4.6	11.0	14.4	12
Russia	-	11.9	14.7	7.8
India	4.72	6.2	6.2	7.1
China	8.1	15.4	26.6	28
South Africa	5.6	7.2	5.7	5.3

Source: World Development Indicators

As this brief outline has shown, South Africa performs poorly by comparison with the other BRIC countries in respect of the more technologically sophisticated manufacturing sectors.

2. Technology and Innovation Performance Indicators

This section of the paper examines a number of economy wide technology and innovation performance indicators in South Africa by comparison with the other BRIC countries. Two input indicators are examined – R&D spending as a share of GDP and number of researchers per population. Two output indicators are examined – patents (including co-invention) and technology balance of payments (technology receipts and payments). These indicators further confirm that South Africa is falling behind the other BRIC countries in the technology and innovation realm.

2.1 R&D Expenditure as a Share of GDP

South Africa’s gross expenditure on R&D has been increasing and is currently very close to the government’s declared target of 1 percent. This is somewhat below that of Russia, China and Brazil – but higher than India. As South Africa’s economy is significantly smaller than the other BRIC countries, overall expenditure on R&D in South Africa is significantly less. Moreover, since GDP has tended to rise more slowly in South Africa, particularly by comparison with China and India and, more recently with Brazil, South Africa is, over time, devoting comparatively less overall resources to R&D.

Table 5. R&D as Percentage of GDP; BRICS, 2000- 2009

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Brazil	1.02	1.04	0.98	0.96	0.90	0.97	1.00	1.07	1.08	-
Russia	1.05	1.18	1.25	1.29	1.15	1.07	1.07	1.12	1.04	1.25
India	0.77	0.75	0.74	0.73	0.74	0.78	0.77	0.76	-	-
China	0.90	0.95	1.07	1.13	1.23	1.32	1.39	1.40	1.47	-
South Africa	-	0.73	-	0.78	0.85	0.90	0.93	0.92	0.93	-

Source: World Development Indicators

2.1.2 Researchers per Population

South Africa has a far lower share of population engaged in R&D than China, Russia or Brazil – but a higher share than India. The rate of growth has been lower than in Brazil, India and particularly China.

Table 6. Researchers in R&D per million population; BRICs (1997 – 2007)

	'97	'99	2001	2003	2005	2007
Brazil	-	-	441	496	588	658
Russia	3594	3375	3460	3365	3230	3274
India	115	--	110	--	136	--
China	47	422	581	667	856	1077
South Africa	199	--	312	303	362	396

Source: World Development Indicators

2.1.3 National Patents and Co-Invention

Pre-1998, the number of South African patents at the United States Patent Office (USPTO) significantly exceeded that of any of the other BRIC countries. Indeed, the number of South African patents was only a little less than the total for **all** the other BRIC countries combined. But, while patents registered at the USPTO on the part of all the other BRIC countries have increased significantly every year after 1998, for South Africa the number of patents registered per annum effectively stagnated. At the end of 2011, the number of South African patents was 13 percent of all the other BRIC countries combined.²

Currently, Brazil and Russia still have fewer patents at the USPTO. But this reflects South Africa's past relative strength and many of these patents are old and will expire. The numbers of patents currently being registered by Brazil and Russia significantly exceed that of South Africa. South Africa's share of global and middle income country patents at the USPTO has declined significantly.

Table 7. Patents at the USPTO (All Patent Types); BRICS 1998 – 2011

	Pre-1998	'98	'99	'000	'01	'02	'03	'04	'05	'06	'07	'08	'09	'010	'011	All Years
Brazil	836	88	98	113	125	112	180	161	98	148	118	133	148	219	254	2831
Russia	370	194	185	185	239	203	203	173	154	176	193	181	204	287	307	3254
India	405	94	114	131	180	267	356	376	493	506	578	672	729	1137	1259	7189
China	554	88	99	161	265	391	424	596	565	970	1235	1874	2270	3303	3786	16581
South Africa	2091	132	127	125	137	123	131	115	108	127	116	124	139	142	144	3831

Source: United States Patent and Trademark Office. Patent Technology Monitoring Team (2011) Patents by Country, State and Year – All Patent Types (December 2011)

² For an examination of patents and other technology indicators and the factors that account for South Africa's performance, see Kaplan et al, 2011.

