South African mining equipment and related services: Growth, constraints and policy*

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Making the Most of Commodities Programme (MMCP)

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MAKING THE MOST OF COMMODITIES PROGRAMME

Like many other developing economy regions, Africa is benefitting from a sustained boom in commodities prices. Received wisdom has been that commodities production is an inherently enclave activity and that it undermines the viability of industry. The Making the Most of Commodities Programme challenges this negative view of the commodities sector. It's research analyses the determinants of backward and forward linkages, identifying policy responses which will broaden and deepen them. In so doing it contributes both to achieving sustainable growth and the spreading of benefits to a wider population. By incorporating younger researchers, building a research network, and dialogue with policymakers, the MMCP also seeks to build analytical and policy capacity, and to influence policy outcomes.

The MMCP focuses on a diverse range of commodity sectors in a number of African economies, as well as on key infrastructural determinants of effective linkage development. A number of common factors are identified which will increase linkages beneficially and which lend themselves to policy intervention - the role of ownership, the nature and quality of infrastructure, the national system of innovation, spillover of skills to and from the commodities sector, linkages in regional economies and the nature and consistency of policies directed towards the commodities sectors.

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Abstract*

South Africa has the largest, most diversified and longest established mining sector in Africa. South Africa has developed considerable expertise in mining and mining related supply industries and it has a number of firms located at the global technological frontier. This report provides measures of South Africa's success in export markets and of the technological capacities that underpin that success. Although South Africa currently has a significant cluster of firms in mining equipment and related services which are at the global technological frontier, its competitive position is being undermined both as a site for production and for research and development. The report analyses the factors undermining South Africa's competitive position, as well as examining the policy failures in meeting these challenges.

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Executive Summary

South Africa has the largest, most diversified and longest established mining sector in Africa. South Africa has developed considerable expertise in mining and mining related supply industries and it has a number of firms located at the global technological frontier.
This report is concerned with the development, but more especially with the current state of and future prospects for the mining equipment and related mining services industries. In this regard, the report makes ten key propositions:

1. South African mining activities have, from a very early stage, required the utilisation of advanced technologies and systems.
2. The local deployment of such technologies and systems combined with a particular structure of the South African mining industry and state directed policies, allowed for the early development of considerable development of local technological expertise. State policies and linkages with the National System of Innovation (NSI) have accordingly been critical. Market structure, rather than ownership, has also played an important role.
3. The technological content of mining and mining related activities everywhere has increased significantly over the last two decades as a result of a number of factors – including increased globalisation, market segmentation and the changing role of MNCs and the engagement of generic technologies – particularly IT.
4. This significantly enhanced technological content of mining related activities coincided with two critical changes in South Africa: the decline of mining output for some minerals, notably gold and the end of apartheid in 1994. As a result, South African mining firms have engaged in substantial expansion abroad. This, in turn, has created significant opportunities for exports of mining related equipment and services.
5. South Africa has a significant cluster of firms in mining equipment and related services which are at the global technological frontier. This is evident in respect of trade (exports), IP and leading products. Indeed, this cluster is the only significant area of industrial activity where South Africa is located at the global technological frontier.
6. South Africa's competitive position is however being undermined – both at the "lower" manufacturing end and at the "higher" end of R&D and new product development.
7. These issues are not currently being addressed. The sector receives very little state support and, other than downstream beneficiation, which is in any event ill-advised, there is no defined strategy for the sector. Polices to meet these challenges, both at the "bottom" and at the "top" are urgently required.
8. The major thrust of government's strategy currently is beneficiation i.e. government attempts to encourage activities downstream of mineral production.
9. This strategy is misplaced and should be replaced by a strategy that seeks to encourage the "lateral "migration of firms and technologies into new products and new markets.
10. Such policies should be designed and implemented in consultation and in concert with the firms and with the industry and export associations.

This study utilises patent and trade data supplemented by interviews. Interviews were undertaken with ten companies; the Chamber of Mines; the export association (x2) and the major science council engaged with this sector (Appendix 1). Interviews were focused on two issues: the linkages between technology development and exporting and the opportunities and

constraints that currently face the sector both in relation to technology development and in relation to export markets.

This report comprises six sections:
Section 1: The development of technological competencies in mining and mining related activities.
Section 2: The evidence for and the measurement of South Africa's technological competencies
Section 3: Why is South Africa competitive?
Section 4: Strengths and weaknesses
Section 5: Current policies and supports
Section 6: Developing an alternative strategy and policies in order to Make the Most of Commodities.

1. The development of technological competencies in mining and mining related activities.

There is a widespread perception that natural resource (NR) based activities, and mining in particular, by contrast with manufacturing industry, are not the sites of significant technological change. Together with the purported long term decline in the prices of commodities relative to the prices of manufactures, low levels of technological change were the foundations for the Singer – Prebisch thesis in favour of a development path based on the development of manufacturing industry. Singer argues that "...they (NR based activities) do not provide the growing points for increased technological knowledge, urban education, the dynamism and resilience that goes with urban civilisation as well as direct Marshallian external economies." (Singer, 1959: 476 quoted in Marin et al, 2009:4).

The new growth theory places technological change and technology spillovers at the center of the growth process. If indeed NR activities are characterised by very limited technological change and by limited spillovers to other sectors and activities, in terms of the new growth theory, it would follow that NR activities are not a sound basis for long term development. From this perspective, an important role of policy for commodity dependent developing countries is accordingly to ensure increasing diversification into other activities, notably manufacturing.

However, there is a growing recognition that NR activities are increasingly subject to technological change. Indeed as Porter notes, technological change is increasing in all sectors and activities.[1]

There are many factors that have lead to increasing technological change in mining and mining related activities. These factors include inter alia the growing utilisation of generic transformative technologies especially ICT; the reorganisation of the industry to allow for the growth of specialist mining services companies; the segmentation of markets; the intensification of technological challenges particularly as the industry has to meet stricter safety and environmental standards and to discover and exploit more marginal resources.

[1] "..all industries today are high-tech. all industries use information technology, new materials, and new kinds of technology to dramatically improve the way they do things. There are no low-technology industries; there are only low-technology companies that have not yet woken up to the potential of technology to transform what they do." Porter, 1990 quoted in Upstill and Hall, 2006:138.

Marin et al provide a detailed discussion of the forces that are driving innovation in NR activities. They divide these forces into four categories:

- Market requirements – product segmentation; public opinion and environment
- S&T advances – ICT and other new technology paradigms such as biotech. And nanotech.
- Market context – globalisation; outsourcing; environment and other regulations; government policy
- Market volume – the intensification of traditional challenges, including the diminishing quality of resources.[2]

The literature sees technological progress as being central to the minerals industry as a relatively recent phenomenon, coinciding with the introduction of the ICT paradigm in the organisation of the global mining corporations (Marin et al, 2006; Upstill and Hall, 2006). However, at least in the case of South Africa, sophisticated technologies and developments in basic sciences such as Chemistry were widely utilised in order to resolve critical problems in relation to local mining deposits for almost a century. Moreover, while these technological capacities were initially imported skills, they were, at least in some important instances, rapidly localised in the early development of the Witwatersrand

For example, the development of the cyanide process in the 1890s "...led to an influx of metallurgical professionals from around the world and gave birth to one of the early professional societies in Johannesburg, the Chemical and Metallurgical Society or the 'Cyanide Club' as it was popularly known." (Pogue, 2006:82)

However, while there is little doubt that NR activities in general, and mining related activities in particular, are increasingly the site of technological change, this is not a sufficient basis to assert that such activities can be an effective locus for development. There are two reasons for this.

