

A LINKAGE MODEL FOR THE SOUTH AFRICAN MINERAL SECTOR: A PLAUSIBLE OPTION

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A research report submitted to the Faculty of Engineering and the Build Environment, University of the Witwatersrand, in fulfilment of the requirements for the degree of Master of Science in Engineering

Johannesburg, 2012

DECLARATION

I declare that this research report is my own unaided work. It is being submitted for the degree of Master of Science to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

.....
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ABSTRACT

The mining industry is an important sector of the South African economy contributing approximately 10% to the GDP in the last decade. It is also the largest contributor to the country's exports, bringing in the necessary foreign income.

The strength of the South African mining industry stems from the country's mineral endowment and mining expertise built over many years of mining. Some of the legacies of mining in South Africa are the establishment of cities of Johannesburg and Kimberley and the creation of the biggest stock exchange and economy in Africa. However South Africa is crippling with one of the highest income inequalities in the world, high unemployment rate, and poverty despite its mineral endowment, stable political climate, and constitutional democracy.

To fight inequality, unemployment, and poverty, this document proposes the use of Resource-based Research and Enterprise Development Model or the Linkage Model as one of the instruments at the disposal of the government. The Linkage Model is strategic in nature and is primarily based on the economic linkage theory. It comprises of six components or pillars, namely government support, research funding, functional research institutions, adequate research skill supply, resource-based research output, and commercialisation of research findings. Through the latter, it is hoped that employment opportunities will be created in industries that support the mining industry.

ACKNOWLEDGEMENT

I will like to express my gratitude and acknowledgement for the contribution and assistance of the following persons towards the completion of this report:

My wife, Mmabatho, and my son for their love, patience and understanding.

My supervisor, Dr H. Mtegha, for his motivation, guidance and support.

My colleagues at the University of the Witwatersrand for their fruitful discussions during my research.

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LIST OF ABBREVIATIONS

AEMFC	African Exploration Mining & Finance Corporation
BEE	Black Economic Empowerment
BRICS	Brazil, Russia, India, China and South Africa
BUSA	Business Unity South Africa
CMSA	Chamber of Mines of South Africa
CSIR	Council for Scientific and Industrial Research
DBE	Department of Basic Education
DBSA	Development Bank of South Africa
DED	Department of Economic Development
DHE&T	Department of Higher Education and Training
DME	Department of Minerals and Energy
DMR	Department of Mineral Resources
DST	Department of Science and Technology
DTI	Department of Trade and Industry
GDP	Gross Domestic Product
HDSA	Historically disadvantaged South African
IDC	Industrial Development Corporation
I/O	Input-Output Analysis
MEC	Mineral-energy-complex
MIT	Massachusetts Institute of Technology
MPRDA	Mineral and Petroleum Resources Development Act
Nedlac	National Economic Development and Labour Council
NRF	National Research Foundation
NUM	National Union of Mineworkers
OEM	Original Equipment Manufactures
PGM	Platinum Group Minerals
PhD	Doctor of Philosophy (doctorate degree)

PI	Primary Industry
R&D	Research and development
RSA	Republic of South Africa
SADC	Southern African Development Community
SDA	Skills Development Act
SIMRAC	Safety in Mine Research Advisory Council
SOE	State Owned Enterprise
SUT	Supply Use Table
TU	Technology Usage
UP	University of Pretoria
UJ	University of Johannesburg
UNISA	University of South Africa
USA	United States of America
USSR	Union of Soviet Socialist Republics
WBS	Wits University Business School
Wits	University of the Witwatersrand, Johannesburg

LIST OF SYMBOLS

\$	USA Dollar
km	kilometre
kt	thousand metric tonnes
Mt	million metric tonnes
R	South African Rand
T	metric tonne and equals to 1000 kilogrammes (kg)
Ton	Imperial ton and equals to = 1 016.04691 kg
Tpa	metric tonnes per annum

1. INTRODUCTION

1.1. Overview of mineral sector economics in South Africa

South Africa is blessed with mineral endowment to the extent that in 2008 “approximately 53 different minerals were produced from 1 515 mines and quarries” (DMR, 2009a: p1). Despite this enormous economic potential, South Africa has a high unemployment rate hovering at approximately 25% compared, for example, to other BRICS countries with the unemployment rate in Russia, Brazil, China and India being at 6.6%, 6.7%, 9.6% and 10.7% respectively in 2010 (SAIRR, 2011).

In addition to the problem of the South African unemployment rate, there is also a problem of dependence on social grants for those living in poverty. It was estimated that there were 5.2 million South African registered tax payers in 2008, and 13 million social grants recipients. Out of the 13 million, 8.8 million were children (SAIRR, 2011 and Jacobs *et al*, 2010).

One of the benefits of social grants so far, according to Jacobs *et al* (2010), has been their ability to narrow down the inequality gap in South Africa. At one stage South Africa was one of the most unequal societies in the world with a gini coefficient of 0.68¹. A coefficient of one (1) in this case would indicate a society where one person earns all the income and the rest of the working populace earn

¹ Source: <http://www.sabinetlaw.co.za/presidency/articles/government-releases-development-indicators-2010>

nothing, while a coefficient of zero (0) would indicate a society where all the working populace earn the same income.

According to HDR (2010) the average South African income gini coefficient between 2000 and 2010 was 0.578, an improvement attributed to social grants. Irrespective, the income gini coefficient of 0.578 was the worst in the BRICS countries and relatively unimpressive compared to some of the SADC countries despite South Africa being the regional economic power (see Table 1.1).

Table 1.1: 2000 – 2010 Income gini coefficients of selected countries

BRICS Countries		Selected SADC Countries	
Country	2000 – 2010 Income gini coefficient	Country	2000 – 2010 Income gini coefficient
India	0.368	Mozambique	0.471
China	0.415	Swaziland	0.507
Russia	0.437	Zimbabwe	0.510
Brazil	0.550	Lesotho	0.525
South Africa	0.578	South Africa	0.578
		Botswana	0.610
		Namibia	0.743

Source: HDR (2010)

It can be argued that the burden of social grants on a small pool of tax payers and companies is not sustainable in the long term if deliberate actions are not taken. Assertion is made here that a viable method of bridging the inequality gap has to come from a sustainable economic model that will result in economic growth and creation of entrepreneurial opportunities. A window of opportunity, as argued in this research report, is the intensification of mineral beneficiation accompanied by economic linkages in the economy.

According to the South African government, there are four stages of beneficiation, namely primary, secondary, tertiary and final stages (Table 1.2). The primary stage comprises of activities such as mining, recovery, reduction and smelting with the emphasis being on the conversion of raw minerals into concentrates. The secondary stage is a transition stage between mining sector and industrial sector, and is largely concerned with the conversion of mineral concentrates into intermediate products. The tertiary stage involves refinement of intermediate products to produce high-value intermediate products. Lastly the final stage involves manufacturing of final products (MPRDA, 2002).

Table 1.2: The example of beneficiation stages in South Africa²

Stages of Beneficiation	Metals	Industrial Minerals
Primary	Saleable smelted products (copper cathode)	Processed raw material (granite blocks)
Secondary	Fabricated alloys and metals (copper tubes)	Basic final products (granite slabs)
Tertiary	Semi-manufactures articles (armatures)	Refined products (polished granite tops)
Final	Fabricated articles (electric motors)	Fabricated articles (granite workstations)

Adapted from Robinson and von Below (1990)

All mines in South Africa are involved in the primary beneficiation of their products when considering that at least all mines undertake a mining activity of some sort. The debate of mineral beneficiation in South Africa should therefore revolve around secondary, tertiary and final stages. These are the stages where industrial competency has an upper hand in relation to mining. In South Africa, industrial

² Table 1.2 should be read in conjunction with Figure 1.2.

activities fall under the domain of the Department of Trade and Industry (DTI) while mining activities fall under the Department of Mineral Resources (DMR).

The industrial sector on the other hand is both the supplier and customer of the mining sector within a symbiotic relationship generally referred to as the mineral sector. Logically it would be expected that this symbiotic relationship within the South African mineral sector would result in higher levels of mineral beneficiation. On the contrary, mineral beneficiation amounting to only R40 billion was achieved in 2009 compared to raw mineral sales of R225 billion (DTI, 2010). That being the case, Jourdan (2001) asserted that the classification process under the Standard Industrial Classification undermines the contribution of the South African industrial sector in the mineral beneficiation value chain.

Industrial processes, in particular manufacturing, are important downstream activities in the mineral sector. Manufacturing is generally regarded as having a higher potential than mining to create job opportunities for low skilled people because of its high labour absorbency. On the other hand mining, especially at the scale at which it takes place in South Africa, is capital intensive. One of the characteristics of capital intensive industries is their low labour absorptive capacity (especially of non-skilled personnel).

This was illustrated by Pegg (2006) when pointing out that Sadiola Gold Mine in Mali created approximately one mining job per \$700,000 invested. In another case Randgold created one job for every \$1.23 million invested to develop a new mine in Mali (Pegg, 2006).

Davis (1998) earlier pointed that mining industries internationally have low labour absorptive capacity with two thirds of mining countries in the world having less than 3.5% of their total working force employed in their respective mining industries. In 2008 the South African mining industry employed only 3.3% of the country's work-force in non-agricultural formal sector (DMR, 2009a).

The ability of the mining industry to create significant employment opportunities rests in its symbiotic relationship with the industrial sector. It is from this premise that this report seeks to provide a plausible solution to the problem of the inability to create meaningful employment opportunities in the mineral sector such that issues of unemployment, inequality and poverty in South Africa are addressed.

In so doing, this report will seek to develop a model that could enhance the South African mining competency and knowledge while creating a fertile ground for the growth of the secondary and tertiary industries. The model will incorporate research and enterprise development components. The envisaged model will take cognisance of the South African Mining Charter and relevant industry initiatives. The model will also draw from established theories such as backward and forward linkages, input-output (I-O) analysis and economic clusters.

1.2. Motivation for research

1.2.1. Mining and mineral beneficiation

South Africa has a long modern history of mining dating as far back as 1846 when the British acquired a copper mine in Namaqualand from the Dutch. Forty years later the discovery of gold in the Witwatersrand basin firmly put South Africa on the mining radar. Hundred and sixty years later, after the dawn of modern history of mining in South Africa, there were approximately 1 515 operating mines and quarries in the country producing 53 different minerals. Furthermore it was estimated that in 2009 there were 5 906 abandoned mines and shafts that had to be rehabilitated at an estimated conservative cost of R30 billion, with 1 730 of them considered as high risk (DMR, 2009a and Auditor General, 2009).

Despite a period of more than a century and half of mining, Citibank in 2010 stated that South African's known in-situ mineral resources were worth \$2.5 trillion, the largest in the world then (see Figure 1.1). Some analysts viewed the Citibank's statement as an opportunity for South Africa to come up with a long term plan for mineral beneficiation (Creamer, 2010).

Currently very little of South African minerals are beneficiated beyond primary stage. A decade ago Mintek *et al* (2000) established that a ton of stainless steel containing chromium was worth 147 times more than a ton of chromium in chromite ore and the value of polished diamonds was between 30 and 173 times

more than that of rough diamonds depending on where they were along the value chain³.

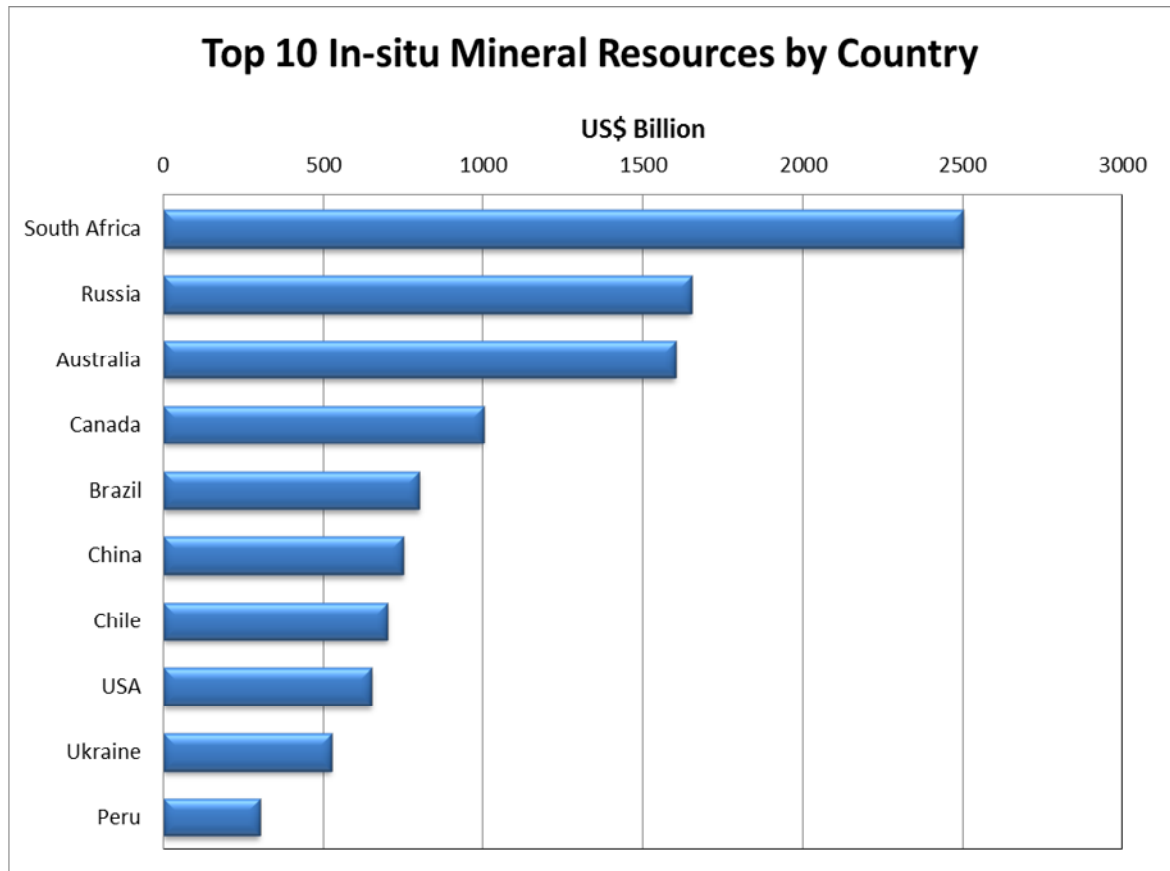


Figure 1.1: Top 10 in-situ minerals resource value by country
Source: Citibank in Baxter (2011)

The benefits of higher stages of mineral beneficiation are clearly evident when one looks at the South African ferrous industry. In 2008 a sale of 65.4Mt of ferrous ore realised R45 billion in revenue whereas a sale of 4.2Mt of processed ferrous metals realised a revenue of R52 billion. In the same year the total sale of South African minerals (excluding diamonds and strategic minerals) was R300.3 billion (DMR, 2009a).

³ Subject to size (carat), clarity, colour and cut

By beneficiating more minerals along the mining value chain, the country would not only generate more tax revenue from the growth in value of beneficiated minerals as shown in Figure 1.2, but would also be creating more job opportunities when new companies or divisions are established to provide products and services to the mineral sector along the entire value chain. According to the DMR (2009b), South Africa will benefit enormously by beneficiating the ten minerals shown in Table 1.3.

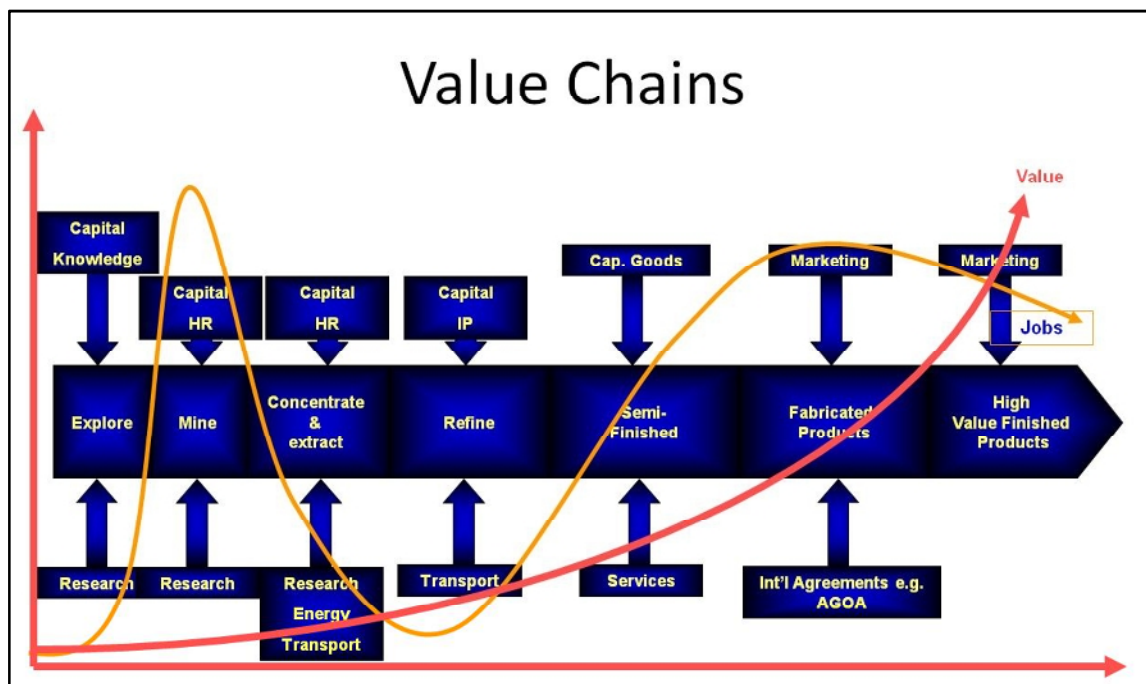


Figure 1.2: Mineral beneficiation along the value chain
Source: Mtegha (2009)

Table 1.3: Selected minerals and downstream beneficiation

Selected Commodities										
Selected Value Chains	Gold	PGMs	Diamonds	Iron Ore	Chromium	Manganese	Vanadium	Nickel	Titanium	Coal & Uranium
Energy										✓
Steel/Stainless steel				✓	✓	✓	✓	✓		
Pigment production									✓	
Auto-catalyst and diesel particulate		✓								
Diamond processing and jewellery	✓	✓	✓							

Source: DMR (2009b)

1.2.2. South African unemployment rate

As stated earlier, South Africa has a persistently high official unemployment rate hovering at 25%. The situation becomes gloomier when the extended definition of unemployment rate⁴ is considered. Under the extended definition, the South African unemployment rate reached 42.5% in 2003 and eased to 34.3% in 2007 (Kingdon and Knight, 2009).

Another perspective of unemployment situation in South Africa was provided by Business Unity South Africa (BUSA), which developed three scenarios for the official unemployment rate trajectory in South Africa using output elasticity of employment methodology and GDP growth (Table 1.4). The employment growth in the three scenarios was projected from 2010 to 2025 using the 2010 official

⁴ Extended definition of unemployment includes those individuals who are capable of working but are discouraged to look for work, whereas official unemployment rate takes into account only those who are actively looking for a job.

unemployment rate of 25.3% as the base. The projected South African employment growth was compared to that of Malaysia.