Since patenting activity has risen significantly globally and especially on the part of middle income countries, South Africa's global share and share of middle income country patenting has declined significantly,

Globally, there has been an increasing trend towards international co-invention whereby nationals of different countries engage in joint research resulting in co-invented patents. National patents alone give an incomplete picture of a country's innovative capacities. Moreover, as the product of a joint effort, co-invented patents are generally of high value. Emerging markets and the BRIC countries, in particular, have experienced a rapid growth in international patenting. "Co-invented patents and Chinese patents owned by Western multinationals have, in recent years, accounted for the largest fraction of newly granted USPTO patents. International co-invention is also increasingly important in Indian patenting, though less so than in China." Kaplan et al, 2011:8. Co-invention has also been important to Eastern European countries, especially Russia.

Prior to the mid-1990s, co-invention was insignificant for all of the BRICs. From the mid-1990s, particularly for China, but for India and for Russia also, co-invention increased significantly. For Brazil, the increase was less significant, but still evident. The contrast with South Africa is marked. "Co-invented patents have not expanded rapidly in South Africa – the total number of co-invented patents especially, as well as the rate of growth of co-invented patents is generally lower than for comparable countries. Over time, there is no pronounced trend in the total number of co-invented patents in South Africa. As with South African patents therefore, co-invented patent activity by South Africans is low and there is no discernible trend for this to increase over time." (Kaplan et al, 2011:10) The share of co-invented patents in South Africa's total patent activity is significantly lower than for China, Russia and India. The share of co-invented patents is lower in Brazil than in China, India or Brazil. However, Brazil's share of co-invented patents is still more than twice as high in South Africa (Bransetter, 2009:13)

An examination of South African patenting and co-invention at the USPTO revealed only two significant clusters of patents – namely in mining related technologies³ and in fuel technologies⁴. These two clusters of patents are a larger share of total patenting in South Africa than in other comparable countries. An examination of the quality of these patent clusters, based on citations received,⁵ revealed that the mining related technology patents were higher than for South African patents in general and was comparable with similar

³ A patent belongs to the "Mining Technologies" cluster if it belongs to one of the following 3-digit USPC classes: 299 - Mining or In Situ Disintegration of Hard Material, 051 - Abrasive Tool Making Process, Material, and Composition, 023 - Chemistry: Physical Processes, 037 – Excavating, 075 - Specialized Metallurgical Processes, 172 - Earth Working.

⁴A patent belongs to the "Fuel Technologies" cluster if it belongs to one of the following 3-digit USPC classes: 210 - Liquid Purification or Separation; 208 - Mineral Oils: Processes and Products

⁵ Patent applicants at the USPTO are required to disclose knowledge of the "relevant prior art." This entails citations to earlier inventions and other technical advances that are antecedents of the inventions for which the applicant is seeking patent protection.

patents in Australia, Canada and the United States. Fuel technology related patents, by contrast, were of a significantly lower quality (Kaplan et al, 2011:12).

There were no other areas of significant patent activity. In biotechnology, for example, there were very few patents and these patents appear to be significantly less highly cited than the equivalent foreign patents (Kaplan et al, 2011:13).

Outside of mining and related technologies, where South Africa has a long tradition of expertise and technological innovation, therefore there is no indication of innovative strength. In the emerging high-technology areas which are patent intensive, such as biotechnology, there are very few South Africa patents and these tend not to be of high quality.

2.1.4 Technology Balance of Payment (TBP)

The TBP consists of receipts that countries earn through the royalty and licensing payments of technology to foreigners and the payment that are made by nationals to foreigners so as to acquire or licence their technology.

Licensing receipts are a particularly significant measure of a country's technological strength and in particular, the extent of technological and innovative activity located at or close to the global technological frontier. South Africa's declining position with respect to the other BRIC countries is very evident.

Table 8. Royalty and Licence Fee Receipts; BRICS, 1990 - 2010 (current US \$million)

	'90	'95	000	001	002	003	004	005	006	007	008	009	010
Brazil	12	32	125	112	100	108	114	102	150	319	464	434	397
Russia	-	4	91	60	147	174	227	260	299	393	453	494	625
India	1	1	83	37	20	24	53	206	61	163	148	193	129
China	-	-	80	110	133	107	236	157	205	343	571	429	830
South Africa	19	45	49	21	19	27	37	45	46	52	54	48	59

Source: World Development Indicators

In the period 1991 -1995, South African royalty and licence fee receipts significantly exceeded that of all the other BRIC countries. South Africa averaged royalty and licence receipts \$58 million per annum. The average for Brazil was \$ 22 million; for India \$1million and for Russia well below \$ 5million.⁶ By contrast, in the period 2000 – 2010, South African royalty and licence fee receipts were very significantly less than that of any of the other BRIC countries. South Africa averaged \$ 42 million. The average for Brazil was \$ 220 million; for India \$102 million; for Russia \$ 293 million and for China \$ 291 million.