First, it depends on the relative rather than the absolute standing of NR activities. Minerals are often regarded as low technology because the conventional indicator used to determine the technological intensity of an industry is R&D expenditure as a percentage of turnover. Utilising this measure Basic Metals and Other Metallic Mineral Products are well below those of other industries. However, much of the development expenditures in this sector are non-R&D expenditures e.g. on design, experimentation and scaling up. The R&D measure when applied to the mining industry also ignores more technology intensive activities such as exploration. Finally, technological change in the sector may be embodied in the capital goods and intermediates that are employed. The capital good and intermediate industries are characterised by far more significant R&D activities, although here too, may research activities are of the applied type rather than formal R&D. This could be captured by the ratio of acquired R&D intensity i.e. the R&D embodied in capital goods and intermediates employed to simple R&D intensity. "The Basic Metals and Other Metallic Products sectors rank highest of all industry sectors by this measure…" (Upstill and Hall, 2006:138).

Second, even if NR activities are increasingly subject to technological change, the effect that this will have on overall development is dependent on the impacts of that technological change on other sectors and activities – i.e. what are the technology spillover effects? Here again, it is important to draw a distinction between different activities engaged in mineral and

[2] Marin et al, 2009: 9.

mineral related sectors. In particular the input supplier industries, providing intermediates and capital goods and support services, employ sophisticated technologies and provide products to the mining industry which have potential in other markets and for other sectors.
This report proposes that policy be directed at supporting the movement of companies that supply the mining sector and that have sophisticated technological competencies to spread those competencies "laterally" so as to engage in new activities and new markets.

The development of technological competencies in the field of mining and related activities can potentially impact on growth through three main channels:

- Extend the life and returns on mining investment as new knowledge is applied
- Develop new areas of mining equipment and specialist services which can be realized on global markets
- Enhance knowledge and competencies in other areas through technology spillovers and migration from mining and mining related areas.

Briefly, dealing with each of these issues in turn in relation to South Africa:

- Extending the life and returns to mining: In essence, as in the US mining sector, many South African mineral deposits were not especially rich. It was only the application of technological knowledge that allowed for the deposits to be profitably exploited and the life of the deposits to be extended such that large scale investment was justified.

- Transition to the supply of equipment and specialist services: The much acclaimed Scandinavian model whereby competencies in raw material extraction are increasingly shifted to the development of competencies in the supplier industries – capital equipment and specialist services - is evident in South Africa. As mining has declined, there has been an increase in mining equipment and specialist services such as consulting and exploration supplied to global markets albeit with a heavy concentration on regional markets. This shift would appear to have occurred without government support. However, this would be misleading. Finally, there are clear indications that the development of capacities in mining equipment and specialist services is currently being restrained by a number of factors. These issues are discussed further in section four.

- The Migration of skills/competencies to other areas: technical knowledge developed in mining tends to be mining specific. Mining, unlike some other areas such as electronics or chemicals, is, in general, not an area that produces knowledge and innovation that are widely utilized elsewhere. From interviews, we could find only a few examples of significant technological migration from mining and mining related areas to other areas. There are indications that whatever potential there is for migration, this is particularly limited in the case of South Africa.

The most important impact of the development of competencies in the field of mining and related activities has been the development of a globally competitive industry supplying mining equipment and specialist services, not only to the mining industry but also more broadly, thus providing the potential to enhance development.

2: The Evidence for and the measurement of South Africa's advanced technological competencies

South Africa's advanced position in mining equipment is evident in two respects:
The first is in Intellectual Property (IP), most notably patents. South Africa has a significant concentration in mining and mining related areas. Moreover, these patents are of high value. Even subsidiaries of mining TNCs undertake considerable development work in South Africa, feeding this back into their operations and R&D centers.

The second is in global trade, notably exports. South Africa's exports of mining equipment are large and have been increasing rapidly. Mining equipment dominates the export of capital equipment from South Africa. Moreover, mining equipment exports have a high local value added – high compared to other exports such as autos for example. The South African Capital Equipment Export Council estimates local content for mining equipment at approximately 90% (Interview). High local content of exports is a further indication of significant local competencies in this area.

Data is provided on patents and on export performance below.

2.1 Patents

Patents are a major measure of output of inventive activity. Both the number of patents and the quality of patents can be measured. Where a country has a significant clustering of high quality patents, this is a clear indication of innovative capacities and activities that are located at or close to the global technological frontier. Mining technology in South Africa is compared to technology in a number of areas utilizing patent counts and patent values.

2.1.2 Methodology[3]

An examination of South African patents at the USPTO revealed the existence of two significant technological clusters broadly labelled "Mining Technologies" and "Fuel Technologies." Each cluster represented a much larger share of total patenting in South Africa (app. 4.5%), than in other countries (less than 2%) - USA, Australia, Canada, etc.
These two clusters seem to contain groups of relatively highly cited South African patents. Patents belonging to these two technological clusters were thus identified using 3-digit USPC classes and the quality of these patents were then compared to that of similar patents in some other countries - US, Australia, and Canada.
The following were compared:

- average number of citations received
- average number of truncation-corrected citations received
- average number of citations received for top quartile of patents in a cluster
- average number of truncation-corrected citations received for top quartile of patents in a cluster
- all the above measures for "other" patents (those not belonging to either of the two clusters) - to have a benchmark
- average age of patents - as a rough check of the validity of the above comparisons a

[3] All patent data were undertaken by Lee Bransteter of Carnegie Mellon University for a World Bank Study entitled Closing the Skills and Technology Gaps In South Africa

The truncation-correction refers to the fact that it takes time for citations to arrive. Older patents will naturally have more citations than younger ones. A truncation-correction allows for a more "fair" comparison between samples of patents with different age distributions, facilitating a comparison of differences in average citations received.

Each patent in each of the two clusters was matched randomly to a patent in the US, Australia, and Canada that was applied for in the same patent class at the same time. The samples were then tested to assess whether the mean citations received for the entire sample and mean citations received for the top quartile of the sample are equal across countries.

2.1.3 Mining Technologies

The descriptive statistics comparison shows that South African mining patents are much more cited than other South African patents. While the overall quality (as measured by the number of citations received) of South African patents is somewhat lower than that of US patents (a part of which might be due to the home-country bias), and slightly lower than that of Australia and Canada, the citedness of the cluster of mining technology patents is on par with that of the same cluster of US patents, and markedly higher than that of the same cluster of either Canadian or Australian patents.