Table 1.4: Scenarios of South African unemployment levels from 2010 to 2025

Year	LEVEL OF UNEMPLOYMENT (expressed as a percentage)					
	Average Road 3 % GDP Growth Rate per annum		High Road 7 % GDP Growth Rate per annum		Very High Road 9 % GDP Growth Rate per annum	
	Malaysia	South Africa	Malaysia	South Africa	Malaysia	South Africa
2010	25.30%	25.30%	25.30%	25.30%	25.30%	25.30%
2015	23%	26,9%	15,4 %	24,2%	11,4 %	23%
2020	19,7%	27%	3,1 %	22,2%	-	19,7%
2025	16,6%	27,7%	-	20,5%	-	16,6%

Source: BUSA (2010)

From Table 1.4 it can be seen that at the South African historical GDP growth of 3%, the official unemployment rate in South Africa would have deteriorated to 27% in 2025 compared to a reduction of almost 9% in Malaysia. At the GDP growth of 9%, it is forecasted that the unemployment rate in South Africa will only drop to 16.6% by 2025 compared to 0% in Malaysia.

From the empirical study of BUSA (2010), it can be concluded that GDP growth in exclusion of other employment generating policies will yield suboptimal results in South Africa. This was the case between 2000 and 2008 when South Africa was criticised for having a jobless economic growth (BUSA, 2010).

To reduce unemployment rate and realise economic growth, South Africa needs a wholesale review of policies targeting services, outsource, value chain,

knowledge, bio-, green, leisure and grey industries⁵ (BUSA, 2010). Most of these industries are part of the fast growing tertiary sector of the South African economy with few featuring in the secondary sector dominated by manufacturing. Although the importance of the above mentioned industries in recent times (with the exception of the grey industry) is acknowledged, it is however asserted in this report that the primary sector of the economy, in particular mining, can still contribute significantly to the economic well-being of the country. Through its connectedness in the South African economy, mining can stimulate growth in secondary and tertiary sectors of the economy if appropriate policies are adopted. For example the resource-based research that is linked to mining and mineral beneficiation competency and enterprise development could be engineered to create the required labour absorptive employment opportunities in the manufacturing industry, with finance provided by institutions in the tertiary sector.

1.3. Proposed research outcomes

This research report aims to achieve the following research outcomes:

- To provide the understanding of how economic linkages between mining and other sectors can be used to create employment opportunities in South Africa. Employment opportunities in the context of this report means the potential and not actual jobs created.
- To develop a South African mineral sector linkage model that incorporates research and development (R&D); a network of supporting agents such as

⁵ Grey industries are those industries that operate outside the regulatory system and will include but not limited to illegal drug dealing, human trafficking, prostitution and all prohibited trading.

government departments; Science Councils⁶; universities; and enterprise development agencies, with the ultimate aim of creating employment opportunities in the mineral sector.

1.4. Scope of the study

The successful completion of this study will largely depend on focusing on the following areas.

- a. A history of mineral beneficiation in the South African mineral sector and its multiplier effect.
- b. Analysis and extent of economic linkages created by the mining industry in South Africa with the view of identifying areas that could provide South Africa with a competitive edge.
- c. Identification of bottlenecks that could hinder adequate level of resource-based research in the mineral sector.

The scope of this study will be confined to the South African mineral sector although lessons may be drawn from other local economic sectors and international experiences where appropriate.

1.5. Contents of the research report

- Section 1 introduces the research topic by giving a general overview of the significance of the South African mining industry in the economy and socio-

⁶ Science Councils refer to CSIR, Mintek and Council for Geoscience (CGS).

economic problems the country is facing. Furthermore section 1 outlines the motivation for the research and objectives that should be met.

- Section 2 touches briefly on the resource-based theories. In particular it focuses on the economic linkage theory, the multiplier effects of mining in the economy, and the nature of enterprise clustering brought about by mining in South Africa.
- Section 3 looks at the 160 years of modern history of mining in South Africa and the impact that the politics have on mining.
- Section 4 briefly touches on the case studies of products and services developed in South Africa in the past 100 years as a result of mining activities. This section also reviews the role that Science Councils and universities play with regard to resource-based research and beneficiation.
- Section 5 looks at how mining research unfolded in the South African mining industry after the Chamber of Mines of South Africa Research Organisation (COMRO) was absorbed by the Council of Scientific and Industrial Research (CSIR) in 1993.
- Section 6 discusses six components or pillars of the Resource-based Research and Enterprise Development Model and the implementation thereof.
- Lastly, the conclusion section summarises salient points coming out of this research report.

2. RESOURCE-BASED THEORIES

2.1. Introduction

Over the years there have been many resource-based theories developed such as 'economics of exhaustible resources' by Hotelling, 'mining rent' by Smith and Ricardo, 'backward and forward linkages' by Hirschman, 'input-output analysis' by Leontief, and 'intensity of metal use' by Malenbaum. Notwithstanding the extensive coverage of resource-based theories elsewhere, this chapter will focus on the economic linkage theory, industrial clustering, and mining multiplier effects as they apply in the South African economy.

2.2. Economic linkages

Economic linkages arise when economic activities in one industry lead to economic growth in other industries and/or the emergence of new industries. Fundamentally economic linkages are forward or backward biased. Forward biased linkages are called forward linkages whereas backward biased linkages are called backward linkages (Hirschman, 1958).

Hirschman postulated that the effects of economic linkages depend on whether a primary industry (i.e. an industry that generates the demand) is important or is strong. The difference between these two forms of industries is that important primary industries may not necessarily create new industries in the local economy while strong primary industries invariably create new industries in the local economy.

Given the connectedness of mining in the South African economy today, it can be hypothesised that the current form of the South African economy has its origin in mining. This hypothesis is not is not far-fetched when considering that mining has given rise to the South African industrial sector and the stock exchange among others. Through synthesis it can be concluded that the South African mining industry in the past (and possibly even today) was a strong industry with the ability to give rise to backward and forward linkages.

A forward linkage is also known as a downstream linkage, which is basically a beneficiation or value-adding activities by downstream industries. In the case of mining, in the South African context, downstream industries would largely be found within the industrial sector (e.g. steel and chemical sectors). A backward linkage or an upstream linkage, on the other hand, arises because of economic relationship between the primary industry and its suppliers (e.g. exploration). Therefore the economic chain entails procuring from backward linkages in order to supply forward linkages.

In recent times it has been accepted that there are also two additional types of economic linkages. The third type is called lateral linkage. According to Lydall (2009: p112) the lateral linkage arises “from the modification and application of generic technologies to other industrial sectors”. This largely stems from the interaction of the primary industry or mining industry, in this case, with its service providers on one hand and the interaction between service providers on the other hand. According to Jourdan (2001) the application of modified generic

technologies across various industries in the South African mineral sector is due to multiplier effects of lateral linkages of the mining industry in the economy.

Hirschman placed much more value on backward linkages than on forward linkages in developing countries, stating that forward linkages could never occur in pure form, as they are always accompanied by backwards linkages. In countries where industries are not yet developed, Hirschman postulated that it would be much easier to establish backward linkages from the final product and systematically move backwards along the value chain until an industry that produces a primary product is established.

In analysing backward linkages in depth, Lydall (2009: p112) came up with three types (possibly pointing to the importance of backward linkages as mentioned by Hirschman earlier). Using the platinum group metals (PGM) sector as an example, Lydall described the first type as a vertical backward linkage “which generally arise as a consequence of the demand at the producer level for a particular product and service”. The second type was described as a horizontal backward linkage typified by “research partnerships and close interaction between supplier firms, mining companies, and related and supporting industries over a long period of time around to solve common industry challenges”. The third type was described as “technological or production-related linkages, which arise as a result of the introduction of new technologies or an improvement of existing systems in the various stages” of system or entity life.

Hirschman (1958) also posited that where primary industries employ primitive means of production, the extent of backward linkages will be limited compared to where modern technology is employed. Similarly mines with primitive means of production will develop weak linkages with their suppliers and customers.

The implication is that technology in mining is important. Modern mines are capital intensive entities and the more they are designed to use modern technology, the higher is the likelihood that they will develop stronger linkages in the economy. Given that mines are linked to other industries internationally through their import and export capability, it does not automatically mean that the benefits of these linkages will accrue locally unless there is a clear policy in this regard.

Figure 2.1 shows mining value chain with local forward, backward and lateral linkages that could be created as a direct consequence of an operational mine. On the other hand Figure 1.2 shows the value of mining products and corresponding employment opportunities along the mineral sector value chain. Situations depicted in Figure 1.2 and Figure 2.1 could take place at regional, national or global level. The implication being that while mining is beneficial in one way or the other, it does not necessarily mean it will benefit local economies all the time.

Mines are established because there is a deposit that could be mined economically. The establishment of mines and subsequent recapitalisation will induce the development of financial instruments in the financial sector. Similarly, the development of mines and subsequent operation will induce the demand of goods and services from the industrial and services sectors. Mines and their

suppliers and customers will further require skilled human resources to meet their obligations to each other. The capacity of local institutions and companies to supply mines and beneficiate mining outputs will largely determine the extent to which mining benefits accrue locally.

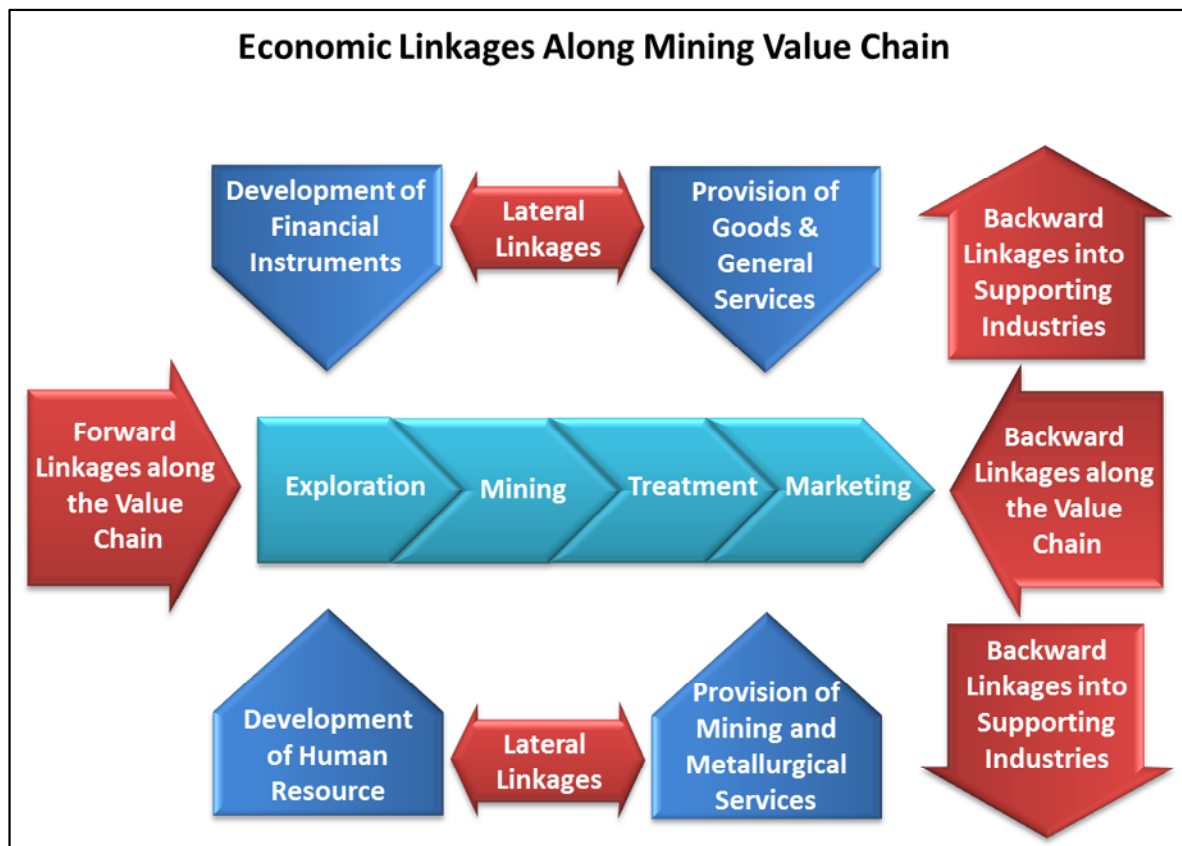


Figure 2.1: Mining value chain and economic linkages

The establishment of mines and their local (regional or national) benefits lead to a fourth type of economic linkage called fiscal linkage. According to Eggert (2001: p22) the fiscal linkage arises out of "tax and royalty revenues regional governments use to develop infrastructure such as hospitals and schools and to purchase other goods and services". A good example would be the use of royalty revenue from Impala Platinum by Bafokeng nation to develop their ancestral land of Phokeng near Rustenburg.

2.3. Industrial clusters

The success of economic linkages largely depends on the nature of clusters in the economy. Walker (2005: p2) defined a cluster as “a concentration of expertise among closely linked industries and companies in which extensive investment in specialised factors of production catalyses a positive growth trajectory”.

Porter (1990) identified four characteristics of clusters. Firstly, clusters generally tend to concentrate geographically. Companies agglomerate around customers, inputs sources or access to information. Secondly, clustering is competitive by nature. This character of clustering forces companies to be innovative in order to survive or outsmart competition which in turn grows the industry. Thirdly, clustering is supportive, i.e. group of companies within the cluster support each other through provision of inputs, customer diversification and spread of information through interaction with customers and mobility of expertise. Fourthly, clustering safeguard against inertia, inflexibility and inward focus that could hold the industry back.

In the South African mineral sector, clustering “has a distinct geographic and spatial dimension” (Walker and Minnitt, 2006: p14). Companies mining the same commodity tend to agglomerate geographically due to the concentration of minerals in specific areas. For example, locations of coal mines are dictated by geographical location of coalfields, similarly location of platinum mines is dictated by geographical location of the Bushveld Complex or the Witwatersrand basin in the case of gold mines. Generally there is a high concentration of mines in Mpumalanga, Limpopo, Northwest and Gauteng Provinces, and to a lesser extent in Free State and Northern Cape Provinces. The location of mines on the other

hand tends to determine the location of concentrators while refineries cluster around places where it is cheaper to access electricity and feedstock (Walker and Minnitt, 2006).

Heavy industrial engineering companies tend to cluster in Ekurhuleni, while consulting agencies, financial institutions and software development companies tend to cluster around Johannesburg, both being metropolitans in the Gauteng Province. This type of clustering could be due to the legacy of gold mining in the Witwatersrand basin. Similarly research institutions and universities that deal with the mineral sector are generally located in the Gauteng Province. While companies, institutions and universities that interact with the mineral sector have fixed locations, they also have national presence which characterise their spatial coverage.

According to Walker (2005), the South African mining industry has two tiers of supplier companies. The first tier consists of companies that deal directly with mining companies which include engineering consultancy firms, original equipment manufacturers, input suppliers, agents, and distributors. The second tier consists of subcontractors and input suppliers (e.g. components and consumables) that service the first tier companies. The number of people employed tends to increase as the supply chain moves further away from the primary industry (Walker and Minnitt, 2006). This phenomenon leads to employment multiplier effect that one would expect in backward linkages.

2.4. Economic multipliers

2.4.1. Input-output analysis of the South African mining industry

Wassily Leontief is regarded as the father of input-output (I/O) analysis which has its origins in the works of classical economists such as Adam Smith and David Ricardo (Kurz and Lager, 2000). "Input-output analysis is a basic method of quantitative economics that portrays macroeconomic activity as a system of interrelated goods and services"⁷. In developing I/O model, a country or a region is divided into sectors representing economic activities and the flow of inputs (products, services and labour) and outputs (products and services) between these sectors is then quantified in monetary terms.

The intensity of intra-sector purchases and sales within the I/O model constitutes the connectedness or linkages in the economy whereas the final demand represents exports of goods and services, and consumption by government and households. The gross sector output achieved to meet the final demand indicates the multiplier effect within the economy or the 'buy and sell chain reaction' across industries caused by the initial demand. Theoretically the 'buy and sell chain reaction' is terminated by taxes, imports, savings and profit repatriation (Coughlin and Mandelbaum, 1991).

In the context of this report, it will be assumed that the demand is initiated by mining companies. The effects of the demand or the interaction between mining

⁷ Source: <http://www.referenceforbusiness.com/encyclopedia/Inc-Int/Input-Output-Analysis.html>. Accessed 10 April 2011.

companies and their suppliers and customers result in multipliers that reverberate throughout the economy.

To determine the value of economic multipliers, governments (Statistics South Africa in the case of South Africa) produces I/O models called Supply-Use Tables (SUT) prepared in accordance with the guidelines of 1993 or 2008 System of National Accounts.

According to Stilwell *et al* (2000: p20) the following are assumptions made when compiling SUT:

- The models are final demand driven;
- different production activities are grouped into homogeneous sectors, each producing one product type;
- there is no substitution of intermediate inputs;
- each sector's demand or intermediate inputs changes in direct proportion to the output from that sector; and
- no technological change occurs during a period of measurements.

Take for example the analysis of the 2003 South African SUT by Tregenna (2007).

It can be observed in Table 2.1 (reading from top to down) that important sectors to the mining industry in so far as inputs were concerned were services (28.4%), labour (24.6%), transport (21.9%) and manufacturing (15.2%). When the import component was excluded from mining inputs as shown in Table 2.2, local services, labour, transport, and manufacturing contributed 26.4%, 34.4%, 19.9% and 9.4%

of mining inputs respectively. The difference between Table 2.1 and Table 2.2 arise due to the import component of mining inputs from different sectors. When considering that services, transport and manufacturing inputs into the mining industry are generally provided by agents of multinational companies registered in South Africa and not to mention that these agents are sourcing their products and services abroad, it can be deduced that the mining import component (the difference between Table 2.1 and Table 2.2) is a lot higher than stipulated.