Whereas all the other BRIC countries have significantly increased their royalty and licence fee receipts over the last two decades, South Africa's receipts have declined by 30 percent.

⁶ Russian earnings averaged \$3.8 million for 1994 and 1995. No earlier data is available. No data are available for China

Royalty and licensing payments is a key indicator of the extent to which a country is securing technology from abroad. Technology importation is generally complementary to local technology development – countries that are enhancing their indigenous technological capacities are simultaneously increasing their import of technology.

In terms of payments for technology sourced abroad – South Africa exceeded India and Brazil in the period 1990 -1994. South Africa was both a bigger importer of technology and a larger exporter. After 1995, while South African payments for royalty and licence fees increased steadily, they did so much less rapidly than for China, India and Russia, but also more slowly than for Brazil. In the 1990s, South Africa’s royalty and licence fee payments exceeded that of Brazil. However, Brazil then surpassed South Africa and the gap has been steadily increasing

Table 9. Royalty and Licence Fees Payments (Current US \$). 1990 -2010 (selected years)

	1990	1995	2000	2005	2010
Brazil	54	529	1415	1404	2850
China	-	-	1281	5321	13040
India	72	90	282	672	2438
Russia	-	4	68	1593	5066
South Africa	131	293	246	1071	1941

Source: World Development Indicators

2.1.5 Conclusion

South Africa performs poorly by comparison with the other BRIC countries in respect of economy wide technology and innovation performance indicators, both in terms of input and more especially output indicators. These economy wide indicators accord with lower shares of technology based manufacturing, slower rates of output growth and exports and lower proportion of technology based manufactured exports for South Africa as compared to the other BRIC countries.

R&D, licence and patenting activity, and technology receipts and payments are important indicators of whether countries are currently closing the technological gap with the industrialised countries. Moreover, where countries have succeeded in global markets for manufactures, patenting activity, in particular, has been shown to be an indicator of likely future technology based activity.

Thus, South Africa’s poor performance in this regard is therefore an indicator not solely of current weakness, but also of the likely future prospects for technology and innovative intensive manufacturing and service activities. In only one area, namely in mining related technologies, is there evidence that South Africa is proximate to the global technological frontier. South Africa’s presence in mining and related activities is of long standing. Examination of the patent data reveals no indications of new emerging clusters of knowledge of any significance in South Africa.

3. South Africa's High Technology Firms – Development and Constraints

Why has South Africa's rate of growth in all the areas of technological and innovative capacity been so low and lagging that of the other BRIC countries? Why has South Africa not succeeded in developing significant new clusters of high technology based firms which undertake R&D and are successful in export markets or secure global patents? What innovation and technological adaptation activities are South African firms engaged in and what are the factors that constrain and inhibit the growth of existent technology based firms in South Africa? Of particular importance, what are the factors that constrain and inhibit the growth of new technology based firms?

In order to answer these questions, a number of interviews were undertaken with South African technology-based firms. Utilising extensive case study material, supplemented where available by statistical data, the concern is to map the nature of the technology or innovation; the constraints under which South African firms operate and the extent to which current policy addresses these constraints.

Technology-based firms were defined as firms which were investing considerable share of their revenue in innovation or technological adaptation; firms whose competitive position in the market relied heavily on technological adaptation or innovation and which were either at the global technology frontier or were technological leaders in the local market.

Three "clusters" of firms were interviewed:

The first "cluster" of firms was located in mining equipment or specialist mining services. As outlined earlier, this is the one area where South Africa has a significant number of valuable patents. Complementing this technological capacity, South Africa has a large number of firms in mining equipment and specialist services which spend considerable share of their resources on innovation and/or significant technological adaptation and many of these firms are global market leaders with a significant presence in globally competitive export markets. 12 firms belonging to this cluster were interviewed. Firms were from across the size spectrum and also included three foreign owned firms which have a strong presence in South Africa. These firm level interviews were supplemented by interviews conducted with the relevant export council; with one of the key publicly funded science councils that engages with this cluster and with a relevant university based research unit.