Table 1: Quality Comparison – Mining Technologies, Individual Patent Based (USPTO Data)

Counts

	All Patents	Mining Technologies Patents	Share (%)
South Africa	2,969	128	4.3%
United States	1,587,915	7,882	0.5%
Australia	16,283	311	1.9%
Canada	65,580	853	1.3%
AVERAGE	**1,672,747**	**9,174**	**0.5%**

Citations Received (Not Truncation Corrected)

All Population

	All Patents	Mining Technologies Patents	Other Patents
South Africa	5.52	7.06	5.44
United States	8.52	6.99	8.53
Australia	5.39	4.15	5.41
Canada	6.69	4.70	6.72
AVERAGE	**6.53**	**5.73**	**6.53**

(Top Quartile of the Population)

	All Patents	Mining Technologies Patents	Other Patents
South Africa	16.21	22.23	16.06
United States	24.28	18.45	24.29
Australia	16.49	11.49	16.56
Canada	18.97	12.35	19.00
AVERAGE	**18.99**	**16.13**	**18.98**

Citations Received (Truncation Corrected)

All Population

	All Patents	Mining Technologies Patents	Other Patents
South Africa	7.95	9.01	7.90
United States	14.13	9.97	14.16
Australia	9.41	6.16	9.47
Canada	11.43	6.91	11.49
AVERAGE	**10.73**	**8.01**	**10.76**

(Top Quartile of the Population)

	All Patents	Mining Technologies Patents	Other Patents
South Africa	26.90	30.97	26.75
United States	49.64	32.41	49.68
Australia	36.52	21.13	36.68
Canada	42.09	24.18	42.16
AVERAGE	**38.79**	**27.17**	**38.82**

Average Age

	All Patents	Mining Technologies Patents	Other Patents
South Africa	1991.61	1990.79	1991.65
United States	1993.29	1990.59	1993.31
Australia	1994.20	1991.93	1994.23
Canada	1993.97	1992.07	1993.99
AVERAGE	**1993.27**	**1991.35**	**1993.30**

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

2.1.4 Fuel Technologies

There is a second cluster of South African patents – in fuel technologies. But, by contrast with mining and mining related patents, South African fuel technology patents are less cited than patents in either of the three comparison countries.

Table 2: Quality Comparison – Fuel Technologies, 3-Digit USPC Class Based (USPTO Data)

Counts

	All Patents	Fuels Technologies Patents	Share (%)
South Africa	2,969	132	4.4%
United States	1,587,915	20,521	1.3%
Australia	16,283	314	1.9%
Canada	65,580	1,260	1.9%
AVERAGE	**1,672,747**	**22,227**	**1.3%**

Citations Received (Not Truncation Corrected)

All Population

	All Patents	Fuels Technologies Patents	Other Patents
South Africa	5.52	5.18	5.53
United States	8.52	7.89	8.53
Australia	5.39	6.66	5.36
Canada	6.69	6.81	6.69
AVERAGE	**6.53**	**6.64**	**6.53**

(Top Quartile of the Population)

	All Patents	Fuels Technologies Patents	Other Patents
South Africa	16.21	13.60	16.37
United States	24.29	21.01	24.35
Australia	16.49	16.63	16.55
Canada	18.97	18.15	19.02
AVERAGE	**18.99**	**17.35**	**19.07**

Citations Received (Truncation Corrected)

All Population

	All Patents	Fuels Technologies Patents	Other Patents
South Africa	7.95	7.04	7.99
United States	14.14	11.16	14.18
Australia	9.41	10.65	9.39
Canada	11.43	10.64	11.45
AVERAGE	**10.73**	**9.87**	**10.75**

(Top Quartile of the Population)

	All Patents	Fuels Technologies Patents	Other Patents
South Africa	26.91	20.66	27.31
United States	49.64	32.79	49.84
Australia	36.52	33.74	36.92
Canada	42.09	34.69	42.25
AVERAGE	**38.79**	**30.47**	**39.08**

Average Age

	All Patents	Mining Technologies Patents	Other Patents
South Africa	1991.61	1991.63	1991.61
United States	1993.29	1991.32	1993.32
Australia	1994.20	1993.01	1994.21
Canada	1993.97	1992.49	1993.99
AVERAGE	**1993.27**	**1992.11**	**1993.28**

A 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

This admittedly somewhat rough comparison seems to indicate that there indeed exists a South African cluster of excellence in mining technologies, but not in fuel technologies (where coal liquefaction and similar patents dominate the cluster). Moreover, mining and mining related patents are the only significant South African cluster of high value patents.

2.1.5 Further testing – matching patents

Utilising a matching methodology to match each South African patent to a similar American, Canadian, or Australian patent - matching by application year and 3-digit USPC class – gives somewhat weaker results. These hypothesis tests show that the average number of citations for a mining technology South African patent is greater than that of an identical Australian patent, but it is not greater than that of a similar Canadian or US patents.

Table 3: Quality Comparison, Hypothesis Tests – Mining Technologies, 3-Digit USPC Class Based (USPTO Data)

All Population

Ho: Citations Received are Equal	Ho: Not Equal	P-Value	Ho: Greater in South Africa	P-Value	Ho: Fewer in South Africa	P-Value
United States	REJECT Ho	0.000	CANNOT REJECT Ho	1.000	REJECT Ho	0.000
Australia	REJECT Ho	0.014	REJECT Ho	0.021	CANNOT REJECT Ho	0.993
Canada	REJECT Ho	0.005	CANNOT REJECT Ho	0.997	REJECT Ho	0.003

(Top Quartile of the Population)

Ho: Citations Received are Equal	Ho: Not Equal	P-Value	Ho: Greater in South Africa	P-Value	Ho: Fewer in South Africa	P-Value
United States	REJECT Ho	0.000	CANNOT REJECT Ho	1.000	REJECT Ho	0.000
Australia	CANNOT REJECT Ho	0.597	CANNOT REJECT Ho	0.299	CANNOT REJECT Ho	0.701
Canada	REJECT Ho	0.004	CANNOT REJECT Ho	0.998	REJECT Ho	0.002

Table 4: Hypothesis Tests, Hypothesis Tests - Fuel Technologies, 3-Digit USPC Class Based (USPTO Data)

All Population

Ho: Citations Received are Equal	Ho: Not Equal	P-Value	Ho: Greater in South Africa	P-Value	Ho: Fewer in South Africa	P-Value
United States	REJECT Ho	0.000	CANNOT REJECT Ho	1.000	REJECT Ho	0.000
Australia	REJECT Ho	0.000	CANNOT REJECT Ho	1.000	REJECT Ho	0.000
Canada	REJECT Ho	0.000	CANNOT REJECT Ho	1.000	REJECT Ho	0.000

(Top Quartile of the Population)

Ho: Citations Received are Equal	Ho: Not Equal	P-Value	Ho: Greater in South Africa	P-Value	Ho: Fewer in South Africa	P-Value
United States	REJECT Ho	0.000	CANNOT REJECT Ho	1.000	REJECT Ho	0.000
Australia	REJECT Ho	0.000	CANNOT REJECT Ho	1.000	REJECT Ho	0.000
Canada	REJECT Ho	0.000	CANNOT REJECT Ho	1.000	REJECT Ho	0.000

Now, it is conceivable that SASOL's patents, while very limited compared to the patent portfolios of the global petrochemical giants it competes with, are of extremely high quality. Unfortunately, our patent analysis does not support this view. In fact, comparisons of forward citations to similar patents suggests the opposite – that in the particular areas SASOL has focused on, its patents are of systematically lower quality than that of its competitors.