Table 2.1: Backward linkage inputs with import component included

	Agriculture	Mining	Manufacturing	Electricity gas and water	Construction	Trade	Transport	Finance	CSP	Government	Services total
Agriculture	2.4	0	4.9	0	0	0.2	0	0	0.1	0.1	0.1
Mining	0.7	0.5	10.8	16	4.3	0	0.2	0.2	0.3	0.3	0.2
Manufacturing	31.1	15.2	38.4	7.9	33.9	9	21.2	7.1	14.5	10.2	11.8
EGW	1	2.3	1.2	15.7	0.3	1.1	1.4	0.6	1.1	0.4	1
Construction	0.3	0.6	0	3.4	19	0.9	0.4	1.2	0.6	0.8	0.9
Trade	6	2.6	7.2	2	4.1	6.2	8.7	4	6.1	2.9	6
Transport	7.6	21.9	3.8	1.7	2.1	10.4	14.3	5.4	4.2	3.4	8.7
Finance	2.8	2.6	6.3	5.3	8.2	17.9	8.1	23.7	19.1	5.3	18
CSP	2.6	1.3	1.4	0	0.3	0.3	0.4	1.5	2.1	3.6	1
Government	0	0	0	0	0	0	0	0.1	0.9	4.7	0.1
Services	18.9	28.4	18.7	9	14.6	34.9	31.5	34.7	31.5	15.1	33.6
Labour	26.6	24.6	7.3	39	13.2	19.1	13.8	21.5	19.5	53.2	18.6
Total	100	100	100	100	100	100	100	100	100	100	100

Source: Tregenna (2007)

Table 2.2: Backward linkage inputs with import component excluded

	Agriculture	Mining	Manufacturing	Electricity gas and water	Construction	Trade	Transport	Finance	CSP	Government	Services total
Agriculture	2.2	0	4.5	0	0	0.2	0	0	0.1	0	0.1
Mining	0.4	0.4	6.1	14.9	2.1	0	0.1	0.2	0.2	0.2	0.1
Manufacturing	22.5	9.4	27.8	5.2	25.7	7.3	12.9	5.1	9.2	6.5	8
EGW	1	2.3	1.2	15.6	0.3	1.1	1.4	0.6	1.1	0.4	1
Construction	0.4	0.7	0	4	22.1	1.3	0.5	1.6	0.8	0.8	1.2
Trade	6	2.6	7.2	1.9	3.8	6.1	8.6	3.9	6	2.8	5.9
Transport	6.9	19.9	3.5	1.5	1.8	9.9	13.6	5.1	4	3.1	8.2
Finance	2.7	2.5	6	5.1	7.3	17.2	7.8	23	18.1	4.9	17.3
CSP	2.5	1.4	1.5	0	0.3	0.3	0.4	1.5	2.3	3.5	1
Government	0	0	0	0	0	0	0	0	0.8	7.4	0.1
Services	18.2	26.4	18.2	8.5	13.2	33.5	30.4	33.5	30.5	14.3	32.4
Labour	37.2	34.4	24	43.3	23.4	23.1	24.3	25.5	26.9	56.1	24.7
Total	100	100	100	100	100	100	100	100	100	100	100

Source: Tregenna (2007)

With respect to mining outputs or forward linkages, it can be observed in Table 2.3 (when reading across from left to right) that 61.7% of mining outputs were used as inputs into the manufacturing sector whereas 26.6% was sold directly for final consumption. When the import component was excluded from the analysis as shown in Table 2.4, it can be observed that 34.7% of mining outputs were used in manufacturing while 56.42% was directed for the final consumption. In the case of Table 2.4, the final consumption includes material sold directly by mines for final consumption and those exported for further beneficiation outside South Africa.

Taking manufacturing as an example, the difference between values in Table 2.3 and Table 2.4 is the location of factories (final consumers to some extent). In Table 2.4, manufacturing is exclusively in South Africa while in Table 2.3 it is

anywhere in the world including South Africa. It can therefore be concluded, from Table 2.3 and Table 2.4, that large quantities of South African mining output by value are exported to other countries.

Table 2.3: Forward linkages outputs with import component included

	Agriculture	Mining	Manufacturing	Electricity gas and water	Construction	Trade	Transport	Finance	CSP	Government	Final consumption	SUM
Agriculture	2.4	0.04	63.12	0.01	0.01	0.98	0	0.05	0.21	0.23	32.95	100
Mining	0.3	0.45	61.66	5.83	3.44	0.03	0.31	0.61	0.24	0.53	26.6	100
Manufacturing	2.39	2.67	38.43	0.51	4.79	3.22	6.58	3.53	2.36	3.22	32.3	100
EGW	1.26	6.37	19.43	15.75	0.63	6.13	6.79	5.05	2.76	1.85	33.98	100
Construction	0.18	0.8	0.01	1.52	19.04	2.33	0.77	4.34	0.64	1.77	68.6	100
Trade	1.28	1.27	20.04	0.36	1.62	6.22	7.55	5.61	2.79	2.52	50.74	100
Transport	1.88	12.38	12.27	0.34	0.95	12.07	14.25	8.76	2.2	3.41	31.49	100
Finance	0.43	0.92	12.69	0.68	2.31	12.89	5.02	23.75	6.22	3.34	31.75	100
CSP	1.2	1.45	8.5	0.01	0.22	0.59	0.81	4.47	2.05	6.93	73.77	100
Government	0	0	0	0	0	0	0.03	0.09	0.47	4.75	94.66	100
Services	1.09	3.75	14.06	0.43	1.55	9.4	7.34	13.01	3.85	3.57	41.95	100

Source: Tregenna (2007)

Table 2.4: Forward linkage outputs with import component excluded

	Agriculture	Mining	Manufacturing	Electricity gas and water	Construction	Trade	Transport	Finance	CSP	Government	Final consumption	SUM
Agriculture	2.21	0.03	58.25	0.01	0.01	0.91	0	0.04	0.2	0.23	38.11	100
Mining	0.16	0.36	34.72	5.42	1.69	0.02	0.17	0.52	0.17	0.35	56.42	100
Manufacturing	1.73	1.65	27.82	0.33	3.64	2.62	4	2.53	1.51	2.12	52.05	100
EGW	1.26	6.34	19.39	15.65	0.59	6.16	6.8	5.03	2.79	1.94	34.05	100
Construction	0.22	0.83	0.01	1.82	22.07	3.25	1.02	5.74	0.87	1.91	62.26	100
Trade	1.28	1.27	20.02	0.35	1.5	6.14	7.42	5.43	2.74	2.52	51.33	100
Transport	1.72	11.29	11.29	0.32	0.83	11.42	13.63	8.25	2.09	3.29	35.87	100
Finance	0.42	0.87	12.05	0.65	2.06	12.33	4.84	22.97	5.92	3.22	34.67	100
CSP	1.18	1.49	8.91	0.01	0.22	0.67	0.83	4.6	2.29	7.03	72.77	100
Government	0	0	0	0	0	0	0.04	0.07	0.4	7.39	92.1	100
Services	1.05	3.48	13.64	0.41	1.4	9.02	7.1	12.57	3.73	3.5	44.1	100

Source: Tregenna (2007)

2.4.2. Effects of mining multipliers in South Africa

Table 2.5 shows typical mining multipliers in the South Africa economy (Jones and Baxter 2002: p83-84).

Table 2.5: Typical mining multipliers in South Africa

Multiplier	Description
Social	Construction of infrastructure by mining companies such as housing, roads, schools and clinics, and provision of utilities such as electricity and recreational facilities.
Primary incomes	Household demand for goods as the consequence of primary income derived from the mining industry.
Employment	Jobs created in other industries as a consequence of demand or supply of goods by the mining industry.
Income terms-of-trade	Net positive effect on balance of payments, foreign reserves, monetary policy and general business confidence induced by mining exports.
Capital formation	Positive effect by the mining industry in attracting inflow of foreign capital and generating domestic capital as well.

The size of mining multipliers in the economy is generally dependent on the scale of mining. On the other hand the scale of mining largely depends on the level of technology employed. The relationship between mining multipliers and the rest of the economy is proportional to the amount of money invested in the region by primary industries (mining in this case) and in turn this investment depends on three factors namely, the size of the region, the current level of development (e.g. urban or rural), and the proximity of the region to other well-developed regions. For

example the bigger the region, the more likely it will satisfy the demand of the mining industry. The more developed the region, the more likely it will absorb outputs of mining industry as well as satisfying its demand. The proximity of a mining region to a well-developed region will likely undermine the mining multiplier effects in the mining region in favour of the well-developed region (Eggert, 2001).

Consider Gauteng Province in South Africa. This province is a home to the South African manufacturing hub in Ekurhuleni and financial sector hub in Johannesburg with software specialists and consultants spreading throughout the province. In addition it is the second highest populated province in the country with the highest concentration of professionals and skilled people. It is for these factors that the Gauteng Province is well poised to satisfy the demand of mining (inputs) as well as beneficiating mining outputs. According to Eggert's argument, mining multipliers in the Gauteng Province should be stronger than anywhere else in the country.

On the other hand the eastern limb of the Bushveld complex in the Limpopo Province is not a well-developed region and its proximity to the Gauteng Province is expected to undermine its mining multipliers according to Eggert (2001). The Mpumalanga Province is inferior to the Gauteng Province in all aspects related to mining apart from the abundance of coal and platinum group metal (PGM) deposits, and the land mass. The mining of PGMs is similar to that of gold and due to this reason, PGM mines in the Bushveld Complex are more likely to attract commuting professionals and skilled labour from the Gauteng Province. These professionals and skilled labour are likely to spend their income in the Gauteng Province instead of Mpumalanga Province. Furthermore products and services are

likely to be sourced from the Gauteng Province, an act that will further undermine local enterprise development initiatives in the Mpumalanga Province.

What takes place on a provincial level also takes place on a country level. Resource countries tend to send their raw materials to developed countries for beneficiation due to a lack of local capacity. The best option in this regard is for resource countries to maximise their mining multipliers by increasing the amount of money invested locally and minimise leakages in a form of unbeneficiated exports. Admittedly, it is a difficult task in the current environment of globalisation and multi-nationalism.

2.5. Concluding Remarks

There are many resource theories such as the economics of exhaustible resources, mining rent, backward and forward linkages, input-output analysis and intensity of metal use that can be used to quantify the importance of resources in a country. In the case of South Africa the author opted to create a better understanding of the effects of mining in the economy through the economic linkage theory, industrial clustering and mining multipliers. This was achieved by incorporating the input-output analysis theory, which is generally translated into SUT by governments.

Over the years the economic linkage theory was expanded from its original two-dimensional backward and forward biased theory to a four-dimensional theory by incorporating lateral and fiscal linkages. A four dimensional view of the economic

linkage theory is relevant to the South African mining industry because of its connectedness in the economy.

Hirschman (1958) placed much more value on backward linkages in developing countries because of their multiplier effects. To this effect Lydall (2009) identified three forms of backward linkages, namely vertical backward, horizontal backward and technological linkages. The latter has the ability to spill over into other industries when new technologies emerge or existing technologies are modified.

Economic linkages manifest themselves through economic multipliers. Jones and Baxter (2002) identified five primary mining multipliers in South Africa, namely social, primary incomes, employment, income terms-of-trade and capital formation. To this effect, assertion is made that technology intensive mines will lead to much more entrenched mining multipliers due to the spill over effects of technological backward linkages. It is also believed that the development of technology will flourish under the industrial clustering strategy. The advantages of industrial clustering, among others, are their ability to raise the level of technology employed or supplied because of their competitive nature and ability to safeguard against technology inertia due to the ease of mobility of customers and expertise between different companies within the cluster.

The downfall of clustering in the South African context would be that the emerging PGM sector in the Mpumalanga Province will not result in the expected economic benefits because of its proximity to the Gauteng Province. The latter has well established clusters in Ekurhuleni and Johannesburg.

On a national level, the analysis of the South African SUT by Tregenna (2007) paints a picture where the mining industry exports most of its products while significantly relying on imported inputs. However the author would like to believe that this situation can be rectified if there is a political will to change. It should be noted this change is imperative because mining is the cornerstone of the South Africa economy with a long illustrious history of tenacity and ingenuity.

3. A BRIEF HISTORY OF MINING IN SOUTH AFRICA

3.1. Introduction

Mining is a significant component of the South African economy. The contribution of mining to the economy can be traced as far back as 1870 when diamond bearing kimberlite pipes were discovered in Kimberley. The Kimberley diamond pipes were so significant to the extent that South Africa replaced Brazil as an important source of diamonds for the European market (Letcher, 1936).

In retrospect, diamond mining was a crucial training ground for managers and financiers who would later play a crucial role of building a vibrant gold mining sector from scratch in the Witwatersrand basin. While the city of Kimberley was established by diamond miners and merchants, gold mining in the Witwatersrand basin resulted in the creation of Johannesburg. Gold in the Witwatersrand basin attracted professionals across the globe and gave rise to the notion of Mining Houses⁸. Difficulties experienced in the early days of gold mining led to the establishment of the Chamber of Mines of South Africa (CMSA) and under its leadership many interesting inventions were made that led to the growth of mining in general.

⁸ Financial corporations established to finance mining ventures

3.2. Pre-Witwatersrand mining

South Africa has a long history of mining dating as far back as 1000 years ago when copper was mined and smelted in Phalaborwa⁹ (see Figure 3.1). Archaeologists also discovered that inhabitants of Mapungubwe, an ancient civilisation not too far from Phalaborwa, traded with other civilisations such as those of China, Egypt and Middle East in refined iron, copper and gold among others¹⁰. In addition, there is a body of evidence that shows that gold was mined centuries ago in the district of Lydenburg-Pilgrim's Rest (Letcher, 1936).



Figure 3.1: Early history of mining in South Africa

Adapted from <http://www.distinctiveafrica.com/Map%20of%20South%20Africa.htm>

⁹ Source: http://www.phalaborwa.org.za/service_mining.htm

¹⁰ Source: <http://www.mapungubwe.com/cultural.htm>

At the beginning of the sixteenth century Portuguese explorers encountered Arab merchants along the south-eastern coast of Africa. They learned from the Arabs of the availability of gold inland. Upon receiving this information, they drove Arabs off the south-eastern coast of Africa and established trade relationships with Africans, possibly with the motive of acquiring gold mines (Letcher, 1936).

In the seventeenth century the Dutch established a colony in the Cape Peninsula. While they were in the peninsula, they heard of copper mining in Namaqualand, a stretch of land along the south-western coast of Africa. Governor Simon van der Stel sent an expedition team northwards which encountered copper mining residents of Namaqualand. Upon verification of copper deposits, the Dutch drove off the locals from their land before establishing a European style copper mine at Koperberg in 1685 near what is today a town of Springbok. Copper resources at Koperberg were described as 'inexhaustible'. Apart from copper, there were also reports of silver mine near Hout Bay and elsewhere in the Cape Colony, but proved to be a mere speculation (Botha, 1934).

3.3. Early history of mining in the Witwatersrand basin

Depending on an individual's point of view and motives, a starting point for the history of mining in Southern Africa can be anywhere between the times man first inhabited the southern part of Africa and 1870. Notwithstanding, for the purpose of this report, the starting point of the modern history of mining in South Africa will be taken as 1846 when the British took over copper mining in Namaqualand from the Dutch.

After taking over copper mining in Namaqualand from the Dutch, the British realised that they needed energy source if they were to have a viable economy in the Cape Colony. The energy requirements of copper mines and industry in the Cape Colony led to an extensive exploration for coal, perhaps driven by the knowledge of the importance of coal for a viable industry back at home. After an extensive exploration, the first colliery was established in the coalfield of Stormberg in 1864 and soon thereafter other collieries were established in other coalfields across the country including Bethal where local communities had been mining coal for many years and the Vereeniging coalfield which played a crucial role in the development of mines in Kimberley (Pogue, 2006a).

The news about the discovery of coal and other minerals in South Africa spread throughout the world and soon explorers from USA and Europe were descending down to the shores of South Africa. There was optimism among these explorers that bigger and richer deposits would be found and through their relentless efforts, gold deposits were discovered along the Blyde River. The Blyde River discovery resulted in a speculative gold rush in 1873 (Pogue, 2006a).

Notably the turn of events that put South Africa on the global mining map started with the discovery of kimberlite pipes in Kimberley in 1870 and later the discovery of gold in the Witwatersrand basin in 1886 (Robinson and von Below, 1990). The discovery of gold in the Witwatersrand basin led to the establishment of Johannesburg, undoubtedly the most successful mining town in the world. The vastness of gold deposits (albeit low in grades) in the Witwatersrand basin, led to

the establishment of Mining Houses (finance corporations) that carved the economic landscape of South Africa from their headquarters in Johannesburg.

In the early days of mining in the Witwatersrand basin, mines had to import skills from the USA, Britain and other European countries. In particular managerial skills and engineering consultancy were imported from the USA while technical skills and underground mining expertise were imported from the northern parts of England. In an attempt to establish local mining capacity, native white¹¹ miners (mostly Afrikaners) were taught the necessary mining skills in the evening at the Transvaal Technical Institute¹² (Mawby, 2000).

The discovery of gold in the Witwatersrand basin in the 1880s attracted many diggers. By 1886 many of these diggers realised that the grade and vastness of the Witwatersrand basin was not suitable for diggings but rather lent itself to European mining techniques. Soon thereafter several mines were established along the strike of the Witwatersrand basin outcrop. As the news about the gold discovery spread, the Kimberley barons such as Barney Barnato and Cecil Rhodes who made their fortunes from mining diamonds, left Kimberley for Johannesburg. The barons were fairly experienced in raising capital internationally as well as managing complex mining ventures (Mawby, 2000).

By 1890, many of small mines in the Witwatersrand basin were facing production challenges to the extent that this situation precipitated a recession. A combination of a recession, the complexity of mining gold reefs, and the difficulty of raising

¹¹ White in this case refers to people of European descent

¹² A precursor of the University of the Witwatersrand

capital led to the consolidation of mining claims. The barons seized the opportunity by using their capital or access to capital to takeover struggling mines and built mining empires (Mawby, 2000).

The consolidation of mining claims similar to that of Kimberley gave rise to the notion of Mining Houses. The nature of Mining Houses was such that they owned shares and control mines rather than operating them. Mining Houses were responsible for providing capital, technical assistance and creation of capacity through cross subsidisation and sharing of overheads. There was a complex cross shareholding of mining concerns among Mining Houses but in general a mine was deemed to be under the control of a Mining House with the largest shareholding. The interesting feature of Mining Houses was their collaboration in finding solutions to common problems amidst their stiff corporate competition. By 1907 there were eight significant Mining Houses in the Rand accounting for a large portion of gold production as shown in Table 3.1 (Mawby, 2000).

Many of the Mining Houses in Table 3.1 have their humble beginnings in Kimberley. For example Consgold was partly financed by the proceeds from De Beers Consolidated Mines (DBCM). JCI on the other hand was established with the proceeds from the sale of Barnato Diamond Mining Company to De Beers in 1888¹³. Even Sir Ernest Oppenheimer, the founder of Anglo American Corporation in 1917, had his initial training in mining in Kimberley.

¹³ De Beers took over Barnato Diamond Mining Company to form De Beers Consolidated Mines

Table 3.1: Top eight Johannesburg based Mining Houses in 1907

Mining House	Gold Production (ounces)
Rand Mines Limited (Corner House or Rand Mines)	182 000
Consolidated Gold Fields (Consgold)	56 000
East Rand Propriety Limited (ERPM)	48 000
Johannesburg Consolidated Investment (JCI)	38 000
Randfontein Estate	32 000
General Mining and Finance Corporation (Genmin)	26 000
Goerz & Company	26 000
S Neumann & Company	26 000

Source: Mawby (2000)

A glance over the history of mining in South Africa reveals a distinct pattern that moved from diamonds to gold and now PGMs as the dominant sector in terms of value. Basically diamond mining gave rise to gold mining. Recently gold mining has given rise to PGM mining. Coal mining has always played a crucial role of providing energy, initially through the generation of steam and lately through the generation of electricity and manufacturing of synthetic fuels.