The second "cluster" of firms had won local awards for technology development. These firms were winners of the Technology Top 100 – an annual competitive award given to technological leaders. These firms had all won in one or more category of technological advance. They were all manufacturing firms. Five firms were classified as emerging companies and had been established or engaged in technological advance relatively recently; one firm was classified as an established firm.⁷ All of the firms were small. There were six firms in this "cluster."

⁷ In fact, this firm had also been established relatively recently – within the last 7 years.

The third “cluster” of firms was located in the ICT software sector. This is a sector where South Africa has indeed enjoyed some success. A number of South African firms have developed very innovative products and have succeeded on global markets. Four leading ICT firms were interviewed – three of the firms had engaged very successfully in global markets; the fourth was a Technology Top 100 winner and a recognised national leader in its area.

A number of the firm interviews were initially carried out in the course of a World Bank study on technology absorption in Southern Africa, Goldberg et al, 2011.⁸

In addition, this firm level examination draws on an earlier study based on interviews with high technology firms, Breitenbach et al, 2006. This study interviewed 19 high technology firms drawn from a wide range of sectors and activities. None of the firms interviewed in this 2006 study were included in any of the interview clusters.

Finally, this section also draws on some, albeit limited, statistical data.

3.1 The Nature of Technological Change/ Innovation

Mining capital equipment and specialist service companies are producing a number of products in which they are global market leaders – washing spirals, alumina ties, pumps, ventilation equipment and other products. There are also a range of services in which companies are at the global forefront – shaft sinking, geology and plant design. These products and services have a significant technological content. Many of the products and services were initially developed to address the particular problems faced by the South African mining industry and then extended to the export market. For example, the poor quality of much of South Africa’s coal required that it be extensively washed. The spirals developed to address this challenge and the underlying technology thus developed was later applied to washing in other situations – in the Canadian tar sands, for example. Hydropower, shaft sinking and ventilation arising from the technical challenges of very deep level gold mining in South Africa have similarly resulted in the accumulation of technological expertise that is at the global forefront and that underpins the success of South African firms in global markets.

A number of mining capital equipment and specialist service companies are also engaged in the extensive adaptation of technologies and products derived from abroad. All of the firms interviewed regarded the local mining industry as composed of very demanding buyers who require globally competitive products and support. Extensive technological adaptation in order to meet very demanding local operating and environmental conditions and the quality requirements of the South African mining industry are regarded as clear indications that products and services meet global standards and are recognised as such by global customers. Two of the three foreign owned firms interviewed maintained large operations in South Africa where they undertake extensive adaptation and bespoke design of their products such as hammer bits and drilling consumables and services such as design drawings for the local and the regional market. These companies are attracted by the size of the market but also by

⁸ Eight of the mining equipment and specialist services firms and three of the firms in ICT were interviewed in the course of the World Bank study.

the extensive network of skilled specialists and input suppliers that are available to them locally.

In summary, mining capital equipment and specialist service companies undertake extensive technological product and process adaptation as well as extensive product and process innovation that results in globally leading products.

Technology award winning firms were all engaged in technological adaptation. None of these small firms were developing or manufacturing products that could be considered new to the world. Firms were motivated to engage in technological adaptation in order to meet the requirements and specifications of local customers or to address particular local challenges. For example, the differences in power supply and the presence of a lot of abrasive materials require that imported pump designs and technology be extensively adapted to meet local conditions. In addition, two of these firms sought to engage in technological adaptation as a means of gaining local market penetration and to challenge a well established market leader. Cheaper product, customised product and more prompt technological back up are seen as the key competitive advantage. All of these firms were small and had limited financial and technological resources. They did not have the wherewithal or the incentive to engage in substantive innovative activity.

In summary, these technology based small firms are engaged in technological adaptation rather than frontier innovation. They are more “typical” of local small technology based firms.

Software firms were all engaged in the development of highly innovative products. Three of the firms were very successful in global markets. The fourth was a recognised leader in the local market. The three firms that are successful in global markets offer a globally leading edge product. The product serves a carefully selected market niche. The foundation of the success of these local is technological. Innovation is the core of their business. These firms spend an extensive share of their revenues on technological development and this development is ongoing requiring constant new and better offerings to their customers. The fourth firm addresses a particular local problem that requires a software based solution. As with the other three, it spends a very high share of its revenues on technological development. While it does not export currently, it sees future potential for exports – notably to countries that have similar problems to those experienced in South Africa.

In summary, South Africa has developed firms in the broad ICT software area which provide leading global products in particular niche areas or, in one case, very extensive adaptation to meet local needs.