For every comparison group, the foreign patents are more highly cited than SASOL patents. In four of the five comparisons (dependent on the level of classification of patent class), the differences – always large – are statistically significant at conventional levels, despite the small number of patents.

The final segment of our quest for additional clusters of inventive excellence in South Africa focused on Biotechnology. U.S. biotechnology patents are located in one of two US 3-digit

patent classes, 435 or 800. We therefore examined patents awarded to inventors based in South Africa in these patent classes and compared them to patents awarded to inventors elsewhere. The first observation comes from comparing the scale of biotech patenting in South Africa versus more advanced countries. We identified a cumulative total of 69 South African biotechnology patents granted to date. Over the same period, the USPTO granted 61,825 American biotech patents, 3,130 Canadian patents, and 1,142 Australian biotech patents. The number of South African patents made statistical tests of quality feasible, but the numbers are so small that they weaken the statistical results.

Nevertheless, the statistical results suggest that South African biotech patents do not appear to be internationally distinctive in terms of their quality.

2.1.6 Conclusion

Mining and related activities is the only cluster where South Africa has a significant number of patents and where the patents have a high value. Despite all the state support over many years for SASOL, patent numbers are very limited and the quality is low. In biotechnology, which is a further area that government has singled out for particular attention and support, the position is even weaker.

2.2 Trade

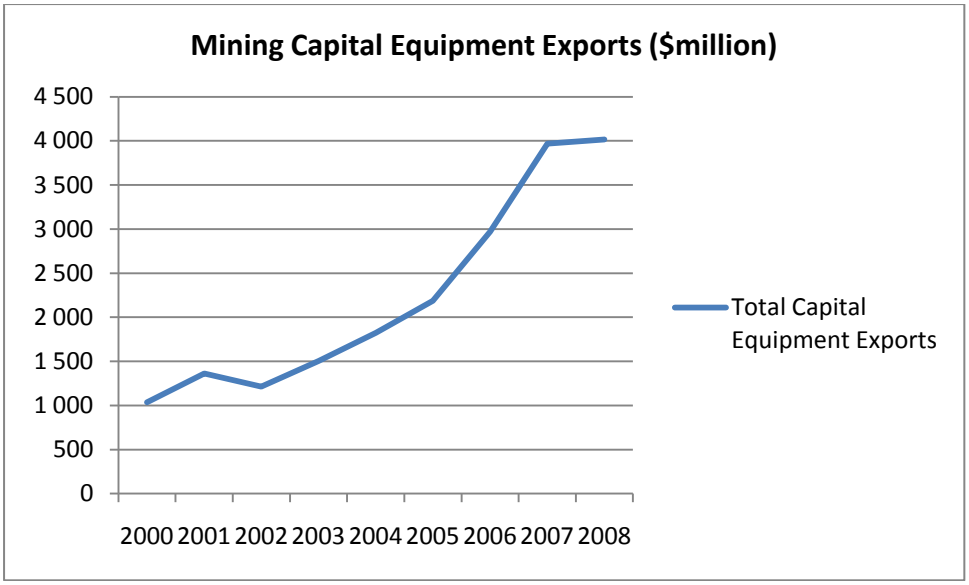
The level and particularly the growth of exports of mining equipment and specialist services is one clear manifestation of global competitiveness. This is particularly so in the light of the fact that there is very little state support of any significance.

Exports can be divided into two broad categories. The first category is exports related to new projects – new mines or mineral processing activities. The second category is the after-market – to existing mines or mineral processing activities. The latter is much more critical, but the competitive edge to supply to the after-market is often secured through firms being engaged in projects from the outset.

The determination of specifically mining exports is a complex issue. Since trade data is categorized by product rather than by customer, it is very difficult to determine precisely what is destined for mining as opposed to other markets.[4] The South African Capital Equipment Council (SACEC) has assessed, at least in the case of South Africa, at an eight-digit HS level, which capital equipment products would be destined for the mining sector. SACEC categorization has been used in the data below.

Currently exports of mining capital equipment are running at approximately $(US) 4billion. Exports have been growing rapidly – in nominal terms quadrupling since 2000.[5] This growth is certainly aided by the commodities boom.[6]

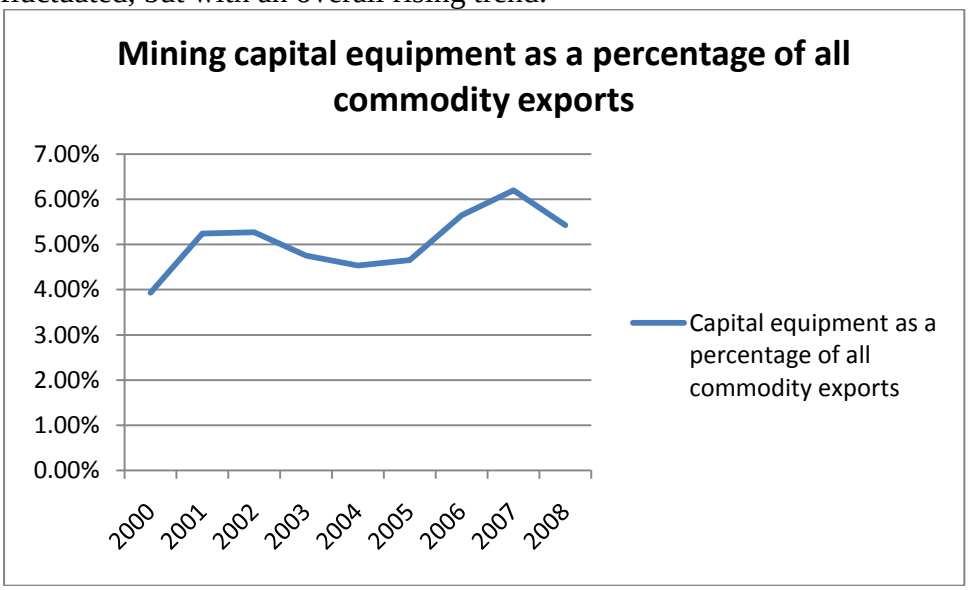
[4] Despite a considerable trawl of the literature, no clear definition of mining capital equipment as opposed to capital equipment in general could be found.
[5] Prior to 2000, there were a number of changes in the definition of products which make it difficult to construct a clear time series.
[6] Note that this excludes mining based services. The export of mining-based services is extensive and growing very rapidly. Many specialist companies exist in this area. No data is however yet available.