3.4. The establishment of the Chamber of Mines of South Africa

The chaotic administration of claims, fraudsters and misrepresentation of results by mining officials led to the need to form an association that would look after the interests of miners in the Witwatersrand basin. To this effect, the Chamber of Mines was established on 7 December 1887 with the objective of gathering authentic mining statistics and publishing them periodically. Within two years of its establishment, the Chamber of Mines collapsed (Lang, 1987). According to Lang

the demise of the Chamber of Mines was due to its open membership, where anyone with slight interest in mining was eligible for membership. Open membership attracted individuals with differing and ulterior motives who smothered mine operators with real concerns.

The demise of Chamber of Mines brought forth the realisation of the need for an industry organisation. On the 5th of October 1889 the Witwatersrand Chamber of Mines (from here onwards called the Chamber of Mines of South Africa or CMSA) was formed by industry players which included the Corner House, Consgold and JCI. This time around the CMSA was focused solely on mining issues, a decision that led to its enduring life to date despite changing its name numerous times (see Table 3.2).

Table 3.2: Change of names for the Chamber of Mines of South Africa

Name	Period
Witwatersrand Chamber of Mines	1889 -1896
Chamber of Mines of the South African Republic	1897 - 1901
Transvaal Chamber of Mines	1902 - 1952
Transvaal and Orange Free State Chamber of Mines	1953 - 1967
Chamber of Mines of South Africa	1968 -

Source: Chamber of Mines of South Africa (<http://www.bullion.org.za>)

Over time the CMSA amended its membership, which corresponded with the change in the name. Original members of the CMSA were gold mining companies around Johannesburg. As the political environment changed in South Africa and

other commodity mines established elsewhere, the name changed to reflect changing times (Mawby, 2000).

Among other things, the CMSA was instrumental in the facilitation of new technologies in the mines, notably the development of portable rock-drills which dramatically increased production in gold mines. The cooperation of Mining Houses inside and outside the CMSA, the co-option of various professional organisations, and the political support from the government collectively made it less arduous for the CMSA to tackle common problems facing the mining industry.

By 1990 the CMSA was offering various services to its members through its five divisions, namely Corporate Services; Health Care Services; Recruitment Services (The Employment Bureau of Africa or TEBA); External Relations; and Operations. Under the Operations division, various organisations were established including the Chamber of Mines Research Organisation (COMRO); Safety and Technical Services; and Environmental Management Services. COMRO was formally established in 1965 and was mandated to undertake research in mining. To fulfil its mandate, COMRO had to establish various specialist units as shown in Table 3.3 (CMSA, 1990).

Table 3.3: Specialist units under COMRO and their functions

Unit	Brief description	No. of personnel
Executive Research Office	Executive management of COMRO	23
Administrative and Professional Services Branch	Provision of administrative services which include budgeting, accounting, publicity and maintenance of a library	130
Coal Mining Laboratory	Research in coal mining	31
Engineering Services Branch	Provision of mechanical, hydraulic and mechanical services, including building of specialised machinery	96
Engineering System Laboratory	Research in hydraulics, machines and materials	53
Environmental Engineering Laboratory	Research in underground climate and water quality	43
Gold Exploitation Laboratory	Technical Evaluation and prediction of insitu gold distribution	49
Human Resource Laboratory	Consultant agency relating to the development of proper industrial relation procedures and communication	39
Industrial Hygiene Laboratory	Consultant agency relating to health and safety issues	55
Mining Branch	Consultant agency relating to conducting trials and implementing new technologies	75
Rock Mechanics Laboratory	Research in support systems and design of new and safe underground mining layouts	43
Stoping Technology Laboratory	Development of new stoping methods and machinery to improve productivity	31
Hazardous Material Unit	Consultant agency relating to investigation into the use of hazardous material on mines	5

Source: CMSA (1986)

3.5. Home grown mining companies – abridged history

The tripartite animosity between European (oppressors), the less oppressed Afrikaners, and the oppressed Africans did not escape the attention of the CMSA. The class separation endorsed by the CMSA was evident in the mines where Europeans were enjoying preferential treatment, followed by Afrikaners and lastly

Africans who were barred from any significant position other than being just labourers (Pogue, 2006a).

Right from the inception of mining in the Witwatersrand basin, Europeans and in particular British nationals wielded significant influence in mining and consequently benefitted more than any other constituents. Their fortunate position largely stemmed from South Africa being a colonial state of Britain. In the 1940s as the grip of Britain lessened on South Africa, Afrikaners took more prominence in politics and industry with a drive towards their increased participation in mining¹⁴. Significant empowerment of Afrikaners in mining at ownership level came in the late 1940s in the form of Federale Mynbou, a mining company that was established with the blessings of the South African government for the benefit of Afrikaners (Freud, 1991).

Through the help of Harry Oppenheimer of Anglo American Corporation in the 1960s, Federale Mynbou took control of General Mining and Finance Corporation, a company that was established in 1895 by two German nationals and became one of the top Mining Houses in the early days of mining in the Witwatersrand basin. After the merger, the resultant entity traded as General Mining (Genmin) as from 1965. In 1980 Genmin merged with Union Corporation (a company that was established by another German entrepreneur) to form Gencor. In 1994 Gencor bought Billiton International, a company with Dutch origins. Gencor used Billiton to house its non-gold assets soon after the first South African democratic election in 1994. In 1997 Billiton was separated from Gencor to become a standalone entity

¹⁴ Previously Afrikaners were largely focused on farming

with its main listing on the London Stock Exchange. In 2001 Billiton merged with BHP to form BHP Billiton, an Anglo-Australian company.

In 1998 Gencor merged with Gold Fields of South Africa (GFSA) to form Gold Fields Ltd. Gold Fields of South Africa (GFSA), a company that had strong links with the British government, was established in 1887 by Cecil Rhodes and Charles Rudd. In 1892 the company was reorganised into Consolidated Gold Fields of South Africa (Consgold) and became a Mining House that provided mines in the Witwatersrand basin with capital and expertise in exchange for their control. In 1959 a subsidiary of Consgold was established to manage its southern African assets. In 1971 a South African based West Witwatersrand Areas Ltd took over the Consgold's southern African assets and the right to the name of Gold Fields of South Africa¹⁵. The merger of GFSA and Gencor catapulted the resultant entity (Gold Fields) into the second biggest mining company in South Africa after Anglo American Corporation.

Another mining company that has been influential in the South African mining history is Anglo American Corporation (AAC), established in 1917 by Sir Ernest Oppenheimer (a naturalised British national with German origins), thanks to capital injection from USA companies and institutions. In 1926 AAC became the largest shareholder of De Beers Consolidated Mines (DBCM) with effective control taking place in 1929. De Beers was established by Cecil Rhodes and Charles Rudd in 1880 after acquiring claims from individual diamond miners in Kimberley. De Beers and Barney Barnato's Barnato Diamond Mining Company were rivals in diamond

¹⁵ Source: <http://www.enotes.com/company-histories/gold-fields-ltd/history-gencor-ltd>

mining and trade. The rivalry ended in 1888 when De Beers bought Barnato Diamond Mining Company to form DBCM¹⁶.

The ability of AAC to raise capital internationally gradually established it as the largest mining company in South Africa with influence in exploration, mining, research, financing, manufacturing, property and politics. In the late 1930s AAC, in collaboration with other Mining Houses, undertook strong exploration¹⁷ drive in the Witwatersrand basin and the resultant was the discovery of Welkom, Carletonville and Klerksdorp goldfields between 1945 and 1960. The discovery undoubtedly made AAC the premier gold mining company internationally. Subsequent establishment of new gold mines attracted people from all the corners of South Africa and neighbouring countries. The demand for housing and services in the new mining regions gave birth to towns of Welkom, Carletonville, Evander and Stilfontein¹⁸.

Political changes of the 1990s in South Africa forced many mining companies to change how they go about doing business. For example it became imperative for AAC to economically empower blacks¹⁹ in much the same way as it empowered Afrikaners when they took over political power in the 1960s. The economic empowerment of black people gave rise to Johnnies Industrial Corporation Ltd (Johnnic) and African Rainbow Minerals (ARM) in the 1990s. The latter is the most successful mining empowerment company in South Africa.

¹⁶ Sources: Timeline: <http://www.google.com/search>; and http://en.wikipedia.org/wiki/Barney_Barnato.

¹⁷ Through exploration it was established that the Witwatersrand basin extends from Johannesburg to Welkom in a north-southerly direction and from Klerksdorp to Evander in a west-easterly direction.

¹⁸Source: <http://www.fundinguniverse.com/company-histories/Anglo-American-PLC-Company-History.html>.

¹⁹ Blacks in this case means Africans, Asians and Coloureds (mixed race people)

In the 1990s mining companies had to deal with a threat of nationalisation or at least the interference of government in mining. To this effect AAC separated its gold assets from other assets which included its international operations and moved its primary listing to the London Stock Exchange (LSE). Consequently its headquarters moved from Johannesburg to London. Because of the London listing, the company changed its name to Anglo American plc. The South African based gold assets of Anglo American were named Anglogold. In 2004 Anglogold merged with Ashanti Gold of Ghana to become Anglogold Ashanti. Anglo American divested from Anglogold Ashanti in 2009.

3.6. Reorganisation of mining in the 1990s

During the rationalisation of the mining industry in the 1990s, South Africa lost out to being a home to global mining giants despite having a long history of mining, the largest in-situ mineral resources in the world, unparalleled expertise in deep level mining and the largest English speaking mining school in the world²⁰. In fact the battle was lost with the formation of Mining Houses in the 1890s. Mining Houses borrowed capital funds from banks and institutions in United Kingdom, USA and Europe which effectively amounted to foreign ownership of South African mines (Mawby, 2000). Furthermore Britain's interest in the South African gold mines was strategic. The Bank of England was used to regulate the sale of gold in support of the British pound (Pogue, 2006a).

Local miners of that time felt left out of the bounty and cheated of the opportunity to better their lives, a legacy that was transferred from British settlers to Afrikaners

²⁰ Source: <http://www.edumine.com/miningschools/school.asp?school=wits>

and from the latter to historically disadvantaged South Africans (HDSA)²¹. In recent times the government of South Africa has sought to empower the HDSA through the promulgation of the Mineral and Petroleum Resources Development Act (MRPDA) and institutionalisation of the Mining Charter (see section 3.7).

While technical competency of South Africans in mining is unquestionable, limited local capital is a constant impediment to the creation of locally based mining giants. For example Figure 3.2 ranks top 10 mining companies in terms of market capitalisation in 2010 and it can be observed that none of the South African mining companies were in the top 10 ranking globally. On the other hand it can be seen in Table 3.4 that the highest ranking South African mining company globally in terms of the value of output in 2009 was AngloGold Ashanti in thirteenth position.

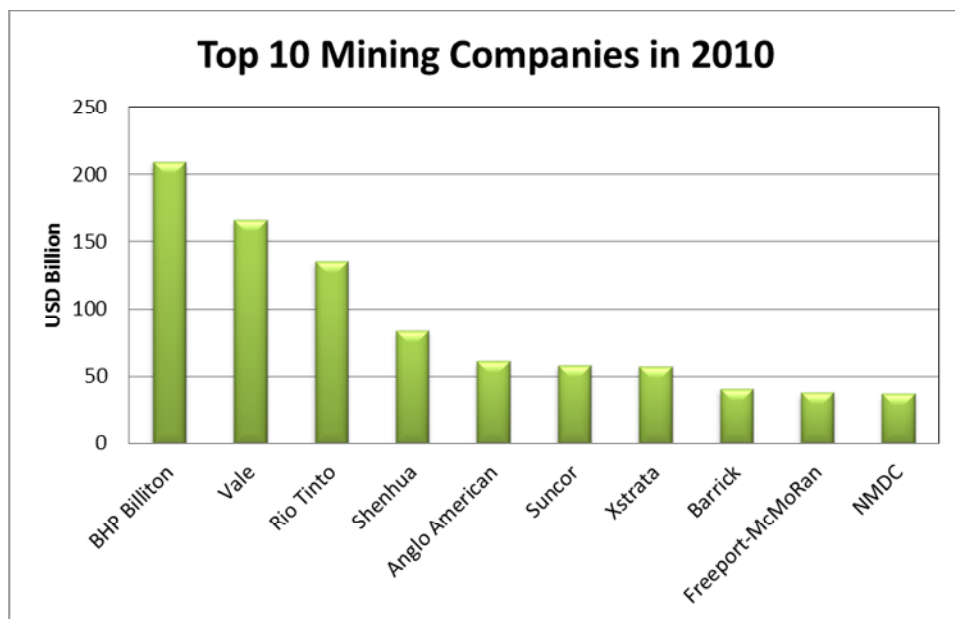


Figure 3.2: Top 10 mining companies ranked according to their market value in 2010²²

²¹ HDSA is term designated to Blacks and White women in South Africa who were excluded from property ownership and economic participation under the Apartheid laws.

²² Source: <http://www.mineweb.com/mineweb/view/mineweb/en/page67?oid=95737&sn=Detail>. Accessed on 01 March 2011.

The action of mining giants such as AAC and Gencor of splitting their assets in an apparent move to anticipate the actions of the incoming government did not help the situation either. The self-preservation path followed by mining companies from the mid-1980s right through 1990s had also a devastating effect on a collaborative research that had been the hallmark the CMSA from its inception and later COMRO as from 1965.

Table 3.4: The world's largest mining companies ranked according to the value of mining output in 2009

<i>Rank</i>	<i>Company</i>	<i>Country</i>	<i>% of total</i>
1.	Vale	Brazil	5.6
2.	BHP Billiton	Australia	5.1
3.	Anglo American	United Kingdom	3.9
4.	Rio Tinto	United Kingdom	3.8
5.	Freeport McMoRan	United States	3.6
6.	Norilsk Nickel	Russia	3.3
7.	Codelco	Chile	2.9
8.	Xstrata	Switzerland	2.9
9.	Barrick Gold	Canada	1.6
10.	Group Mexico	Mexico	1.6
11.	Teck	Canada	1.1
12.	Newmont Mining	United States	1.0
13.	Anglogold Ashanti	South Africa	0.9
14.	Glencore International	Switzerland	0.8
15.	KGHM Polska Miedz	Poland	0.8
16.	Antofagasta	United Kingdom	0.8
17.	Impala Platinum	South Africa	0.7
18.	Vedanta Resources	United Kingdom	0.7
19.	Gold Fields	South Africa	0.7
20.	Kazakhmys	United Kingdom	0.7

Source: Humphreys (2009: p4)

In the mid-1980s support for COMRO started to wane due to a number of reasons that included:

- falling gold prices in line with other non-oil commodities, hence the profitability gold mines declined (see Figure 3.3);
- the end of COMRO's ten year mechanisation programme in 1990 which had a muted success;
- globalisation and divergent strategies of gold miners that led to the end of collaborative research; and
- a threat of the imposition of a mine safety levy by the government due to its increasing intolerant to high mine fatality rates.

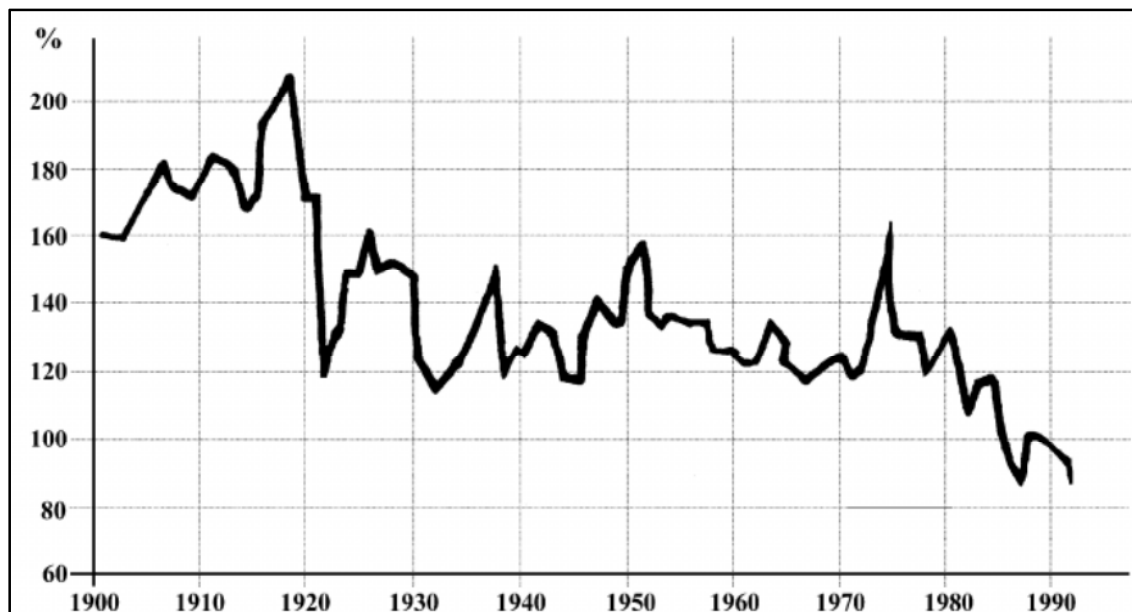


Figure 3.3: Change in the average of real prices of all mineral commodities (excluding oil and gas) from 1900 – 1992

Source: Wirtschaftsvereinigung Bergbau, 2000 in Wagner and Fettweis (2001)

The contemplated safety levy implied that mines would be expected to fund the State's safety research programme in addition to their voluntary COMRO contributions. In anticipation of the safety levy, mines reduced their COMRO contributions in the early 1990s which in turn reduced its research capacity (Pogue, 2006a). Many mines thereafter opted to conduct their own research. The unfortunate part was that the research by mines was more opportunistic, aiming for incremental changes compared to the fundamental and ground-breaking research by COMRO.

The promulgation of the Minerals Act in 1991, that eventually paved way for the establishment of Safety in Mine Research Advisory Council (SIMRAC) in 1993, and the decline in the gold sector profitability in the early 1990s were the last blows to the financial viability of COMRO. The resultant safety levy prompted mining companies to curtail COMRO funding to unsustainable level. In a bid to retain COMRO's intellectual property, a decision was made to bring it under the control of the Council for Industrial and Scientific Research (Pogue, 2006a).

The fate of COMRO was not unique, many of the renowned research institutes internationally were either closed or forced to change in the 1990s. For example the National Coal Board in United Kingdom, the US Bureau of Mines in USA, and research facilities of Charbonnages de France in France were disbanded. The Bergbauforschung in Germany was reduced in size and turned into a commercial entity. The Australians however bucked the trend to establish Cooperative Research Centre for Mining Technology and Equipment in 1991. All these changes in the global mining research coincided with a drop in a number of BSc

and MSc graduates in the North American universities from 700 to 150 in a period from 1990 to 1997 (Wagner and Fettweis, 2001).