3.2 Constraints

Mining capital equipment and specialist service companies almost universally cited the shortages of skills as the key constraint on their technological advance and on their overall growth. This concern was echoed by the export council. There is further statistical corroboration for this concern. In the ES for 2003, skills shortages were cited by all

categories of capital goods firms – exporters and non-exporters, foreign owned and domestically owned – as the top constraint. In the 2007 survey, capital goods firms cited crime as the top constraint, followed then by skills.⁹ Skill shortages are exacerbated by the emigration of skills and the active recruitment of skilled persons by other countries. This is particularly true of Australia which has attracted very large numbers of South Africans with mining and mining related skills. All levels of skills are in short supply. Some firms were concerned by the shortages of engineers, managers and other high level skills. Others singled out the shortages of artisans. At least one major firm with operations in a number of countries, saw the shortage of skills, combined with generous government support (see below) as leading to further technology development activities being cited in Australia rather than in South Africa.

Two other factors were widely cited by mining capital equipment and specialist service companies as constraining technological development – namely access to finance and infrastructure constraints. Finance was cited by four firms as a serious constraint. All of the firms that cited finance as a serious constraint were small and locally owned firms. None of the large firms and none of the foreign owned firms regarded finance as a significant constraint. The concerned firms cited the reluctance of commercial banks to fund longer term product development programmes unless they were provided with very extensive surety or collateral. This was very difficult, if not impossible, for the firms to secure. Infrastructure constraints were cited by almost half of the firms as a serious constraint. The single most important constraint was power. Power outages are seen as a major constraint on productivity and on delivery times. Poor rail transport and ports are also of concern. These logistical constraints impact severely on the local mining industry, but they also impact directly and adversely on the suppliers of equipment and specialist services. A final overall constraint is that of crime. Crime is perceived to have been increasing very rapidly. This is borne out in the ES. In 2007, crime was cited by capital goods firms as the most serious constraint.¹⁰

Technology award winning firms cited finance as a key constraint. Firms complained of severe difficulties in raising seed capita for early product development. One firm very nearly went out of business and had to pledge all the private assets to secure funding from the bank. Three firms were successful in finding early stage investors. In all three cases, these were private investors who took a direct interest in the company and who were acquainted with the company from the outset. None of the firms succeeded in attracting an early stage private venture capital investor. One firm did succeed in attracting a private venture capital investor, but this was only after the product already had a fairly well-established revenue stream. In effect, this was private equity rather than venture capital finance. Firms also cited difficulties in acquiring finance in order to undertake the necessary marketing expenditures to launch the product and also later to ramp up production when products proved successful.

⁹ Goldberg, et al, 2011:76

¹⁰ House and business robberies increased significantly over the period 2005/6 – 2009/2010. 2009/2010 – 2010/2011, household robberies declined but business robberies increased, although marginally by 1 percent. Business robberies were particularly directed at small and medium sized businesses more likely to be run on a cash basis (South African Police Service, 2011: 16-17)

Skills shortages were cited by four of the firms as a significant constraint. A fifth firm stated that there would be a skill constraint were they to consider expanding. The one firm that did not cite skills as a problem operated a business model whereby all of the technology development work was outsourced to specialist engineers with clear performance and product specifications. Only one of the firms interviewed had a (limited) positive experience with state supports for training – the SETA system was by-passed by all the rest.

The limited availability of strong support industries and services were cited as a major constraint by two of the firms. One firm was constrained by the lack of high quality foundries that rendered their products very expensive and restrained the products that they could design and develop. Another firm had major difficulties required an extensive modification to a machine that was initially developed for another purpose and had major difficulties securing that expertise locally where as it was readily available abroad.

Other constraining factors cited were government procurement and black economic empowerment. Government procurement was seen to be inefficient such that the procurement organisations did not clearly specify what they required; it was difficult to know when tenders were sent out; tendering was expensive for small firms and procurement procedures lacked transparency. The risks associated with tendering are particularly severe for a small firm. Black economic empowerment with regard to equity was seen as difficult for a small company. Small companies could not afford to have partners who were not deeply engaged in the business while if the business, in the view of the owner, held enormous promise, there was a clear disincentive to give equity “away” at cheap rates. One of the firms spent a considerable length of time trying to engage black partners at an early stage of its development. None were forthcoming, it was claimed, because the risk was perceived as too great relative to other opportunities readily available to black investors. Finally, none of the respondents had experience of new small technology based black owned companies in their areas of activity. The ready availability of alternative, much less risky ventures to black entrepreneurs was seen to discourage risk taking.