Most companies interviewed have been increasing the share of their product that is exported and some have seen phenomenal increases in export – both as a share and as a percentage of turnover. One company exported R80m. in 2000 and current exports are over R1billion – raising the export share from 15% to 45% of turnover.

Mining equipment dominates the export of capital equipment.

As a share of total South African commodity exports, mining capital equipment has fluctuated, but with an overall rising trend.



A significant amount of exports result from the global expansion of South African mining houses which then utilize the equipment or services of the South African suppliers with whom they have a pre-existing and often long time relationship. The extent to which South African exports follow South African investments globally is an issue that needs further investigation.

African countries – notably in the Southern Africa region – are the major markets for South African exports of capital goods. Eight of the top ten destination countries are Africa and all except Nigeria are located in the region.

Mining equipment is one of South Africa's largest exports; 8.5% of total exports in 2005-2009 and 55% of total capital equipment exports. Unfortunately, the services export data do not allow for mining services to be isolated. But, net export earnings are likely to be substantial and significantly positive.

For all capital equipment, South African imports exceed exports by a large margin – in 2008 and 2009, imports were three times larger than exports. In respect of mining equipment, however South Africa is a net exporter. In mining equipment, South Africa is running a negative trade balance with the rest of the world, but South Africa has a strong positive trade balance with Sub-Saharan Africa (SSA).

South Africa Mining Equipment Exports and Imports ($'000), 2005 -2009

	2005	2006	2007	2008	2009
Trade with world					
Exports	3,292,256	4,721,750	6,200,709	6,742,700	4,130,184
Imports	3,173,526	4,285,689	5,987,691	6,174,743	3,668,875
Trade Balance	118,730	436,061	213,081	567,957	461.309
Trade with SSA					
Exports	786,793	1,025,801	1,494, 146	1,935, 971	1.542,666
Imports	10,972	13,423	15,317	24,485	32,232
Share of Total Exports	24%	22%	24%	29%	37%

Source: COMTRADE database accessed through WITS on 22/02/2011

Moreover, the dense network of mining production and services companies results in a high local value added for this sector – estimated at approximately 90% (South African Capital Equipment Council Interview).

Interviews with mining equipment companies showed a clear link between exporting and technology development. In all cases, exporting relied heavily on the development of technology. In most cases this entailed significant technological development – sometimes embodied in patents, but frequently safeguarded in more informal ways. Technology development tends to be very largely focused on improving and enhancing application. On the product side, new products tend to be improvements and adaptations to meet the demands of new situations – spiral washers for use in oil sands in Canada as opposed to coal deposits in South Africa would be illustrative.

Technological development clearly underpins and is a necessary component of success in export markets. At the same time, competition in export markets is intense in this area – and consequently fuels further technological development.

2.3 Further Indications of South Africa's advanced technological competencies

At the product level: South Africa is a world leader in a host of mining equipment products. These include spirals for washing coal; pumping up water; hydropower; tracked mining;

underground locomotives; ventilation; shaft sinking; turnkey new mine design and operation and many others. The particular "area" where South African expertise is particularly advanced and at the global frontier is in deep level mining and associated competencies. South Africa is much weaker in so-called "yellow metal "areas – such as mining vehicles – where scale economies are critical and where large TNCs dominate.

Outside of mining, there are a number of other areas where South Africa has leading global products – transport and haulage equipment and processing equipment for example. In many cases, the mining sector provided the initial source of demand and successful domestic firms then branched out into other areas.

At the company level: a significant number of South African firms compete effectively with global TNCs, in South Africa, in Africa and other regions. A number of these companies are large, but there are also significant numbers of medium and small sized companies. It is worth noting that the industry receives, at this time, very little support from government (a point to which we return later).

3. Why is South Africa Competitive?

The answer may seem obvious – it is the result of having a mining industry that is very large and long established. Indeed, this is an important part of the answer. However, this is only a part of the answer. There are other aspects of South African mining industry besides scale and long history that are important and there are other factors at play that have encouraged the development of local capabilities and capacities.

Mining is highly location specific. No two mines are the same – geology and other conditions vary hugely. The result is that what can be called "applied competencies" have to be developed with reference to particular deposits and generally "on site." Where local conditions are particularly specific and demanding, the necessary applied competencies will be correspondingly expanded. In South Africa, local conditions were highly specific and demanding. This is most evident in respect of gold mining which had to be mined in hard rock at deeper levels than anywhere else.

Other major South African minerals occurred in a form that was difficult to exploit. Coal in South Africa is very abundant, but almost all of it is of low quality. Platinum was prevalent but found in a form that could not be exploited by known methods. South Africa was able to develop coal and platinum metallurgy that allowed for what were hitherto unprofitable deposits to be profitably mined. There were many spin-off capacities. South African coal had to be washed to remove impurities. This led to extensive development in spirals for washing – a product which is now applied in a number of new areas such as tar sands and in which South Africa leads the world. "We made it work because we had difficult coals.[7]"
A number of factors seem to have been key in allowing the development of local technological capacities attendant to mining.

The first of these is simply scale. The scale and the duration of mining activity provided the possibility of amortising any investment in enhancing technological capacities over a larger output and over a longer time period.

[7] MD of the leading export company

The second is the structure of the mining industry. It was the larger mining houses that had the wherewithal and the incentive to undertake and support research. One of the key functions of the Chamber of Mines was to undertake research and the Chamber's research organisation COMRO supported and funded considerable research activity. While research efforts were cooperative, historically one large mining finance group contributed the majority of resources to cooperative research efforts (Pogue, 2006:7).

The third is economies of scope. The existence of a wide diversity of minerals and mines allowed for specialist companies to arise that could more effectively and economically ad apt and develop products and solutions for individual customers. Economies of scope are important in encouraging the development of specialist suppliers.

A final factor is the development of structures, organisations and policies that sought to develop national innovation capabilities. In various ways, and for complex reasons, the South African government has sought to enhance technological capacities. This process of encouraging the development of technological capabilities begun very early on, indeed prior to Union. The national system of innovation interacted closely with the mining industry.

"With the formation of the Union of South Africa in 1910, a South African national system of innovation came into existence. It drew upon the various colonial and national innovation systems that preceded it. During this period the private sector, primarily the Witwatersrand gold mining industry, provided significant guidance over and direction within the national system of innovation (Pogue, 2006:7).

Thus, explicit policies to develop and advance technological capabilities played their part. However, government was not ubiquitous in the development of local technological capabilities. The cyanide-based extraction technology, for example, was developed in the Zuid Afrikanse Republic. "Yet the ZAR provided no technical or educational support for the mines, Despite its terrific economic impact, the ZAR treated Witwatersrand gold mining as am enclave that needed accommodation rather than as an emerging sector of its national economy. The Witwatersrand community nevertheless established a local innovative system, reliant on linkages with the Cape Colony and the international mining community (Pogue, 2006:7).