3.7. Politics and the mineral sector in South Africa

The ability of mines to create wealth has made them a target for nationalisation by the African National Congress Youth League (ANCYL) in recent times (ANCYL, 2010). In retrospect, the association of mines with nationalisation in South Africa started in the 1940s. Afrikaner nationalists back then, when mines were overwhelmingly owned by English-speaking persons, pondered with the idea of nationalising mines. This idea was pondered despite the Afrikaners being given an opportunity to make inroads into the mining industry as both investors and workers by the Union government²³ through the establishment of Federale Mynbou (Sanlam, n.d.).

Despite the pressure from its constituents, the Union government settled for taxation policies aimed at creating mining employment for the Afrikaners while at the same time invigorating industrial sector activities. During this time (late 1940s to 1960s) the industrial sector was growing at a faster rate than the mining sector (Freund, 1991).

When South Africa became a republic under the National Party (NP) in 1961, mining and industrial sectors were largely in private hands. The NP regime used mining exports (especially gold) as an important source of foreign income. There was a general contentment in government to leave mining in private hands as long

²³ South African government under British dominion from 1910 to 1961

as it was bringing in the necessary foreign revenue inflows to bolster the inward looking industrial sector (Black, 1991).

To direct the country's industrial development for the benefit of the Afrikaner working class, the government strategically used parastatals such as SASOL, ARMSCOR, TELKOM, ESKOM and ISCOR to compete with the private sector in areas where these parastatals had a clear advantage (Aron *et al*, 2009). Many of these parastatals became monopolies in their respective industries, the legacy that still exists today. Few State owned mining companies such as SASOL (steam coal), ISCOR (metallurgical coal) and FOSKOR (phosphate) have shown that protected niche markets with strong beneficiation drive can be successful while direct competition with private sector companies in areas where there is a lack of downstream beneficiation can be unsuccessful as it is the case with Alexkor (diamonds)²⁴. The latter was established in 1925 as State Alluvial Diggings to mine diamonds along the west coast of South Africa²⁵.

During the 1970s, South Africa followed an import substitution policy as it was the case with other resource-based countries of South America. This was contrary to the outward looking export oriented policy of Asian countries (Gelb, 1991 and Edwards *et al*, 2009). The import substitution and the limit on funds that could be invested off-shore by South African companies led to some Mining Houses such as AAC and Genmin to diversify into the industrial sector which grew from a GDP contribution of less than 13% in 1946 to more than 23% by 1970 while direct contribution of mining to the GDP declined (Black, 1991).

²⁴ Sasol and Foskor were privatised while Alexkor is still a State owned enterprise (SOE)

²⁵ Source: http://www.alexkor.co.za/NewsMiningWeekly01062003_Priv.asp

The diversification of Mining Houses into the industrial sector as well as strong beneficiation focus of SASOL, ISCOR and FOSKOR gave impetus to the development of the industrial sector and job opportunities for the growing white population (especially Afrikaners) then.

According to Gelb (1991), 1974 marked the downturn in the South African economy, a trend that persisted right through into the 1990s. The downturn coincided with the 1973 oil crisis. This downturn period was marked by the rise in inflation, drop in private sector investment, drop in personal saving, capital flight due to sanctions against the NP government (because of Apartheid), depreciation of the rand against the dollar and drop in employment opportunities (mainly Africans). In the midst of all these economic problems, the oppressed black majority intensified their revolt against the government's repressive laws.

When the ANC was unbanned in 1990 there was a general expectation that it will follow socialist or communist economic policies which included nationalisation (largely stemming from the Freedom Charter). This did not happen due to a number of factors that included the collapse of commandist economies during the 1980s, especially the USSR which supported the ANC in exile. The free market system gained global prominence during this time and the only way that the ANC government could attract capital inflows was to abandon any intentions to nationalise the economy (Ceruti, 1996).

It should be noted that the South African democracy is a product of a negotiated settlement. In negotiations concessions are made based on the strength of the

opponent and realities on the ground. The strength of the ANC's opponent was in its access to state machinery and financial resource (fiscal), while that of ANC was vested in its mass support base and distant international opponents of apartheid (Ceruti, 1996 and Aron *et al*, 2009).

During the negotiations (between 1992 and 1994) domestic debt was approaching unsustainable levels and the budget deficit was at 8%. At the same time Kwazulu-Natal was on the verge of a civil war and black South Africans in general were becoming impatient with the winding negotiations. Given these situations and others mentioned afore, the ANC saw it fitting to stick to the deadline of elections by 1994 and in the process concessions were made lest the situation deteriorated to undesired state (Ceruti, 1996).

It is therefore not surprising that the ANC government that emerged after 1994 elections opted for export-oriented economy supported by a steady private sector investment. These were underpinned by privatisation of state assets, prudent fiscal policy and responsible monetary policy. All these developments meant that the nationalisation of mines policy was off the table for the time being (Aron *et al*, 2009).

Despite concessions and retraction on nationalisation policy, many South African mining companies sought dual or multiple listing on JSE and others such as LSE and New York Stock Exchange (NYSE). International assets were separated from local assets in the process. Separation of assets and dual listings diluted

ownership of South Africans in companies mining mineral resources in South Africa, leading to a loss of industry control.

Nonetheless political changes of the 1990s in South Africa opened up opportunities for HDSA to own mines. Previously the HDSA were denied ownership of mines under Apartheid laws. This new development led to the accumulation of wealth among a handful of the HDSA. In 2004 the industry was transformed further through the promulgation of the Mineral and Petroleum Resources Development Act of 2002 (MPRDA) which made the State the custodian of all mineral resources.

The combination of the MPRDA and the Mineral and Petroleum Resources Development Royalty Act (Royalty Act) of 2008, with respect to State custodianship on the country's mineral resources, borders on indirect expropriation or a process of creeping expropriation²⁶ of mineral resources according to Leon (2009). The custodianship basically translates into nationalisation on mineral resources and not that of the mines. But most importantly the MPDRA legislated the creation of a Mining Charter under section 100(2)(a) in 2002, with the revised version taking effect in 2010. The aims of the Mining Charter, among others, are to facilitate economic participation of HDSA in the mining industry and promote mineral beneficiation within the borders of South Africa (MPRDA, 2002 and Mining Charter, 2010).

²⁶ "The incremental encroachment of an investor's ownership rights by a host state, which effectively neutralises such investor's rights" (Leon, 2009:p 597)

It is safe to say that the current South African mining legislation and policy seek to empower HDSA through pseudo free market system as opposed to outright nationalisation. This is in line with the action of the Union government where nationalisation of mines was avoided in favour of the next best option.

That being the case, privately owned mining industry in South Africa has always been part of the job creation agenda whether directly or indirectly. In line with this characterisation of the mining industry, this report re-emphasises the ability of mining within the mineral sector to create employment opportunities through economic linkages provided there is political will to that effect.

3.8. Concluding remarks

The history of mining in South Africa dates as far as 1000 years ago when copper was mined in Phalaborwa. There is also evidence of gold mining and trading between the residents of Mapungubwe, Arabs and Orientals. Mining activities by the locals persisted up to the dawn of modern history of mining in South Africa, which can be said to have started in 1846 when the British took over copper mining in Namaqualand from the Dutch.

Mining in South Africa was given impetus by the discovery of diamonds near Kimberley in 1870 and the discovery of gold in the Witwatersrand basin. Both discoveries were so large that they attracted many international professionals in the mineral sector and entrepreneurs to South Africa. The arrival of professionals and entrepreneurs in South Africa led to the formation of the Chambers of Mines of South Africa in 1889 and Mining Houses in the 1890s.

From the humble beginnings in Kimberley, mining subsequently led to the formation of many towns in South Africa which include Johannesburg, Carletonville and Welkom. With towns, came other economic activities as people flocked into these towns in search of employment. This economic and social potential of mining has always fascinated politicians. It was then not surprising that the nationalists among the Afrikaners sought to nationalise mines in the 1940s. However the idea was thwarted in favour of the establishment and strengthening of industrial parastatals such as ISCOR, SASOL, ARMSCOR and ESKOM. Through these parastatals, including those in agriculture and transportation, many employment opportunities were created for the Afrikaners. The idea of nationalisation of mines rose again in 1990s when the ANC was preparing to govern South Africa. This was again thwarted in favour of trade liberation and privatisation of parastatals after 1994. In 2010 the ANCYL raised the issue of nationalisation of mines again and the response was again to look for alternative solutions.

Back in the 1980s when the political tension between blacks and whites reached climax, and when it was evident that the communist-backed ANC will eventually become the government in South Africa, Mining Houses reorganised themselves for the possibility of the nationalisation of mines. For example Gencor and AAC bought international mining assets and separate them from the South African assets.

When the pro-capitalist ANC government allowed dual listing of big companies after 1994, companies such as Billiton (a product of acquisition strategy of Gencor) and AAC took the opportunity to relocate their primary listing to foreign countries. This move resulted in South Africa not being a home to big international mining companies despite a century of mining and innovation in underground mining.

The innovation in mining was mainly driven by COMRO, a research organisation that existed in many forms since the 1890s and formerly established in 1965. The fate of COMRO was sealed by the reorganisation of the mining industry and the establishment of SIMRAC in the early 1990s. When COMRO closed down its operations in 1993 and many scientists in its employment emigrated elsewhere, many feared that this move will usher the death-knell to the resource-based research in South Africa. However this was not the case as it will be shown in section 5 of this report that research in mining continued beyond 1993, albeit not as strong as during the pre-1993 era.

4. LINKAGES IN THE SOUTH AFRICAN MINING INDUSTRY

4.1. Introduction

The development of a new mine has the potential to stimulate regional economy through creation of employment and collection of rent and taxes by regional authorities and the central government. Employment created by a mine is either direct or indirect. All those that are in direct employment generally derive their primary income directly from the mine. Indirect employment on the other hand is created in other sectors because of the demand for products and services generated by the mine or local beneficiation of mine outputs.

The establishment of mines in South Africa has managed to stimulate regional economies with varying levels of success. Undoubtedly Johannesburg and surrounding towns have benefited enormously from the 120 years of gold mining. Mining activities around Johannesburg have resulted in the aggregation of manufacturing companies or their representatives in Ekurhuleni and financial corporations, mining consultants, and mining analysts in Johannesburg.

The mining of gold and other commodities in South Africa was supported by intensive R&D programmes of Mining Houses and CMSA in one hand and the Science Councils on the other hand. At the dawn of the modern history of mining in South Africa, engineers and scientists that participated in R&D programmes came from European countries and USA. Over time, as technically oriented

universities and Science Councils were established by the government, South Africans began to participate in research programmes.

R&D and ultimately the implementation of new technologies have the potential to create linkages in the economy. This phenomenon can be explained better by considering case studies such as those discussed in section 4.4. Notwithstanding, research competency of South Africa such as those housed in Science Councils and universities appear not to be adequately augmented by R&D capability and the ability to translate research into commercial goods and/or services.

4.2. Mining related Science Councils in South Africa

Mining in South Africa has led to the formation of reputable research institutions such as the Council for Mineral Technology (Mintek) in 1934²⁷ and the Chamber of Mines Research Organization (COMRO) in 1965. Sadly COMRO was taken over by the Council for Scientific and Industrial Research (CSIR) in 1993. The takeover retarded the momentum of fundamental and applied mining research in South Africa. The resultant unit under the CSIR had no option but to focus on niche research projects in areas of safety and health while production related R&D was taken up by original equipment manufacturers (OEM) in collaboration with mining companies (Pogue, 2006a).

²⁷ Source: <http://www.mintek.co.za/>

Mining is also directly responsible for the formation of the University of the Witwatersrand (Wits) which started in Kimberley in 1896²⁸. Today the School of Mining Engineering at Wits is recognised as the largest English speaking mining school in the world.

4.2.1. The Council for Geoscience

The Council for Geoscience (CGS) is a public entity established under the Geoscience Act of 1993. It is mandated “to gather, compile, interpret and disseminate geoscience knowledge for South Africa, as provided for by the Geoscience Act” (CGS, 2010).

The CGS undertakes work across various disciplines including mining. Some of the work done during the reporting season of 2009 and 2010 included exploration for rare earth minerals in South Africa. The rare earth minerals are becoming valuable commodities due to the growth of high technology manufacturing and green industry, one of the industries identified by BUSA (2010) as having the potential to create meaningful jobs in South Africa.

Significant world deposits of rare earth minerals are known to be in China and governments of developed countries (including China) are said to be building strategic stockpiles of these minerals. If deposits of significant value were to be found in South Africa, it is envisaged that new extraction techniques that are

²⁸ Source: http://www.wits.ac.za/aboutwits/introducingwits/short-history-of-the-university/3162/short_history_of_the_university.html

sensitive to their rarity and subsequent downstream industries will have to be developed so that more value and job opportunities can be realised (CGS, 2010).

The CGS is also investigating underground carbon dioxide storage capabilities. This is in line with carbon sequestration research by the coal industry. If successful, both carbon dioxide storage and carbon sequestration will render coal generated electricity and manufacturing of iron, steel, and petrochemicals environmentally friendly to some extent. Most importantly carbon dioxide storage and carbon sequestration will emerge as new industries with the potential to absorb labour. Similarly the study by the CGS on the use of cost effective polyurethane foam in sealing sinkholes in dolomitic areas and abandoned mine shafts across the country could have the potential of creating jobs in the medium term while rendering unsafe land safe (CGS, 2010).

Other exciting work undertaken by the CGS involves the exploration of new coal resources with the view of extending the life of coalfields such as Waterberg, Somkhele, Kangwane, Sasolburg-Vereeniging, Free State and Springbok Flats (CGS, 2010).

4.2.2. Council for Scientific and Industrial Research

The Council for Scientific and Industrial Research (CSIR) is a multi-disciplinary entity established in 1945 through the act of parliament to conduct R&D in South

Africa. The scope of the CSIR includes research in biosciences, defence and security, manufacturing, materials development and mining²⁹.

The CSIR absorbed COMRO in 1993, a move that was prompted by the intolerance of government for high accidents rates on the mines and the waning collaboration between Mining Houses insofar as research was concerned. After absorbing COMRO, the CSIR began providing consultancy services in the field of mine health and safety to the mining industry through SIMRAC (Pogue, 2006a).

Achievements of CSIR include the reduction of pneumoconiosis (silicosis) in gold mines, the revamping of heat stress management in deep underground mines, the introduction of borehole radar for accurate delineation of reef topography and the implementation of preconditioning technique that reduced incidents of rock burst at the stope face and subsequently enabled the mining of Ventersdorp Contact Reef at great depths³⁰.

Currently CSIR is conceptualising mechanised mining methods using equipment as small as a bottle of wine in deep underground mines (the Nederburg miner). It is envisaged that the final product will be automated or tele-operated with no human beings in sight. CSIR is also looking into introducing supervisory, control and data acquisition (SCADA) systems in underground mines. This system has the potential of providing timely data, creating new knowledge faster than the current system, and reducing operating costs³¹.

²⁹ Source: http://www.csir.co.za/profile_of_csir.html

³⁰ Source: http://www.csir.co.za/mineral_resources/pdfs/factsheet_mining.pdf

³¹ Source: http://www.csir.co.za/mineral_resources/mac.html

Apart from mining technologies, CSIR is actively involved in downstream mineral beneficiation technologies. To this effect, CSIR has developed a hub for Titanium Centre of Competence. The objective of the Titanium Centre is to develop the South African competency in the beneficiation of titanium ore. South Africa has the world's second largest resource of titanium after Australia and yet it is not producing titanium metal. It is projected that South Africa will have the capability of producing 20 000tpa of titanium powder by 2020. In addition to the production of titanium powder, the CSIR hopes to develop domestic capability of moulding complex titanium shapes and thereby giving South Africa a competitive edge (CSIR, 2010 and Venter, 2011).

In addition to the Titanium Centre of Competence, CSIR is spearheading the entrance of South Africa into the light metal industry through the Light Metals Development Network under the Advanced Metals Initiative. This initiative is designed to give South Africa a unique competency in the light metal industry, a feat that is supposed to give the country a competitive edge as well as creating jobs (CSIR, 2010).

4.2.3. The Council for Mineral Technology

The Council for Mineral Technology (Mintek) was established by the government of South Africa in 1934³² as a research institution, which provides metallurgical services and products to the extractive industry. The mandate of Mintek is articulated in one of its key objectives as being to “develop efficient mineral

³² Source: <http://www.mintek.co.za/>

processing technologies and sustainable value added products and services” (Mintek, 2010: p10). While being guided by its key objectives, Mintek has diversified its portfolio to cover the entire mining value chain while retaining its main focus on the metallurgical industry. Through the years the company has managed to transform itself into a global player by exporting its technology and collaborating with other international research institutions.

Some of the research projects that Mintek is currently looking at include finding other uses of gold through its AuTek Project in collaboration with AngloGold Ashanti, new uses of platinum, and enhancing the understanding (characterisation) of PGMs. In addition, Mintek is focused on developing superior extraction technology of titanium and iron (from magnetite) in the Bushveld Complex given that they are believed to be among the largest deposits in the world. Most importantly (in the context of high unemployment rate in South Africa) Mintek, where possible, commercialises technologies through its subsidiary, Mindev. For example Mindev in conjunction with Jubilee Platinum piloted the ConRoast technology in treating PGM ore with high content of chrome (Mintek, 2010).

Mintek has also a division that capacitates artisanal miners with mining skills, management of safety and health in the workplace, and environmental management. In particular miners are taught to produce final products from their mining operations. For example clay miners are taught how to produce bricks for buildings and clay-pots for the decoration market (Mintek, 2010). The effect of this approach is the creation of localised economic linkages.

4.3. Institutions of higher learning in mining engineering

There are four institutions of higher learning (tertiary) in South Africa that offer junior degrees or diplomas in mining engineering, namely the University of the Witwatersrand (Wits), University of Pretoria (UP), University of Johannesburg (UJ) and Florida Campus of University of South Africa (UNISA). Only Wits and UP offer post graduate degrees in mining engineering (see Table 4.1). Just like Science Councils, all institutions of higher learning that offer mining tuition are located in the Gauteng Province.

Wits was established in 1896 to provide formal mining education to officials working in the mines of Kimberley. It was originally called the South African School of Mines. As mining got stronger in the Witwatersrand, after the discovery of gold, the School of Mines was moved to Johannesburg and renamed the Transvaal Institute of Technology and the Transvaal University College (TUC) in 1904 and 1906 respectively. In 1908 the administration of TUC was split in two, one half moved to Pretoria and was renamed the Transvaal Universiteit Kollege or TUK in short. When TUK attained university status in 1930, it was officially renamed the University of Pretoria (UP). The other half of the administration that remained in Johannesburg was renamed the Transvaal School of Mines. In 1922 the Transvaal School of Mines was given a university status and changed its name to the University of the Witwatersrand (Wits)^{33,34}.