Software firms developing niche products for global markets rely heavily on highly skilled software engineers. The competitive edge of South African firms rests in their ability to attract highly skilled software engineers and developers at globally competitive wage rates. South African wage rates for said to be some 60 percent of those prevailing in Europe or the United States for a similar level of skills. The firms were firmly of the view that the quality of their personnel was equivalent to that available anywhere. Moreover salaries are lower in South Africa. At the same time however, three of the firms were having difficulty in attracting sufficient numbers of local staff. Two of the firms were, as a result, forced to employ people from outside South Africa. One of these firms located much of its development work in India while the other firm imported software skills from India to work in South Africa.

The cost and quality of bandwidth is cited by two of the firms as a major constraint. The higher cost of bandwidth is also a factor in one firm favouring undertaking developmental

work outside of South Africa.¹¹ Restrictions on the international movement of Intellectual Property (IP) from South Africa is cited as the factor that would prevent one of the companies from considering South Africa as the preferred site for the location of a major product development office. By contrast with other technology based firms, finance is not seen as a major constraint.

3.3 Government policy and local linkages

Mining capital equipment and specialist service companies had divergent views on government support. A significant number of the firms – more particularly the smaller firms – tended to have a negative picture. They were either unaware of government policies or supports available or else they made only marginal use of the supports available. The larger firms were more likely to utilise government supports – the tax incentive for R&D; support for technology development under the Support Programme for Industrial Innovation (SPII) or training under the SETA programme. The firms were universally of the view that the quality of the publicly funded research and support institutions in regard to mining, but also in regard to metallurgy and refining and other mining related areas had declined substantially since 1994. All of the relevant science councils – the CSIR, Mintek and Geological Sciences – had suffered a decline in funding.¹² South Africa's largest research institution, the CSIR, which previously had very significant programmes in relation to mining, principally in trackless mining and rock engineering, was said to have hardly any research capacity remaining. A number of firms still made use of these institutions, particularly Mintek, but usage had declined. Firms were now making much more use of research and technical support provided by local private firms and increasingly by firms located abroad. By contrast, in Australia, public funding for mining and mining related research has received increasingly generous funding. As a result, in areas such as trackless mining where South Africa was previously the global leader, capacity is now very depleted. Australian research institutions and firms are currently very dominant. The same trends are evident in respect of university based research. While South Africa has some capacity and some of that is recognised as world class, research here too is said to have declined particularly relative to Australia.

Very few of the firms interviewed engaged with the universities. Only one firm had extensive linkages with university based technological research.

Government policy is regarded by the firms interviewed as having constrained the development of the local mining industry, principally through creating uncertainty over property rights that adversely impact on investment decisions and through inadequate infrastructure provision - electricity that adversely impacts on production and transport that limits exports. Limited investment in mining has, in turn, reduced the opportunities available to local suppliers of equipment and specialist services. It is new investments that require new

¹¹ The West African Cable System (WACS) which went live in May 2012 will boost South Africa's international bandwidth capacity and should result in a reduction in prices. With the launch of Seacom followed by the East African Submarine Cable System (EASSy) and now WACS, the bandwidth bottleneck is no longer on the international leg. The constraints are now in the national backhaul infrastructure and pricing. However, a number of initiatives are underway that will soon alleviate this constraint

¹² For further details, see Kaplan, 2012.

products and services and that therefore provide the major stimulus to innovation and technological advance.

Technology award winning firms similarly had divergent views and experiences with respect to government support. Half of the firms interviewed had either no or a very peripheral engagement with government supports for technology and innovation. Most of these firms were unaware of the supports that were available. One firm had a limited engagement with government supports. Two of the firms, by contrast, had a substantial engagement with government and had secured significant government support at some stage of their development. One firm, in the broad biotechnology area, received very extensive support particularly in its early stage development through the incubator programme. Later it received support for further development through the Support Programme for Industrial Innovation (SPII) and when it was ready to launch its product abroad, the firm received support from the dti Export Marketing and Investment Assistance Scheme (EMIA). This firm was extremely positive about the effectiveness of the support that it received. Other recipients were more mixed in their views with particular complains as to how time consuming and cumbersome it was to access these funds. In terms of direct support for innovation, the experience of the two firms that had accessed government supports was that gaining access has become more difficult over time. Only two of the firms approached government for financial support – in both cases the Innovation Fund. One firm's experience of the Innovation Fund was distinctly negative. The second firm had a very positive experience. With the demise of the Innovation Fund, this firm made application to the newly established Technology Innovation Agency. Their experience of the Technology Innovation Agency was distinctly negative.