An important factor enhancing the development of the industry has been the development of a geographic cluster and attendant supporting institutions. Singer's concern that Marshallian external economies would not prevail in NR based activities, clearly does not apply to the supplier industries of mining equipment.[8]

While the industry is geographically fairly widely distributed much of the mining equipment industry is located on the East Rand, principally in Ekurhuleni, and largely in Farrramere. Utilising a database of 678 companies, the South African mining inputs cluster has the following characteristics: [9]

- Ownership – 33% of firms are foreign; 67% local. Foreign firms are specialist consultants or OEMs.

[8] "..the geographical clustering of input companies in Gauteng has brought with it over time a number of key benefits, most notably increased firm productivity, sectoral growth (particularly in the engineering, metal products , electrical and non-electrical machinery sectors), and improved product competitiveness, both in the local and international market." (Walker and Minnitt, 2006:14)

[9] The data are from Walker and Minnitt, 2006: 13- 17.

- Employment – 95.000. Average number of employees per firm 239.
- 17 large firms account for almost 60% of employment. The majority of firms are either subsidiaries or private companies. Only 7 firms are listed on the JSE.
- Imported items are generally medium to high tech component type goods

The local FET college provides training in skills that are needed by the industry. The South African Capital Equipment Export Council SACEEC) supports exporting and promotes the industry generally.

The South African Capital Equipment Export Council provides a platform for capital equipment exporters, providing information and services to promote exports. SACEEC facilitates the sharing of export related facilities and manpower, researches new markets and disseminates export leads, and encourages the development of export consortia and the sharing of facilities in global markets. SACEEC also works with Government on an ongoing basis to ensure that generic policies and priorities are aligned with the sector development strategy.

There are a total of 112 members who each pay a nominal fee to join the council and an annual fee to remain members. This constitutes a significant share by number of exporting firms and the overwhelming share of exports by value. SMMEs make up 65% of the membership. 95% of members are BEE compliant. All of the ten firms interviewed were active members of the SACEEC.

4. Strengths and Weaknesses

The short-medium term prospects for mining equipment and specialist services look promising. Much depends, of course, on future investments in mining, but indications are positive. Mining investment is particularly likely to grow in Africa – home to a large share of global exploitable deposits. Given the importance of the regional market, and the strong presence of South African based mining companies in the region, this will be particularly beneficial to South African exporters.

However, company interviews suggest a less sanguine future. Three major problems were identified in company interviews - skill shortages and inadequate training; deteriorating public research and linkages with tertiary institutions and access to finance.

Skill Shortages

There has been a decline in the skills and competencies available for the mining sector in part due to the migration of skilled workers abroad. For a skill intensive sector, firms in the capital goods sector identified the shortage of skills as a major constraint. Skill shortages exist at the managerial, artisanal and technical levels such as welders and boilermakers. While wages for artisanal and technical workers are lower than in Europe, they are considerably higher than in other industrializing countries. The wage gap is particularly large with respect to countries in Asia like China which are increasingly developing capacity in the capital goods sector.

The number and it would seem the quality of mining engineers and related skills has been in decline. The Chamber of mines described training at the universities as “pitiful.” The University of the Witwatersrand – once recognized as a premier institution for producing mining and related high- level skills - and the University of Pretoria has seen significant

declines in their capacities in this regard and is said to have one permanent member engaged. By contrast Australia has seven universities offering mining engineering and programmes.
Since at least the early 1990s, mining Houses, the parastatals such as the railways and harbours and the science councils have all significantly reduced their training. This has resulted in a substantially reduced the supply of skilled technicians and artisans.

This skills shortage is being exacerbated by aggressive recruiting on the part of competitor firms, especially in Australia, who have been very successful at recruiting skilled South Africans. By contrast, South African firms complain that they have major problems in securing the necessary work permits for expatriate labor. This affects both locally owned and particularly foreign owned firms operating in South Africa.

The ES data provide further evidence of the constraints in the supply of skills that is faced by capital equipment producers and exporters. The 2003 ES data had 84 capital goods firms and the 2007 ES had data for 145 capital goods firms. Exporters and non exporters as well as foreign owned and domestic firms in the sector in the 2003 survey cited skills shortage as the top constraint. The 2007 ES data had firms citing crime as the top constraint followed by skills shortages.

In a recent survey, 50% of the 45 firms supplying goods and services to the platinum group mining (PMG) sector reportedly surveyed regarded the shortage of engineering and technical skills in South Africa as "…the main obstacle to future growth and dynamism in the PGM industry and 90% feel it is an important determinant for firm-level competitiveness."[10]

On the supply side, worker training is poorly provisioned. The SETAs are regarded by firms as ineffective and the system as inflexible. Exporters of mining equipment were of the view that the number and quality of mining engineers and related skills is on the decline. The Universities of the Witwatersrand Pretoria that were once recognized as a premier institution for producing mining and related high-level skills have both seen significant declines in their capacities in this regard. By contrast Australia has seven universities offering mining engineering programs.

Firms have responded to the shortage of skills by recruiting skilled personnel from abroad. Some foreign owned firms had to bring in more staff from their operations abroad than they would have had the skills been available locally. However obtaining work permits have been cumbersome and the main response has been for firms to train locally. Training is fairly widespread in the industry, particularly on the part of foreign owned firms. Data from the 2003 Enterprise Survey showed that 76 percent of foreign firms in the sector offered training, for an average of 42 days for a skilled and 50 days for an unskilled worker. However, there are some indications that the number of firms offering training has declined. In the 2007 survey, only 59 percent of foreign firms and 44 percent of domestic firms offered training
The skills shortage is leading to companies moving some of their operations overseas. These firms are finding it advantageous to shift their more labor intensive operations outside of South Africa– notably to China. For example, one of the largest South African operations now fabricates 20 percent of needed capital equipment in China whereas previously equipment was produced exclusively in South Africa. A number of firms, particularly the larger operations that can manage extensive outsourcing operations, predict that sourcing product from outside of South Africa will increase rapidly. Of particular concern here are the

[10] Lyndall, 2009:117

wage rates of technicians and artisans. They are far more highly paid in South Africa and moreover in very short supply.

But it is not only manufacturing operations that are likely to be relocated outside of South Africa, the same trend is evident with respect to design and development work. One of the largest South African operations undertaking extensive design and development has decided to develop a new center abroad and predicts that in several areas it will have its main design centre in Australia. Some of the major mining companies are similarly locating their research and development activities abroad. The country favoured is almost invariably Australia; with the main attraction being the availability of highly skilled labour and the linkages to well-funded research centres.

There is now a perceived decline in the local competencies available due to large number of skilled professionals moving abroad (especially to Australia) from the sector and a decline in the research competencies in the local universities, which could imply South Africa's capital goods sector possibly losing its global competitiveness to countries like Australia that continue to increase their competencies in the sector.

Declining Industry- Research Linkages

Apart from accessing the CSIR for testing and verification, there is limited industry engagement with the science councils. Moreover, the few linkages that do exist are said to be becoming more limited over time. This is true particularly in relation to mining, but also with regard to metallurgy and metal refining.