³³ Source: <http://student.wits.ac.za/Residences/Mensres/History.htm>

³⁴ Source: <http://web.up.ac.za/default.asp?ipkCategoryID=2>

Table 4.1: Mining degrees and diplomas offered by South African universities

Institution	Degree/Diploma	
	Undergraduate	Postgraduate
University of the Witwatersrand (Wits)	BSc (Eng)	GDE; MSc (Eng); & PhD
University of Pretoria (UP)	BEng	BEng (Hons); MEng; PhD
University of Johannesburg (UJ)	BTech & HND	-
University of South Africa (UNISA)	Diploma	-

From the inception of Wits and UP, the number of students enrolling for mining engineering degrees (at Wits and UP) has increased steadily. Historically mining students were white males, principally stemming from the sections of Mines and Works Act of 1911 that excluded Africans from being anything other than labourers on the mines and women from working underground (Cruise, 2011).

While other racial groups were not explicitly excluded by the said act, it can be inferred that it was not socially acceptable for them to be mining engineers. While similarly nobody was excluded from studying mining engineering degree at Wits, it is not far-fetched to conclude that conditions in South Africa then were not conducive for other racial groups and women to practice as mining engineers locally.

Nonetheless, racial transformation of the mining engineering degree at Wits began with the enrolment of the first Asian student in 1978 and the first African student in 1983. Gender transformation of mining began in 1990 when Wits enrolled two white female students.

Ultimately women were allowed to work underground after the provisions of the Mines and Works Act and the Minerals Act of 1991 were repealed by Mine Health and Safety Act of 1996. The growth in the number of students (both males and females) enrolled for a mining engineering degree at Wits between 1985 and 2010 is shown in Table 4.2 (Cruise, 2011).

Table 4.2: Number of first year mining engineering students at Wits

Year	Total	HDSA	% HDSA	Female	% Female
1985	32	6	19	-	0
1990	50	20	40	2	4
1995	52	34	65	-	0
2000	48	43	90	9	19
2005	103	102	99	28	27
2010	228	222	97	75	33

Source: Cruise (2011)

Table 4.3 shows the number of mining graduates from Wits and UP. It is notable that the number of female mining graduates has been increasing over time. In 2010 there were 83 graduates from the two universities and 25 (30.1%) of them were black females. Seven of the graduates or 8.4% were white males and there were no white female graduates. This is a remarkable transformation when considering that there were no black mining graduates before 1986 and females before 1994 (Cruise, 2011).

While it is encouraging to see an increase in the number of blacks, and females in particular, studying for the mining engineering degree, it is discouraging to know that these numbers come from a limited pool of matriculants. In 2005 approximately 509 152 grade 12 learners registered to sit in for final examinations

and 455 460 of them were black. Only 31 269 (6.9%) and 48 647 (10.7%) black learners wrote high grade papers in mathematics and physical science respectively. Disappointingly 14 773 (3.2%) and 18 614 (4.1%) passed their mathematics and physical science examinations respectively. If a total number of 509 152 (including whites and others) is taken into account, then a miserly 5.1% and 5.8% of 2005 matriculants passed high grade mathematics and physical science examinations (Breier, 2009). These learners are among those that graduated in 2009 and 2010 as indicated in Table 4.3.

Table 4.3: Number of mining graduates at Wits and UP

Year	University of the Witwatersrand		University of Pretoria	
	Female	Male	Female	Male
1994	1	36	0	0
1996	1	17	0	0
2000	1	27	0	0
2001	1	21	0	0
2002	1	19	1	11
2003	2	20	0	16
2004	5	21	0	19
2005	7	26	1	9
2006	1	24	3	30
2007	16	41	6	18
2008	12	32	2	21
2009	16	37	7	21
2010	20	40	5	18

Source: Cruise (2011)

Mathematics, physical sciences and English (and to some extent Afrikaans) are important subjects at school level for degrees in engineering, science and health sciences at approximately 21 universities and universities of technology in South Africa. All universities have their own attrition rates and this ultimately reduce the

number of graduates in the aforementioned degrees. It therefore turns out that a low pass rate at matric level does very little to curb a skill shortage problem in South Africa.

With little skills to go around, it becomes difficult for South African companies and research institutions to undertake R&D programmes on a large scale. Sadly this fact has the potential to limit a number of economic linkages that could otherwise be unlocked by technology intensive companies (such as modern mines), as it will be demonstrated in the case studies below.

4.4. Case studies in the mineral sector from 1890 to 2006

4.4.1. Case study 1: Dynamite in South Africa

The establishment of mines in the Witwatersrand basin in 1886 created a huge demand for dynamite due to the nature and scale of mining. In response to this growing demand, Paul Kruger (the then President of Transvaal) asked Alfred Nobel to build a dynamite factory at Modderfontein. Alfred Noble responded by establishing Zuid Afrikaansche Fabrieken voor Ontploffbare Stoffen Beperk or 'The Dynamite Company' in 1895 at Modderfontein. Today this dynamite company is known as African Explosives Limited (AEL), a global player in the manufacturing and supply of explosives.

At the onset of its establishment, the Dynamite Company was the biggest dynamite factory in the world until De Beers established its own dynamite factory at Somerset West in the Northern Cape Province in 1903. These two factories

catapulted South Africa into the premier producer and consumer of dynamite in the world at that time³⁵.

In 1908 the Dynamite Company built a second plant in Umbogintwini in Kwazulu Natal. In 1924 the Somerset West, Modderfontein and Umbogintwini plants merged to form African Explosives & Industry, a company that was controlled by the industrial division of De Beers and a forerunner of African Explosives and Chemical Industries Limited (AECI) and AEL³⁶. In 2004, eighty years after the formation of African Explosives & Industry, AECI ventured into the electronic detonation market through Denet³⁷.

During the initial stages of explosive manufacturing, South Africa relied on imported raw material. For example, low grade sulphuric acid produced from pyrite was about the only local raw material used in manufacturing of explosives. Low grade sulphuric acid was used to supplement high grade sulphuric acid imported from Italy. Waxed paper used for wrapping dynamite cartridges was also from Italy. Other imported valuable consumables were sourced from USA and other European countries. However, with the passage of time more and more consumables were sourced locally in line with the growth of the industrial sector.

4.4.2. Case study 2: Gold extraction technologies

When mining began in the Witwatersrand basin, it was easy to recover gold from the oxidised gold bearing ore by using amalgamation treatment process. As mines

³⁵ Sources: <http://www.explosives.co.za/about-ael/our-history.html>, accessed on 05 March 2011

³⁶ Source: http://www.aeci.co.za/aa_history.asp, accessed on 05 March 2011

³⁷ Detnet is a joint venture between AECI and Dyno Noble

went deeper, layers of sulphide were encountered which made it difficult to recover gold with amalgamation treatment process and consequently yields dropped by as much as 50%. The situation was made worse by low grades, rendering many mines unviable. Subsequent closure of mines led to a recession and exodus of labour out of the Johannesburg in search of better opportunities elsewhere (Mawby, 2000 and Pogue, 2006a).

The solution to low yields initially came in the form of chlorination process commissioned by Corner House at Robinson Mine in 1889. However due to its high costs of implementation and maintenance, marginal mines were not able to afford it. Many mines opted to rather continue with less efficient amalgamation treatment process or stop operations altogether. The real solution, however, came in the form of cyanidation treatment process under the MacArthur-Forrest patent. The cyanidation process was developed in mid-1880 and although it was less efficient than the chlorination process, it was affordable and it gave acceptable levels of gold yields. These characteristics led to its quick and wide spread acceptance (see Figure 4.1). In 1896 the MacArthur-Forrest patent was repealed after the intervention of the CMSA on behalf of the gold mining industry in the Witwatersrand basin (Pogue, 2006a). This resulted in a drop in treatment costs in subsequent years.

Another challenge that the mining industry in the Witwatersrand basin faced was the unsatisfactory crushing throughput rate of the stamp mills which was hindering the increase in the underground production. Due to low grades, high production volumes were imperative for the survival of the industry. The solution to the

crushing problem came in a form of tube mills, thanks to the collaboration of metallurgists from different Mining Houses. The introduction of tube mills between 1904 and 1906 resulted in higher rates of production and drastic drop in operating costs (Mawby, 2000).

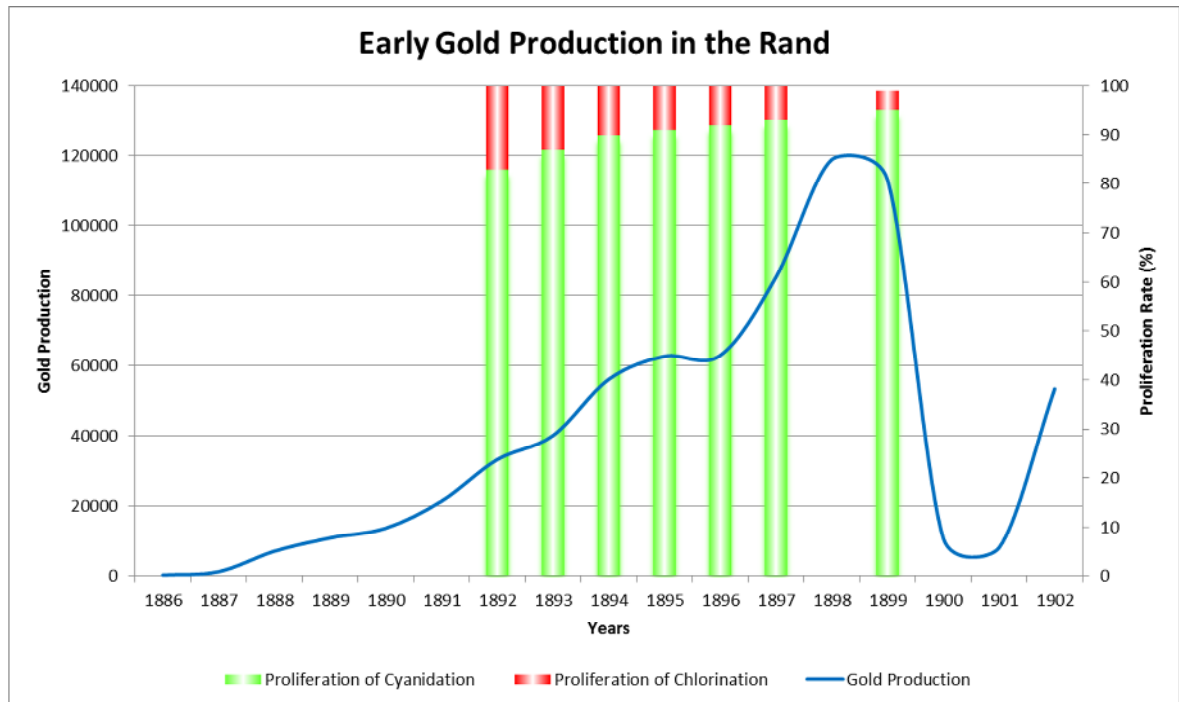


Figure 4.1: Proliferation of extraction technologies in the early days of gold production in the Witwatersrand basin³⁸
 Data sourced from Pogue (2006a)

Metallurgical challenges of the Witwatersrand basin ore, such as those mentioned above, attracted many professionals around the world to South Africa. These professionals held regular public discussions under the auspices of Chemical and Metallurgical Society of South Africa³⁹ with regard to work done on various mines. It is from these public discussions and collaborations that the discipline of extractive metallurgy was enriched (Pogue, 2006a).

³⁸ Proliferation data was not available in 1898, and drop in production from 1899 to 1902 corresponds to the South African War II (formerly Anglo-Boer War II)
³⁹ Now called The South African Institute of Mining and Metallurgy

4.4.3. Case study 3: Portable Rock-drills

The introduction of tube mills between 1904 and 1906 increased the throughput rate of treatment plants beyond the capacity of underground stopes. In addition, labour shortage (African labourers in particular) after the South Africa War made the situation worse. Underground drilling was literally a manual labour, executed by men hammering chisels into the rock and spitting water now and then to allay the dust. A drilling crew in those days consisted of 40 to 60 men and a target for each driller and his assistant was a single one metre hole per day. An incentive bonus was paid for exceeding this target (Pogue, 2006a).

When the South African War broke out in 1899 and later the First World War in 1914, many African labourers were taken away from the mines as general assistants in the military and with the reconstruction that followed thereafter, many did not return back to the mines. This turn of events put extreme pressure on the efforts of mines to attain acceptable production rate in order to stay viable (Pogue, 2006a).

In 1903 there was a concerted effort by mining companies under the leadership of the CMSA to introduce alternative technologies that could increase stope production. The biggest drawback then was the amount of blast holes drilled per day. The only viable solution to the problem was to introduce underground drilling machines which were already being used in USA and South America. From the options available then, the most qualified was the 1897 patented lightweight portable rock-drill. This drilling machine used a hammer technology with a chisel

that had a centre hole along its length to effect pneumatic and/or hydraulic flushing (Pogue, 2006a).

When the patent expired in 1914, the production of these particular portable rock-drills increased rapidly as their demand increased in the mines around Johannesburg. Flushing for these machines was achieved either through hydraulics (water) or pneumatics (compressed air) depending on the manufacturer. Like any other infant technology, these particular portable rock-drills faced a number of challenges in the beginning. For example, their size resulted in the increase in the stoping width which in turn increased dilution, much to the disapproval of some mines. Labour also resisted their introduction fearing wide spread redundancy. However through concerted effort of Mining Houses led by the Corner House and the blessing of the Transvaal government, portable rock-drills gradually became the premier stoping tools over the ensuing years. It took three decades, from 1904 to 1933 for the lightweight rock-drill to have full acceptance as the premier stoping tool as shown in Figure 4.2 (Pogue, 2006a).

The target for blast holes in the stopes before the era of portable rock-drills was a one metre hole per day per operator using hammer and chisel. With the advent of lightweight portable rock-drills, the target increased gradually from a single one metre hole per day to 16.6 and 10.4 one metre holes per hour for hydraulic and pneumatic rock-drills respectively by 1982 (CMSA, 1980). The productivity of rock-drills was obviously a catalyst for their demand and with the demand, the need to continually improve their performance arose.

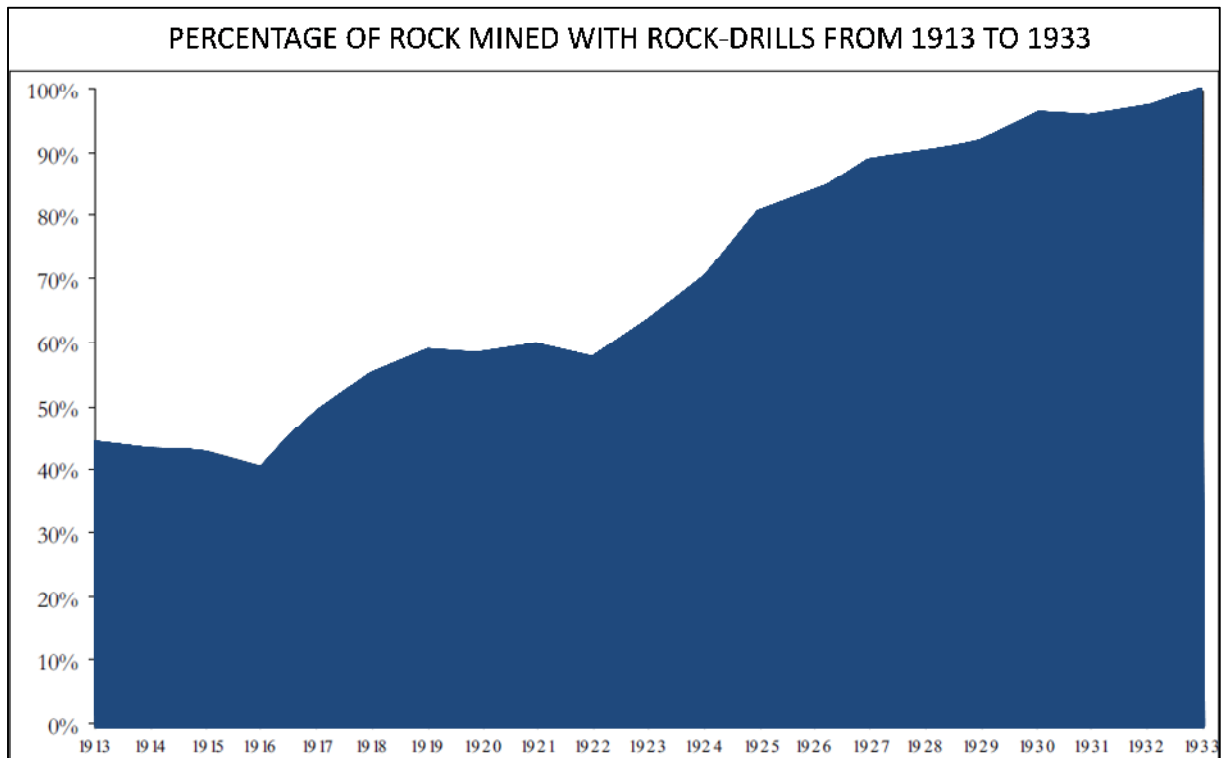


Figure 4.2: Penetration rate of portable rock-drills in the Witwatersrand basin between 1913 and 1933

Source: Pogue (2006a)

When COMRO was established in 1965, it ushered a new era of portable rock-drill development. This development came in two phases. The first phase distinctly comprised of the development of emulsion hydraulic (EH) technology between mid-1960s and late 1970s (Pogue 2006b).

Underground water or service water is highly corrosive and problematic to rock-drills. COMRO together with rock-drill manufacturers such as Ingersoll-Rand investigated the use of 95% to 5% ratio of water to oil (EH) respectively to provide lubrication and prevent corrosion. Unfortunately cumulative amount of oil in water presented an environmental hazard. Efforts were made to alleviate this problem by progressively reducing the amount of oil in water used by rock-drills (Pogue 2006b).

Progressive reduction of oil in water eventually ushered in the second phase in the development of rock-drills between 1980 and 1990. These rock-drills were designed to work with 100% water and the technology became known as the HH technology (Pogue, 2006b).

The development of the HH technology coincided with the development of hydro-power technology which involved the delivery of chilled water from surface to underground stopes for cooling purposes. The gravity head of the chilled water delivered underground provided enough energy in the stopes to power rock-drills and other equipment, a complete power solution for HH technology. The hydro-power technology was explored at Kloof Gold Mine in collaboration with COMRO in late 1970s and was eventually designed as a fully-fledged technology for Northam Platinum Mine in 1990 (CMSA, 1982 and CMSA, 1990).

The successful combination of hydro-power and HH technology at Northam Platinum ushered a new source of power for deep underground mines and the need to produce compatible equipment. Ingersoll-Rand, Novatek and Sulzer, which were invited to partner with COMRO in the development of both EH and HH technologies, became market leaders in the manufacturing of HH portable rock-drills. The need for other hydro-power equipment led to the formation of companies such as Hydro Power Equipment (HPE) in South Africa.