Only two of the firms had any linkages with the universities or the science councils. One of these firms was founded by former employees (largely engineers) of the CSIR and retained considerable linkages with the science council. The more technologically advanced and technologically complex firms where advanced engineering and technical capabilities are required were established by persons with university training and sometimes a background of experience in a science council. Linkages with these institutions were retained and form an important source for further technological development. In the other two-thirds of the firms, while a number of employees and generally the founder/s had received university training – generally in technical or engineering disciplines – there were no effective linkages with the universities or the science councils. These firms tended to be of a lower level of technological sophistication engaged in making limited adaptations to the local market.

Software firms made limited use of government support programmes for innovation and technological development. One of the firms utilises the tax allowance for R&D and one of the firms has obtained limited funding from the SPII programme. Black economic empowerment was seen contributing significantly to costs and to make South Africa a less competitive location. Concerns were expressed about the difficulty of moving intellectual capital (IP) offshore. One company was clear that, because of the difficulty of moving IP offshore, if it were to open a new development office, this would not be in South Africa. Although there would always be ways of getting around this problem, the costs and time

involved in getting around the rules would preclude locating new developmental activities in South Africa.

Software firms had no significant linkages with either universities or the publicly funded science councils.

3.4 Conclusion

The most widespread constraint cited is the shortage of skills. Case studies of other sectors such as autos and components similarly cite the skills shortage as the key constraint on technological development and firm level advance – and this is confirmed by statistical data (Goldberg et al, 2011:70). South African graduates employed by the firms are regarded by the firms as being of a high quality. They are key to the progress that local firms have achieved and, in mining equipment and specialist services, the presence of such skills attracts foreign firms to undertake development work in South Africa. However, high quality South African graduates are in very short supply and this imposes significant constraints on future expansion.

An earlier study of 19 high technology firms reached a similar conclusion. “The high quality of local graduates employed in these firms is fundamental to their success and the single most important contribution of the national system to their development. This is enhanced where local graduates also acquire specific exposure to commercial and industrial settings. ... The biggest single constraint, nevertheless, is that the number of high quality local graduates is distinctly limited. This limitation is simultaneously the most fundamental constraint on the further development of high technology firms” (Breitenbach et al, 2006:3).

Moreover, a number of firms interviewed were of the view that the quality of graduates was declining. This view of declining quality is confirmed in another recent study (Goldberg et al, 2011:70) and in the earlier study of 19 high technology firms. “By and large, the quality of the graduates is reckoned to be very good and comparable to the best internationally. However, certain firms perceive the quality of graduates as declining. Certain specific skills are in very short supply generally and in some cases this has resulted in sourcing people with the required skills (or alternatively outsourcing the work) overseas. (Breitenbach et al, 2006:9).

The skills shortage is an important factor leading firms to locate activities abroad rather than in South Africa. This is most evident in respect of mining capital equipment and specialist services and software.

But, what is probably even of greater significance than the impact of the skill shortage on existent firms is the impact that the skill shortage has had in limiting the formation of new, smaller and less well established firms. Larger and better established firms are able to partially mitigate the skills constraint. It is the larger and better capitalised firms, more especially the very large firms that can afford to offer high salaries to those with scarce skills. Moreover, these firms frequently are able to finance funding for training at tertiary institutions and establish close relations with these institutions so as to ensure that they obtain “privileged” access to the skills that are produced. None of these options are available to

smaller and newly established firms. In essence, the incidence of a shortage of skills and a consequent tight labour market falls disproportionately on the smaller, less capitalised firms and on the firms in formation.

The shortage of finance is the second most significant constraint cited by technology based firms. The financial constraint is most significant at a very early stage where the firm is seeking to develop and prove their product and is hence pre-revenue. Shortage of finance is also a key constraint when the firm, having proven their product, seeks to “ramp up” production in local and particularly in export markets. Again, these constraints are clearly most binding to newly established firms or firms that have not yet entered the market. Small, less well-established firms and especially new technology-based start-ups do not have the complementary assets to exploit any innovation. They are far more reliant on outside funding, particularly in the initial stages. They are therefore more subject to financial constraints and market failure in capital provision. Risks are significant and the cost of failure is high.