There is a widespread view that while both the CSIR and MINTEK have some capacity, there has been a clear deterioration over time. Skilled personnel have been lost and a number of programs closed, particularly at the CSIR. The latter is said to have hardly any research capacity remaining in relation to mining. There has been major decline in mining related activity here. Formerly COMRO – the research arm of the Chamber of Mines – undertook very significant research on behalf of the industry. The CSIR which absorbed COMRO continued to have large scale mining research projects – principally in trackless mining and rock engineering. However, these research programmes had a limited life and currently the capacity at the CSIR has been depleted almost to distinction. It is widely stated in the industry that MINTEK has seen a significant decline in its capacities. The Council for Geoscience is similarly said to be experiencing difficulty and loosing staff.

Few of the firms interviewed had significant links with the science councils – and where they did, these links were becoming more limited over time

In terms of university based research, activity is also depleted. While there is certainly some capacity and some of that is widely recognized as world class, the number of specialist centers is very limited. This is particularly true in respect of mining. There is no specialist mining research units at any of the universities in South Africa although attempts are now being made to establish a center for mining mechanization at the University of the Witwatersrand. There are very few specialist research centers.

The deterioration in publicly funded research for mining, metallurgy and related activities in South Africa has resulted in firms making much more use of privately funded research. There appears to have been a significant growth in local research consultancies that serve the

industry that undertake research or provide specialist consultancy services. Very few of the firms interviewed engaged with the universities – and those that did, did so in very limited ways. Local firms are increasingly accessing publicly funded research institutions and universities located abroad, particularly in Australia.

Access to Finance

A number of the firms interviewed complained that export finance was limited, which sometimes inhibits their incentives to increase technology related investments as well as their access to the global knowledge pool. The export council in particular stressed this issue and indeed export finance, particularly pre-shipment finance, is one of their central requests to the government. The SACEEC which works with the government on an ongoing basis to ensure that generic policies and priorities are aligned with the sector development strategy also regards this lack of export finance as particularly injurious to new exporters who are unable to accept large export contracts due to the lack of adequate finance. Finance is often not available and where it is, it is said to be very costly.

New entrants are also constrained by the lack of venture capital available to finance technology-based start-ups. Potential new entrants cannot find the finance that they require to commercialize research or seed funds required to launch new products. Very few firms have been able to get preferential finance from the IDC.

Firms have utilized the export council to lobby hard for government support for lower cost finance. The IPAP makes provision for concessionary finance for productive activities and particularly for local firms that are bidding for government contracts in relation to the infrastructure program. However, this excludes any support to exporters.

Mining investment in South Africa has been limited. For a variety of reasons, related principally to policy over mineral rights, also infrastructural bottlenecks and lack of local finance for new mines on behalf of smaller companies, investment in the mining industry actually fell during the commodities boom. This then revived somewhat but remains limited. The output of gold has been declining steadily and this is likely to continue. The "demanding clients" that have underpinned the growth of local capacities in mining equipment, the large scale mining investments, remain but are much less in evidence.

On the manufacturing side, a number of companies have begun moving significant parts of production elsewhere – notably to China. Companies are finding it advantageous to shift their more labour intensive operations outside of South Africa. One of the largest South African operations now fabricates 20% of the K equipment for their in China. A number of firms – more particularly the larger operations that can manage extensive outsourcing operations – predict that this will increase rapidly. Of particular concern here are the wage rates of technicians and artisans – who are far more highly paid in South Africa and moreover in very short supply.

But, it is not only manufacturing operations that are likely to be relocated outside of South Africa, the same trend is evident in respect of design and development work. One of the largest South African operations undertaking extensive design and development has decided to develop a new center in abroad and predicts that in several areas it will have its main design center in Australia. Even companies that are enjoying considerable growth and export success underpinned by technological advance have begun to relocate their research and

design functions abroad. Some of the major mining companies too are locating their research and development activities abroad. The country favoured is almost invariably Australia.

> The contrast with Australia is evident. Without going into any detail, it is quite evident that in all of these dimensions, Australia is significantly out-performing South Africa. [1112]South Africa lacks the institutional and policy supports that will be necessary to ensure future growth. Australia by contrast has these supports. Australia is increasingly becoming the location of choice for research and development on the part of South African firms and indeed of South Africans themselves. The number of South Africans to be found in Australian mining companies and research establishments is remarkable.
> This was not always so. As one interviewee put it – "In the 1980s all the clever stuff was in South Africa. This was the magnet. We attracted people from all over the world. Now the magnet is in Australia and we are losing our people, our talent and even our companies to them."
>
> The current success of the South African mining equipment and related activities and services rests in an earlier period of expansion of the mining industry and of elaborate public support for research and training. It is the companies and the people who were so nurtured and supported who are now exporting globally and undertaking technological advance at the global frontier. However, there are clear signs that this will not be sustained in the future. Skill shortages, declining investment on the part of local clients and a lack of institutional and policy support collectively pose a significant threat, temper current success and are likely to severely curtail future prospects.

5. Current Policies and supports

The South African government has selected a number of technologies for support. These are outlined in the Department of Science and Technology's 10 year plan (DST, 2008). These technologies include space science, energy, climate change, biotechnology and human and social dynamics. Biotechnology, for example, has received over R0.5billion in direct support. Mining, by sharp contrast, receives no mention in the 10 Year Plan. The general supports that are available to innovation in any industrial sector have a very limited impact on research in the mining and mining related companies. For example, none of the companies interviewed made extensive use of SPII. Some companies do claim the R&D tax credit, but the applied nature of the research and design results in many of the expenditures related to technology development undertaken by firms not qualifying for support.

Beneficiation

The main thrust of government policy with respect to mineral products is downstream beneficiation. Beneficiation features strongly in the National Industrial Policy Framework and in the Industrial Policy Action Plan (IPAP). The IPAP envisages minimum beneficiation levels for ten "selected commodities." These commodities are not specified, but presumably entail all of the major mineral products. Thus, the IPAP Key Action Programme (KAP) 12.5.1. specifies "Setting minimum beneficiation levels for key commodity chains. Nature of the intervention: The Department of Mineral Resources (DMR) to establish and define

[11] Australia has extensive networking and collaboration between companies and with publicly funded research. This has been described as a "dynamic web." Dodgson and Vandermark, 2000. Se also Upstill and Hall, 2006.

minimum levels of beneficiation for each of the 10 selected commodities. This will lay the foundations to create specific value chains, including in 5 instances up to the fourth level of minerals value addition. " DTI, 2010; 59.

There is widespread support for beneficiation policies. The rationale for such policies appears to be evident.

"Our natural comparative advantage in the underlying resource-based industries along with additional factor endowments (especially relatively inexpensive electricity costs) provides us with an opportunity to be competitive in downstream value addition. The end-game is to acquire a competitive position as far down the value chain towards finished product production as is possible.