4.4.4. Case study 4: Drill bits

The growing stockpile of boart diamonds, especially from the Democratic Republic of the Congo⁴⁰, at the Central Selling Organisation (now Diamond Trading Company) of De Beers during the Great Depression precipitated a need for their profitable disposal. This idea came into realisation when it became possible to use boart diamonds as inserts in core-drilling bits, ideal for exploring the Witwatersrand basin. The drill bits were the results of collaborative work between the subsidiary of De Beers and AAC, Boart Products South Africa (Boart), and Materials Research Institute of Wits. These drill bits were suitable for long-hole drilling by big drill rigs and also gave high penetration rates (Robinson and von Below, 1990).

This was however not a new idea, Longyear used similar drill bits with 'carbodanos' diamonds⁴¹ inserts from Brazil approximately 45 years earlier, except that smaller drill machines were used. New drill bits by Boart enabled AAC to undertake extensive exploration of the Witwatersrand basin and the Zambian copper belt in the 1940s (Robinson and von Below, 1990).

The harsh conditions of underground stopes in the Witwatersrand basin presented further opportunities for Boart in the 1940s. The company developed drill bits with tungsten carbide manufactured in a factory in Springs, one of the biggest in the southern hemisphere despite South Africa not having large resources of scheelite and wolframite ore deposits (Robinson and von Below, 1990).

⁴⁰ The country was called Belgium Congo from 1908 to 1960. The name changed to Republic of Zaire in 1971 and in 1997 it was renamed the Democratic Republic of the Congo.

⁴¹ Source: <http://www.fundinguniverse.com/company-histories/Boart-Longyear-Company-Company-History.html>

When Boart entered the international mining and civil engineering market, it changed its name to Boart International to signify its organic growth. In 1974, Boart International took over Longyear and changed its name to Boart Longyear with manufacturing facilities in major mining and civil engineering centres worldwide and head office in Johannesburg⁴².

4.4.5. Case study 5: Ferrosilicon (FeSi)

The establishment of ISCOR in the early 1930s and later its incorporation in 1937 led to the development of a ferro-metal industry in South Africa. In 1942 ISCOR produced FeSi, a product that later became a solution to the recovery of diamonds at Premier Diamond Mine (now called Cullinan Mine).

A slump in the diamond market precipitated by the Great Depression in the early 1930s led to the closure of a number of diamond mines including the Premier Diamond Mine. In the 1940s when De Beers was planning to re-open the mine, it came to know of the properties of FeSi as a dense medium separator (DMS). The pilot test on the DMS process at Premier Diamond Mine was so impressive that it justified the reopening of the mine and complete replacement of the jigging process⁴³. The successful implementation of DMS process at Premier Mine led to its full acceptance across De Beers operations (Robinson and von Below, 1990 and Basson *et al*, 2007).

⁴² Source: <http://www.fundinguniverse.com/company-histories/Boart-Longyear-Company-Company-History.html>

⁴³ Primordial technology used in the treatment plant to recovery diamonds

The adoption of DMS by De Beers led to the establishment of a FeSi plant by African Minerals Corporation (Armco) at Meyerton (approximately 50 km outside Johannesburg) in 1950. Armco's FeSi division was later merged with Samancor in 1967 to become one of the global leaders in the production of FeSi. Samancor later became a division of BHP Billiton and the FeSi unit became an independent company in 2006 trading under the name of Dense Medium Separation Powders (Pty) Ltd, domiciled in the old premises of Armco in Meyerton, South Africa⁴⁴.

Over the years DMS technology found acceptance outside the diamond recovery into other forms of minerals such as coal, nickel, and iron ore. As a consequence, the market attracted other South African manufactures such as Kumba Iron Ore, Silicon Smelters, Magberg and Nimag. However the global market is dominated by companies from China and Brazil.

4.5. Concluding remarks

The mining industry has faced many challenging problems over the years. Most importantly these problems brought about innovative solutions. These solutions in turn became significant economic activities that created employment opportunities. Some of these significant economic activities were the large scale manufacturing of explosives; the development of cyanidation treatment process which not only rescued gold mining in the Witwatersrand basin at its infancy stage, but also increased the production of gold; the use of portable rock-drills and subsequent developments especially in the 1970s and 1980s; and the use of ferrosilicon in the recovery of diamonds.

⁴⁴ Source: <http://www.dmspowders.com/>

Solutions to the mining industry problems came about due to the collaboration and strive for common objectives by various Mining Houses, glued together by the CMSA. Most significantly COMRO, a research organisation under the CMSA, was instrumental in finding wide ranging solutions to problems afflicting the mining industry. COMRO was funded by mining companies (mostly gold and coal mines) but when their support waned in the early 1990s, it was absorbed by the CSIR.

The lesson learnt from COMRO is that a scientific-based initiative with adequate level of funding can be beneficial to the health of the industry. While it is unlikely that South Africa will ever see the level of collaboration between mining companies that existed prior the 1990s, the government can still create an environment where science can be used to realise more value from mines and mining products. In the absence of COMRO, Science Councils and universities can be used to undertake scientific research. To reach adequate level of research output and to sustain that output, South Africa will have to improve its basic education system such that more learners can pass mathematics and physical science at matric level.

5. MINERAL RESEARCH AND DEVELOPMENT IN SOUTH AFRICA

5.1. Introduction

Research and development has been a force behind innovative solutions that emerged from the South African mining industry. When the support for COMRO waned in the early 1990s and eventually absorbed by CSIR in 1993, there was a fear that resource-based research in South Africa will cease. Fortunately common problems that the mining industry faced and unique problems that afflicted individual mines compelled them to look for research-based solutions.

To this effect, some mines in the gold mining sector collaborated in the DeepMine project to find effective ways of mining beyond 3km below surface. Similarly platinum mines and coal mines collaborated in the PlatMin and CoalTech 2020 projects to find solutions unique to their respective sectors.

5.2. Nature of mining research and development in South Africa

To understand the nature of mining R&D in South Africa, it will be best to have an overview of the nature of mining globally. The globalised nature of mining dictates that mining companies must search for solutions on a global scale. This global perspective unfortunately influences their procurement patterns. In many respects the procurement pattern of mining companies in developing and least developed countries has the potential to undermine the development of domestic

manufacturing capacity and thereby nullifying the effects of local economic linkages postulated by Hirschman (1958).

5.2.1. Nature of mining

Factors that affect global mining community, affect the South African mining industry alike, which in most cases come into conflict with developmental agenda of governments. All mining countries generally seek to attract investors and professionals to their own industries; employ technologies that will attain high levels of efficiency; promote mineral beneficiation; and promote higher levels of economic activity in other local industries. The above are relatively easier to attain when mining takes place on a large scale in a developed country.

In general, large scale mining globally is a capital intensive business venture where the main asset is depleted and land is polluted in order to generate value. To top it all, the easy to reach and high grade deposits have virtually been depleted and those that remain generally have low grades or are in far flung areas in developing countries or regions. In such countries or regions, often local developments are not adequate to support mining. The remedy, almost exclusively, is to import inputs and export outputs, thanks to the low cost of international transportation.

Naturally mining is a risky business and there are primarily four types of risks that have to be mitigated, namely geological, political, commercial, and environmental. The latter is on the increase in developing countries but not yet at the level of developed countries (Emel and Huber, 2008).

Geological risk is an inherent risk in mining and it includes changes in grade, rock-mass strength, and metallurgical properties. Variations of these factors generally occur both horizontally and vertically within few centimetres to several metres across the mineralised rock mass. To this effect, there is an inherent uncertainty in every tonne of ore mined. Variation of factors mentioned above is a daily occurrence and demand constant attention lest they lead to financial losses or fatalities.

Alongside geological risks, there is political risk. All mines, particularly those in developing countries, face constant political risk especially when new political leadership comes into power. Political risk includes “the unmanageability of politicians, the possibility of terrorism or sabotage, the possibility of contract breach or frustration, or the chance of expropriation of assets” (Emel and Huber, 2008: p1397). In South Africa the ANCYL and some trade unions are calling for nationalisation of mines, a move that has unsettled investors and possibly leading to a situation where economic contribution of the mineral sector going forward could be undermined.

Political risk can also precipitate commercial risk, especially in a country where the rule of law is weak. Other than that, commercial risk in its pure form arises because of internal dynamics of mining companies (governance) and external market forces. One of the biggest factors in the external market is the cyclic nature of mineral prices. The combination of fluctuation in mineral prices and the long lead time between initial investment and the recoupment of capital exacerbates the commercial risk (Emel and Huber, 2008). In addition, commodity price cycles

can be detrimental to the extent that “the instability, and ultimate collapse, of commodity prices in 1920s was seen as one of the major factors that caused the Great Depression, contributing to political turmoil and the growth of international tensions in the process” (Oxfam International, p149).

While it appears that there is a relationship between commodity price cycles (business cycle) and their duration, it is difficult though to determine the turning points of commodity price trends. The uncertainty in metal price movements going forward affects the quality of investment decisions. Notwithstanding, it has been observed that the duration of price contractions tended to be longer than the duration of price expansions prior 2000 (Roberts, 2009). However, with the emergence of China in the early 2000s as an important consumer of mineral commodities, the reverse could be true.

The collapse of metal prices can lead to companies being unable to honour their commitment to environmental rehabilitation and end up facing lawsuits. It is for this reason, among others, that mining companies are not fond of strong environmental laws (Emel and Huber, 2008).

In the past, strict environmental laws in developed countries and falling transport costs encouraged mining companies to relocate their operations to developing countries where environmental laws were benign to foreign direct investment at the expense of environmental degradation. With time, the world has awakened to the destructive nature of unregulated mining and subsequent environmental costs that host governments have to bear. In South Africa, mining companies are

required to make financial provision for the rehabilitation of the environment in their Environmental Management Plan. In addition, companies have to comply with the following legislations (DMR, 2009a: p6):

- The Constitution of South Africa (Act 108 of 1996);
- National Environmental Management Act, 1998 (Act No 107 of 1998);
- National Water Act, 1998 (Act No 38 of 1998); and
- National Environmental Management Act: Air Quality Act (Act 39 of 2004).

The abovementioned legislations empower interest groups to challenge (and sometimes frustrate) mining companies and the State if there are perceived transgressions, a feat that can delay new projects or demand the attention of senior managers.

The risks outlined above can be mitigated effectively by investment in research. However investment in research attracts its own risk with very little guarantees that it will yield the required results. In most cases mining companies limit the risk by partnering with knowledgeable and reputable organisations. In a globalised world the comfort of lowering the risk associated with R&D comes from choosing specialist partners from developed countries with a long history of success. This logic invariably leads to an import oriented procurement pattern in developing and least developed countries.

5.2.2. The procurement pattern of South African mining industry

Ideally procurement policies of South African mining companies should lead to an environment where there is buoyant local economy that is sustainable beyond mining. In reality former mining towns (perhaps with the exception of Johannesburg) find it difficult to provide sufficient employment for their residents when mining activities decline or stop altogether.

Take for example the economies of Virginia and Odendaalsrus. The economies of these two mining towns adjacent to Welkom, declined drastically when the gold mining declined in the Free State Province. While investments are starting to trickle into Welkom after a decade of stagnation, the two towns continue to wait for their turn. Similarly the economy of Stilfontein in the Northwest Province collapsed when gold mining ceased and residents were forced to look for jobs in neighbouring towns of Klerksdorp and Potchefstroom.

A study by Lombard and Stadler (1980) showed that gold mining in the 1970s was so important in the economy to the extent that its multiplier effect contributed 42% to the GDP in 1978 while its direct contribution to the GDP was 18.7%. The mining industry, in particular gold mining sector, sourced as much as 95% of its input from the domestic market in the late 1970s. However the import component of these inputs was very high. That is, domestic suppliers sourced their input from international markets in order to supply the domestic mining industry. Similarly large quantities of mining output by value were sold internationally with very little left for local beneficiation. Basically it meant that the local mining sector, in so far

as high valued inputs were concern, was linked to the domestic market through international markets (Lombard and Stadler, 1980).

The importance of gold as the premier foreign exchange earner in South Africa diminished in the early 2000s while at the same time the PGM sector emerged as a premier foreign exchange earner (see Figure 5.1). In a similar manner as the gold sector thirty years earlier, the PGM sector is sourcing 95% to 100% of its inputs from local manufacturers, distributors, and agents. However a closer look revealed that products and services consumed by the local PGM sector have high import component (Lydall, 2009).

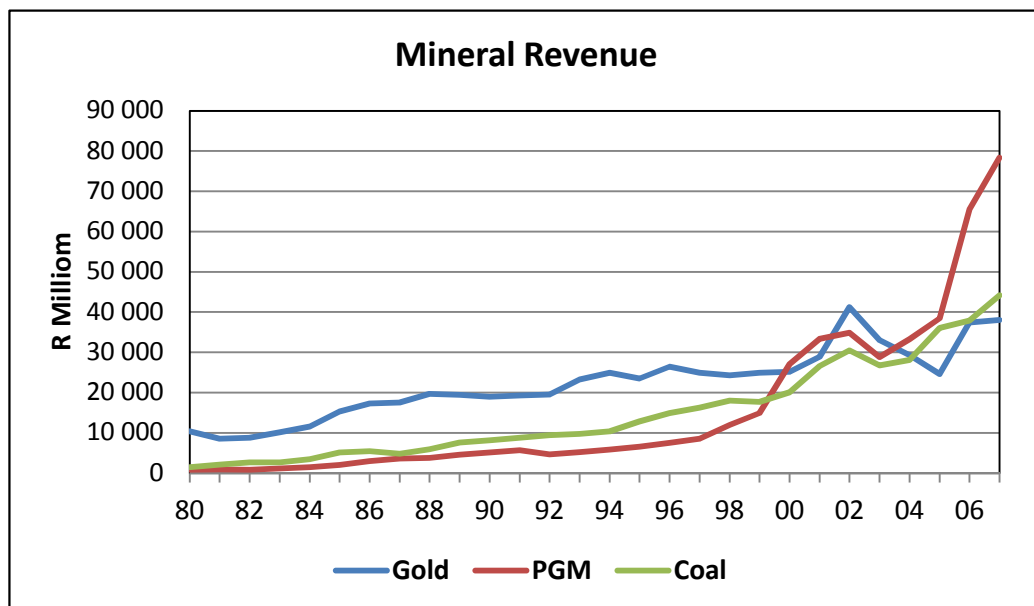


Figure 5.1: Annual revenue of gold, PGMs and coal between 1980 and 2007
Source: Stats SA (2010)

According to Lydall (2009), a general tendency in the PGM sector, and possibly the entire South African mining industry as hinted by Tregenna (2007), is to use local agencies for tendering purposes and local labour to assemble or install final

products. In most cases capital equipment and delicate instruments are pre-assembled in the country of their origin. The use of local agencies and labour gave the appearance of a high consumption of local products and services whereas the actual local consumption was estimated to be between 5% and 20%. Many of the input products and services are sourced from USA and Europe.

In 2009 the total expenditure of the South African mining industry was R399 billion against an income of R332 billion, incurring a deficit of R67 billion (see Figure 5.2). A total of R193 billion or 48% of the total expenditure was spent on procurement of goods and services (CMSA, 2010). The implication is that between R154 billion and R183 billion was procured internationally, undermining local manufacturing capacity in the process.

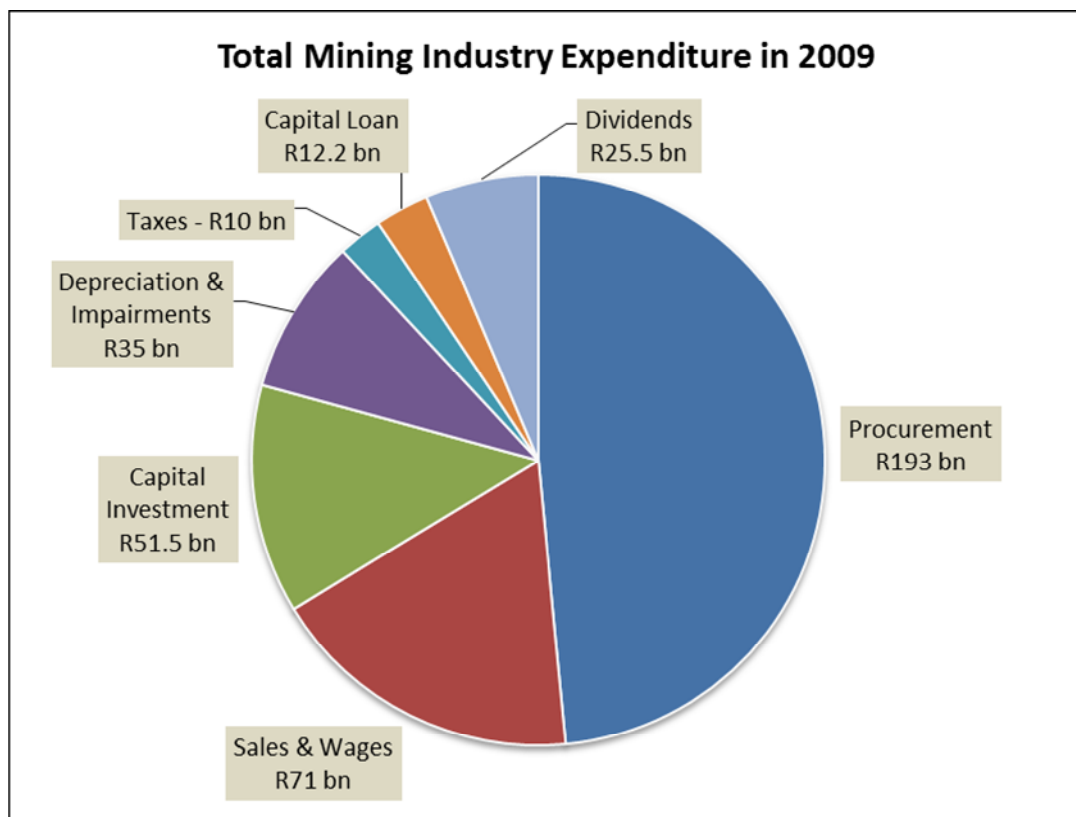


Figure 5.2: Total expenditure of South African mining industry in 2009
Source: CMSA (2010)

According to Lydall (2009: p116), South African mines depended on foreign suppliers in “aerial mapping, mine design, environmental assessment, borehole drilling, radar processing, remote sensing, geological assaying, drilling consumables and replacement items, opencast and underground bulk materials handling and haulage equipment, electrical equipment, comminution (crushers, mills, cyclones) and concentration equipment (flotation cells, filters, pumps), metallurgical testing, chemicals and reagents, driers, converting equipment, smelting and tapping equipment, environmental/gas-treatment and refining equipment”.

This situation presents a challenge and opportunity at the same time. It is a challenge because the know-how lies with foreign companies and institutions. It is an opportunity because it is an indication of the presence of local demand which local companies (if given the right support) should take advantage thereof.