A number of other constraints have been identified – infrastructure and cumbersome regulations for example. Government supports for technology development are accessed by a limited number of firms and those that do gain access often complain about the effort required and the delays incurred. Business linkages with universities and with the science councils are limited and are seen to be declining – particularly with the science councils. But these factors tend to be of a lesser order, less pervasive and more specific to particular firms or areas of activity.

Black economic empowerment is seen by many existent small firms as a constraint – as outlined above. However, Black economic empowerment may have a much more pervasive impact than can be gauged from firm interviews. What was striking in the population of firms interviewed was the near absence of black owned entrepreneurs and firms. This is not unexpected in respect of well-established firms since historically blacks were denied access to business opportunities. But, very few of the new firms had been founded by black entrepreneurs. In particular, there was a near absence of African owned entrepreneurs. No statistical data exist, but the firms interviewed were all of the view that there were very few black entrepreneurs founding technology based new firms.

This is a complex phenomenon and there are certainly a number of explanatory factors - more limited access to personal saving and capital; less exposure to business opportunities; schooling and training that do not encourage risk taking; less familial exposure to entrepreneurship, and others. However, in addition to these factors, government policy in regard to Black economic empowerment may have the unintended consequence of discouraging Blacks from such entrepreneurial activity. Since Black graduates, particularly those with technical and engineering skills, can readily find high paying posts in well established companies, they are far less likely to engage in risk taking new ventures. Black entrepreneurs too, are likely to find far more lucrative opportunities with existent firms. The tendency to choose the less risky option is reinforced where personal savings are more limited.

While there clearly are a number of factors that constrain the emergence and further development of small new technology based firms in South Africa, these constraints are far from absolute. In a wide number of areas, such firms are in evidence and are successful. But, what is of concern is that, outside of mining equipment and specialist services, they are relatively few in numbers.

The evidence suggests that increasing the number of new technology based firms can be addressed through a combination of increasing the supply of skills, particularly in engineering and technical disciplines; ensuring better access to finance, particularly early stage pre-revenue finance and also finance to expand production and providing more incentives and opportunities for Blacks, particularly Africans, to engage in technology based entrepreneurship.

4. Conclusion

The further development of manufacturing is currently at the center of South African government policy to raise aggregate output and enhance economy-wide employment. However, in sharp contrast with the BRIC countries, growth in South African manufacturing output has been limited and manufacturing employment has been declining consistently. Of particular note, the sectoral composition of South African manufacturing has been changing with a persistent decline in the share of the labour intensive sectors. This is not compensated for by rapid growth in more technology intensive sectors. South Africa performs particularly poorly here. Smaller and new entrant technology based firms who would have lower capital intensity and could grow employment face particularly significant obstacles and are currently poorly supported by existent government policies.

Two conclusions for the broad strategic direction of government's industrial policy are evident. First, more attention needs to be paid to enhancing the employment intensity of manufacturing - in particular, the very sharp decline in the most labour intensive manufacturing sectors. Second, at the other end of the spectrum and the subject of this paper, more policy attention needs to be paid to the constraints faced by new technology based manufacturing firm entrants and to addressing the constraints that such firms face. Skill shortages and financial constraints are especially important and need to be addressed urgently if South Africa is to realise its ambitious economic targets.

REFERENCES

Bransetter (2009) Knowledge Flows and Intellectual Property. Paper prepared for the World Bank project Closing the Skills and Technology Gaps in South Africa (Mimeo)

Breitenbach, P., Kaplan, D and Wood, E. (2006) The Influence of Publicly Funded R&D on National Development. 20 Case Studies of small, medium and large South African high-technology firms recognised as SET innovation leaders to identify the value and utility of State R&D inputs on the output and impact of firm products and services in South Africa. (Unpublished report for the Human Sciences Research Council). Graduate School of Business, University of Cape Town.

Goldberg, I; Kaplan, D.; Kuriakose, S.; Tuomi, K.; and Zhang, C. (2011) Fostering Technology Absorption in Southern African Enterprises. The World Bank, Washington D.C.

Kaplan, D. (2012) South African Mining Equipment and Specialist Services: Technological Capacity, Export Performance and Policy Resources Policy. vol.37 (4) December

Kaplan, David; Goldberg, Itzhak; Kuriakose, Smita and Bransetter, Lee (2011) Inputs and Performance of Technology Innovation. Closing the Skills and Technology Gap in South Africa, Background Paper 1 (October). Human Development Group, Africa Region. The World Bank.

South African Police Service (2011) Crime Report, 2010/2011. South African Police Service.