The rationale underlying beneficiation relies heavily on access to feedstock at competitive prices. Proximity to stocks of minerals implies an association with downstream processing as a natural accompaniment to the primary mining activity." (Jourdan (n.d.): 7-8.

However, the International Panel on ASGISA has a very different stance. The panel argued that "..both theory and practice provide reasons to question the presumption that downstream processing is an appropriate development path. The skills and other inputs required to process raw material and market finished products could be very different from those required to mine or grow them….Moreover…as transportation costs have declined, and global markets have become more integrated, the advantage of proximity to raw material production has diminished." (Hausmann, Klinger and Lawrence, 2008a:1)

Utilising a large international data set, the evidence is clear that countries that produce commodities do not move downstream in their development Forward linkages have only a very limited impact as to where a country will emerge as competitive (Hausmann, Klinger and Lawrence, 2008:)

Accordingly, in their final report, the International Panel were unambiguous:

"Beneficiation should not be used as the basis for selective intervention and industrial promotion. Greater processing of natural resource exports does not constitute either an easy or a natural next step in the process of structural transformation, especially in South Africa. Downstream sectors already benefit from proximity to input and South Africa's remoteness from the rest of the world. If these sectors have not developed on their own, it is prima facie evidence that either they face low social returns or confront obstacles similar to those of other sectors. Privileging beneficiation is unwarranted and it takes government's attention away from other opportunities that may have more potential to create export jobs in South Africa." (Hausmann, 2008: Recommendation 16)

Mechanisms to encourage downstream beneficiation employed by government include excise taxes (diamonds) and requiring firms to lower prices to domestic consumers (iron ore and steel). However, these and other measures to "force" beneficiation will result in lower returns, lower levels of investment. This, in turn, will have knock-one effects on the industries which supply the affected minerals with capital good and intermediates.

6. Developing an Alternative Strategy and policies in order to Make the Most of Commodities.

We saw earlier that analysis of patent activity suggests that indeed mining equipment is the only substantial sector where a major cluster of South Africa firms has significant expertise located at the global technology frontier. Patent data is reinforced by the presence of a number of leading and indeed unique South African products and South African firms which are global leaders in the field as well as success in export markets.

Moreover, the relative success of mining-related capital equipment exports is linked to South African engineering and project management capabilities more broadly and this suggests that there are potential significant spillovers into other areas. All this strongly suggests that this sector in particular needs to feature far more centrally in the government's technology objectives. [13]

The challenge with respect to this sector is twofold. First, it is to maintain and enhance the competiveness of the sector, particularly in the light of rising competition in relation to manufacturing (principally from the Far East) and a rising challenge in relation to knowledge and innovation (principally from Australia). To raise competitiveness, enhanced support for mining related R&D, in tertiary education institutions, in science councils and also at the firm level is required. Enhanced support for training should be also provided– particularly in relation to high level and technical/artisanal skills.

Second, the challenge is to support the spread of these technologies and companies into new non-mining related products and markets. To some extent this is already happening. However, there are knowledge and information gaps whereby firms fail to see the potential application outside of known areas and customers and there are costs and risks of new product and new market development. The fact that firms who move into new areas take risks while much of the benefit of success falls to follower firms (second movers) constitutes a market failure that potentially provides a "space" for public policy. The South African capital equipment 'sector' is highly organised and cohesive with an active export association. Hence, the proposal is that a government task team investigates, in close consultation with the industry and export association, how firms might be encouraged to apply their technological capacities to new products and new markets.

The spread of frontier level technologies outside the mining sector into new products and new markets, the lateral movement of existent technological competencies should be encouraged. We accordingly here propose a financial support to encourage innovation – the development of new products for new customers in the following method:

A fund could be created which could be accessed by any company, existent firms or new firms or start-ups. This fund would support firms utilising technological competencies developed in relation to mining to develop products for application outside of mining and to enter into new export or domestic markets. It is important to ensure that support is also open to new entrants since the lateral spread of technologies is often performed by new entrants.
The very existence of such a fund would constitute a signalling device to firms in the industry as to government commitment to enhance new product and new market development and the

[13] Chang proposes a very different approach. Chang argues that countries like South Africa should use their resource rents to invest in alternative areas – such as electronics or telecommunications. Chang, 1998.

associated technological competencies in their sector. Support would be given in the form of provision of "public goods" particularly training, market research and costs of entering markets such as establishing sales outlets, repair and back-up facilities etc. Support would not be given for capital equipment. Applications for support should be judged on a competitive basis and by an arms-length group composed principally of persons with business know how and knowledge of the industry.

Downside risk can be limited in two ways. Firstly, support would be given on a matching grant basis i.e. firms would bear a part of the costs. Secondly, monies for support could be capped and would only be drawn down where and when there were successful applicants.
This approach is different from that of Haussman and Rodrik (2003), who propose policies to encourage new firms and new products – so-called "self-discovery." The Hausmann and Rodrik approach is an "open architecture" whereby support is made available to any new firm or product. The approach here is different in so far as there is direct support to established firms with existent competencies as well as new entrants that can access such competencies as evidenced by their command of technology, their innovative products and their success in global markets. This approach has the distinct advantage of building on and broadening out from existing competencies and firms with a track record i.e. already proven as opposed to going in search of something that is altogether "new."

It also differs from the approach to identifying sectors for support advanced by Justin Lin (Lin and Monga, 2010). Lin's approach assumes that catch-up countries are behind the technology frontier in all activities. However, middle-income countries, such as South Africa, are likely to have sectors/activities that, for a variety of historical reasons that are at or close to the technology frontier. In this event, one key aspect of technology and industrial policy would be to encourage the lateral movement of such competencies into new areas/products and markets – more especially export markets.

Finland is the outstanding example of a successful country whose growth was heavily dependent on broadening its capacities from natural resource based industries, principally forest related, into machinery and engineering industries and later into ICT and electronics. The key factors that underpinned this diversification were"… the persistent emphasis given to higher education, linkages and spillovers among various industries, and the emergence of new knowledge-based industries."[14] Government adopted a systems approach to industrial and technology policies. Strong linkages as between research organizations, universities, firms and industries in relation to knowledge production were promoted and policy was formulated through public-private partnerships involving economic research organizations, industry federations and firms.[15]

Of course, the Finnish example cannot be exactly replicated in South Africa. But, the approach that we are proposing here – particularly the emphasis on diversification through promoting linkages and spillovers, a systemic approach to an integrated industrial and technology policy and the development of policy in close collaboration with the firms and the industry - draws much from the Finnish experience.

[14] Dahlman, Routti and Yla-Antilla, 2009: 3
[15] Dahlman, Routti and Yla-Antilla, 2009: 8

Appendix 1: Interviews

South African Capita Equipment Export Council (x2)
Multotech
Outotec
Chamber of Mines
Murray and Roberts
Turgis Consulting and Wits University
Mintek
Hydropower Equipment
Bell Equipment
Bateman Engineering
Urethane Moulded Products
Sandvik
Atlas Copco
Group 5

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