Notwithstanding, South African enterprises are not just bystanders in the mineral sector. In addition to unparalleled expertise in deep underground mining, Lydall, (2009: p117) stated that South African companies have competitive edge in “mine design and development, construction and structural engineering, ventilation and cooling, contract mining, shaft sinking, mineral processing, tailings treatment, process control, metallurgical testing, and smelting and refining. Local competencies have also been developed around the design and manufacture of niche systems and components (hoisting, winding, hydropower drills, filters, pumps, pinch valves) and strategic consumables (cement, shotcrete, explosives, grinding balls)”.

Products and services mentioned above present an opportunity for South African companies to capture international market share using local labour and expertise. Meanwhile, the rest of the African continent remains the biggest market outside South Africa for these companies despite the continent being notorious for low levels of intra-trading.

5.2.3. Research environment in mining post COMRO

The curtailment of COMRO's budget between 1980s and 1990s led to a reduction of its labour complement from 673 to approximately 200 (Pogue, 2006b). Many of those that left the employment of COMRO were foreign scientists, researchers and technicians attracted to South Africa because of its mining research programmes. Australia, which was beginning to intensify its mining research programme in the early 1990s, became their next destination.

Despite this setback, the CSIR (after taking over COMRO in 1993) continued with mining related research. To this effect, the CSIR collaborated with the mining industry, labour organisations, universities and other government institutions in initiatives such as DeepMine, FutureMine, CoalTech 2020, and PlatMine projects (Bluhm *et al*, 2010). The collaboration model between CSIR and other stakeholders was developed by Dr Güner Gürtunca of the CSIR and Prof. Huw Phillips of Wits in 1996 (Durrheim and Diering, 2002).

The DeepMine project was launched in 1998 and ended in 2002. Its objective "was to develop expertise and technology to mine gold safely and profitably at ultra-depth (3 to 5km) in the Witwatersrand basin of South Africa" (Bluhm *et al*, 2010:

p428). Over 250 researchers across various fields of study were involved in the DeepMine project (Durrheim and Diering, 2002).

The success of the DeepMine project led to the birth of the FutureMine and CoalTech 2020 in 2002. The FutureMine project focused on reducing costs and improving productivity under four main themes namely, rock engineering and seismicity; mining engineering and mineral resource management; information technology; and cooling and refrigeration. Technologies such as the Disc Sampler and the Drill Samper emerged from the FutureMine project and went into proto type stage in 2004 (Venter, 2004). However there is very little evidence of the uptake of these technologies in the mining industry on a large scale.

Currently the mining industry (in particular coal and platinum miners) and CSIR are collaborating in initiatives such as CoalTech 2020 and PlatMine projects to develop new mining and processing technologies. Among other things, the PlatMine project is looking into safety and mine environmental issues as the sector is preparing to go deeper underground than before, as well as cheaper methods of treating the UG2 reef. In the case of the CoalTech 2020 project, researchers are looking at methods of mining the Waterberg coalfield which is touted as the replacement of the Witbank coalfield when the latter is depleted.

Another significant research initiative that came after COMRO was taken over by CSIR was the collaboration of Anglogold Ashanti and Hilti Corporation to develop portable electric rock-drills in 1996. The prototype of Hilti electric drill, TE MD20, was developed in 2001 and trials were undertaken at Moab Khotsong Mine. The

development and implementation of the Hilti TE MD20 took almost ten years with the biggest obstacles being the quantification of benefits and the buying-in from workers. The use of portable electric rock-drill technology is currently in its infancy stage in the deep hard rock mining in South Africa and is competing with well established brands of pneumatic and hydraulic portable rock-drills (Coutts *et al*, 2009).

5.2.4. South African mining research and development in perspective

Despite the large volume of research that came out of the South African mining industry since the 1890s, local mining companies currently rely significantly on foreign companies to develop mining equipment and computer software. This situation has led to foreign ownership of solutions to problems identified locally. For example Hilti Corporation has developed electric rock drill for local underground mines in collaboration with AngloGold Ashanti; Sandvik has developed extra low profile equipment for local narrow reef stopes in collaboration with platinum mines (Pickering and Leon, 2008); and Israeli Desalination Engineering has developed vacuum ice plants for deep and hot underground mines in collaboration with AngloGold Ashanti⁴⁵.

Vogt and van Schoor (2010) have noted that the reliance on foreign companies to convert local research into commercial equipment and services have the effect of delaying the infusion of technology on local mines. Many of imported equipment loaded with cutting edge technologies cannot be supported locally. Consequently

⁴⁵ Source:

<http://www.anglogold.co.za/subwebs/informationforinvestors/reports07/reporttosociety07/energy-mponeng.htm>

broken units are sent overseas for repairs or modifications with long turnaround times, resulting in a loss of acceptance momentum in local mines. This is also complicated by a lack of knowledgeable staff on mine level and head office to advocate for, support and use new technologies.

The lack of local expertise to develop equipment post research influences the procurement pattern of South African mines which is currently biased significantly towards imported goods. The consequence thereof is the low rate of creating local employment opportunities.

5.3. Concluding remarks

Mining in South Africa is part of a global mining community with a number of multinational mining companies currently exploiting local resources. Being part of the global mining community puts pressure on companies to mine safely, healthy, and efficiently in order to increase production, lower costs, and retain a social license to mine. One way of achieving the above is to invest in R&D.

There have been many mining research initiatives in South Africa after 1993. Some of these initiatives included DeepMine, FutureMine, CoalTech 2020 and PlatMine projects. These projects have generated a large pool of knowledge about the nature of orebodies and mining conditions in South Africa. They have also identified potential areas for improvement. However, very few products came out of such research initiatives, pointing to a lack of capacity to develop and manufacture products.

Nonetheless there have been some notable developments, for example the SIMRAC research led to local development and manufacturing of underground safety nets by a local company that have other markets outside the mining industry. Similarly a research into rapid yielding underground hydraulic props was converted into a commercial proposition by a South African company. Even a research about the use of roofbolts in narrow reef mines was converted into a commercial proposition by a local company.

However the rate and the scale of converting mining research into commercial products and services in South Africa is very low by world standards. For example a quick search on the internet (on 19 November 2011) reveals that there is only one company from South Africa listed as a manufacturer of hydraulic props whereas there are over 100 such companies in China. While the Chinese quality is questionable, the point is that Chinese companies have developed a culture of manufacturing and marketing products in large quantities internationally.

The mass production strategy of China probably forces South African companies to look into targeting niche markets. The niche market strategy is appropriate considering that South Africa has the smallest local market compared to other BRICS countries. However, low levels of product development and manufacturing are an obstacle to the efforts of efficiently targeting niche markets. A solution to this problem is imperative though due to the pressing issues of poverty, unemployment and inequality.

Some mining companies opted to partner with foreign companies to develop products that could solve their problems. For example, when AngloGold Ashanti was facing problems of compressed air reticulation on its mines in the mid-1990s, it partnered with a Liechtenstein based Hilti Corporation to develop portable electric rock-drills. Similarly the Automine concept of Finsch Mine was developed by De Beers in partnership with a Swedish based Sandvik in the early 2000s. Even during the times of COMRO, portable rock drills were developed in partnership with foreign companies as Sulzer and Novatek. Ideally it would be preferable if development and manufacturing partnership contracts were entered into with first and second tier local companies. This would ensure a vibrant local economy with the potential of lateral technology and benefits migration.

The problem of low capacity to develop and manufacture products and services following a research is fundamental, structural and endemic in the South African mining industry. The solution to this national problem should be a multi-pronged approach with an overarching goal to converge towards a single solution. One of the plausible solutions to this problem is the Linkage Model discussed in section 6 of this report.

6. THE LINKAGE MODEL

6.1. Introduction

The point of view taken in this report is that mining will continue to be a critical contributor to the South African economy in the current century. To contribute meaningfully, mining must position itself such that it is able to create sustainable job opportunities in other sectors of the economy through its connectedness, particularly in the industrial sector. It is the view of the author that an appropriate vehicle to achieve meaningful contribution of mining in the South African economy going forward is through the Resource-based Research and Enterprise Development Model or the Linkage Model in short. The outcome of the Linkage Model, once it is adopted and put into operation will be known as the Linkage Initiative or Resource-based Research and Enterprise Development Initiative.

The Linkage Model aims to develop new mining technologies, products and services through R&D while simultaneously promoting domestic mineral beneficiation. It is envisaged that new mining technologies, products and services and mineral beneficiation will result in the creation of new enterprises or expansion of existing enterprises into other industries through economic linkages. The Linkage Model discussion is premised on the mining industry being a strong primary industry capable of generating growth in existing industries or creating new local industries horizontally and vertically along the mining value chain as shown in Figure 6.1.

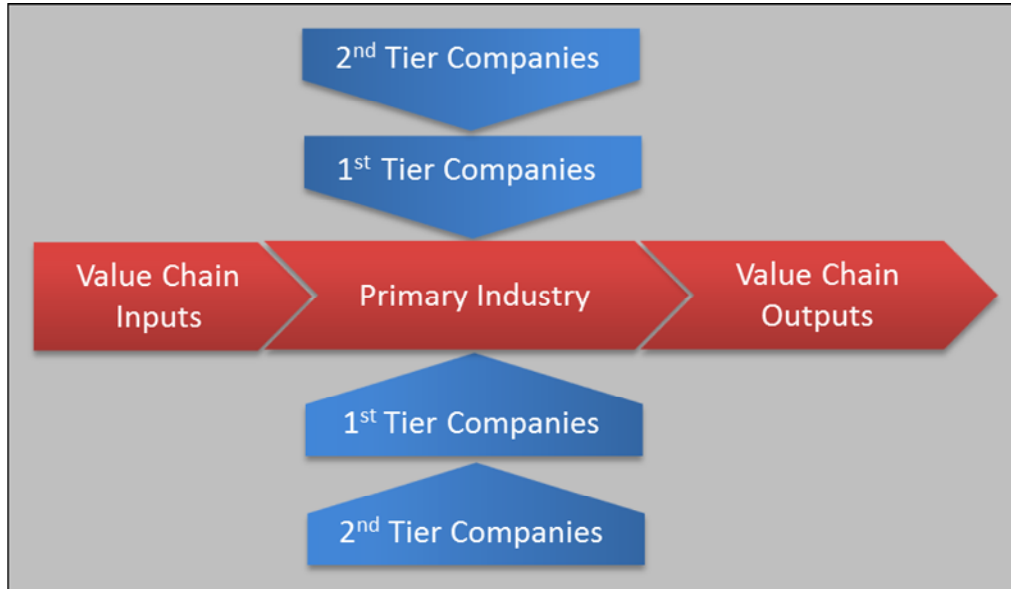


Figure 6.1: The economic activity due to a strong primary industry

The Linkage Model as discussed in this report will thrive under conditions that enable the creation of new or expansion of existing enterprises which are underpinned by thoroughly researched products and services. The implication will then be that the conversion of research into products and services will rely on high entrepreneurial activity in the niche technology and manufacturing sectors as hinted by Lydall (2009). A vibrant entrepreneurial culture is very important if mining and other industries are to be used as appropriate vehicles to combat the problems of poverty, unemployment and inequality in South Africa. In short, the envisaged environment of the Linkage Model is the one where there is a symbiotic relationship between researchers and entrepreneurs.

6.2. The nature of business development in South Africa

For businesses to flourish, adequate legislative and regulatory framework has to be in place. In general South Africa has a progressive Constitution and robust legislation with adequate mechanisms to collect taxes and levies. There is a rule

of law and respect for the Constitution. In addition, institutions such as the Public Protector, six institutional Ombudsmen, Competition Tribunal, Consumer Protection Board, and National Economic Development and Labour Council (Nedlac) have been established to protect the rights of individuals and organisations.

Nedlac, established in 1994, is a framework of tripartite engagement between government, business and labour. It was founded with the appreciation of inequality in South Africa despite mineral endowment, sizeable arable land, strong banking and financial systems, and relatively good national infrastructure. In the past Nedlac managed to harmonise the relationship between business and labour, but recently tripartite members have been at loggerheads over a number of draft labour bills. Business perceives proposed labour bills and amendments as onerous and moving against job creation efforts. Unions on the other hand are split; some are in favour of proposed labour bills and amendments while others would prefer a moderate tone (Bleby, 2011).

Despite the noises coming out of Nedlac, the government of South Africa fundamentally supports private sector investment. This was evident when the new government that emerged after 1994 created an investor friendly environment and opted to privatise some of the parastatals such as ISCOR, and SASOL (Aron *et al*, 2009).

South Africa is also fortunate in that it has many private and public business development agencies. Public development agencies operate on a national,

provincial and regional level (see Table 6.1). The unfortunate part is that these public agencies are controlled by different government ministries, leading to duplication of resources and lack of clear holistic policy on enterprise development. These ministries work in silos and this prevents the free flow of information and timely or directed interventions for small and medium enterprise development (see Figure 6.2). Another weakness is that those that are controlled on a national level compete with those that are controlled on provincial or regional level for funding opportunities, resulting in wastage of funds and opportunity for abuse and corruption.

Table 6.1: Public business development agencies in South Africa

Agency*	Jurisdiction	Department
National Development Agency	National	Social Development
National Youth Development Agency	National	Presidency
Small Enterprise Development Agency	National	Trade and Industry
Khula Enterprise Finance Ltd	National	Economic Development
National Empowerment Fund	National	Trade and Industry
Development Bank of Southern Africa	National	National Treasury
Land Bank	National	Agriculture and Land Affairs
Gauteng Economic Development Agency	Provincial	Finance and Economic Affairs
Eastern Cape Development Agency Corporation	Provincial	Economic, Development and Environmental Affairs
Free State Development Corporation	Provincial	Tourism, Economic And Environmental Affairs
Trade and Investment KwaZulu-Natal	Provincial	Economic, Development and Tourism
Mpumalanga Economic Growth Agency	Provincial	Economic, Development, Environment and Tourism
Trade & Investment Limpopo	Provincial	Economic, Development, Environment and Tourism
Northern Cape Economic Development Agency	Provincial	Finance, Economic Development and Tourism
Invest North West	Provincial	Economic Development & Tourism
Mpumalanga Economic Growth Agency	Provincial	Economic Development, Environment and Tourism
Cape Agency for Sustainable Integrated Development in Rural Areas	Provincial	Economic Development, Environment and Tourism

*The list is not exhaustive

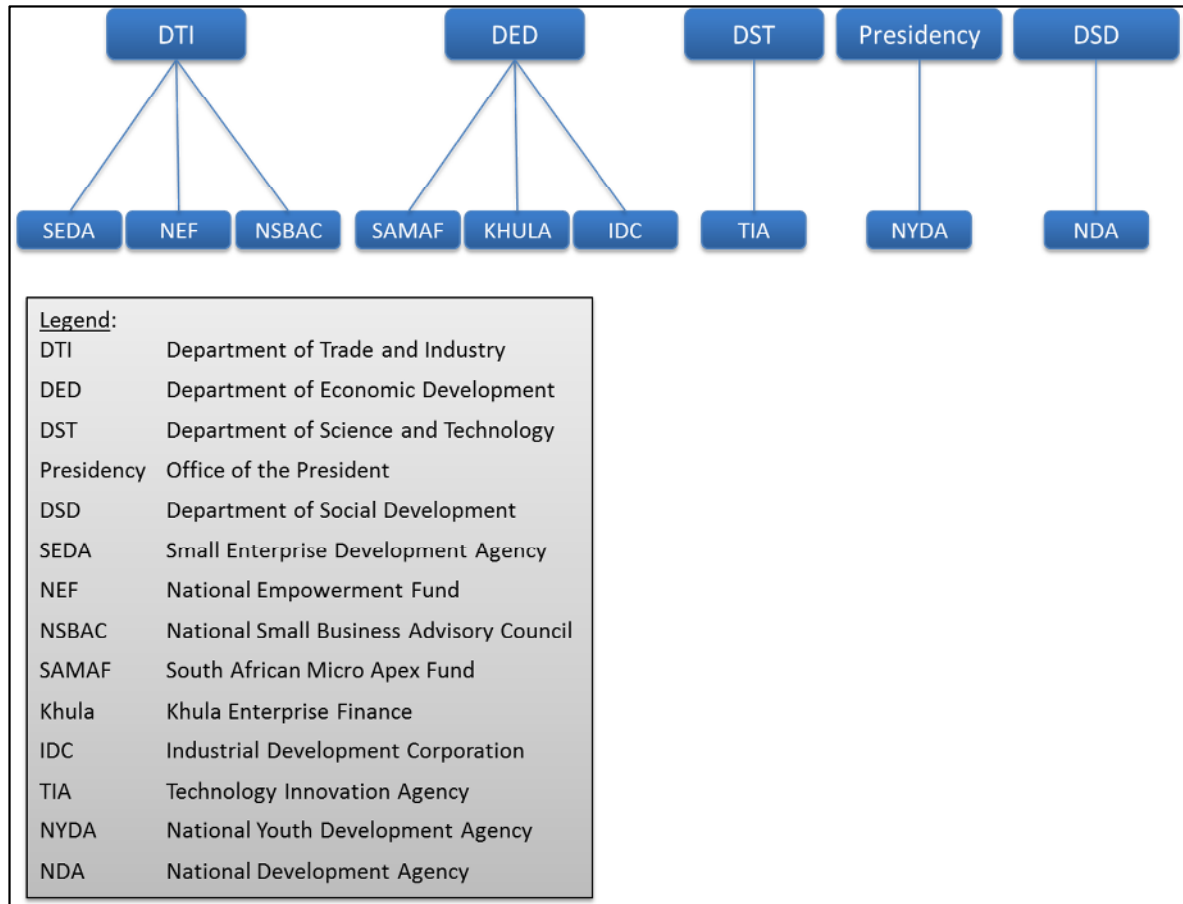


Figure 6.2: South African State funded business development agencies on national level
Adapted from Timm (2011)

In comparison, Brazil and India have only one ministry in charge of small and medium enterprise development. In the case of Brazil the Ministry of Development, Industry and Foreign Trade is responsible for enterprise development and in India the Ministry of Micro, Small and Medium Enterprises is the responsible authority (Timm, 2011).

Perhaps the low entrepreneurial activity in South Africa compared to its BRICS peers, despite the presence of a number of development agencies, is an indication of a lack of a holistic policy on enterprise development. Timm (2011) stated that uncoordinated activities of public business development agencies and

BEE legislation that undermines entrepreneurial skills among HDSAs by promoting rent seeking behaviour are some of the obstacles that inhibit the creation of sustainable enterprises. A research by Virgin Unite (2011) on the other hand revealed that prospective entrepreneurs and youth believe that a lengthy process of registering companies put unnecessary strain on the efforts to start new companies.

In the interest of efficiency and to ensure proper coordination, Timm (2011) suggested that the government should consider establishing a single development agency. However the author believes that this may not be feasible given the diverse nature of enterprises in South Africa. A plausible solution could be the formation of two specialist avenues under the DTI and DED (see Figure 6.3). For example the DTI through IDC and NEF could focus on large enterprise development (see Table 6.2 for the distinction between large, medium and large enterprises) whereas DED through SEDA and Khula could focus on small and medium enterprise development. SAMAF, NSBAC, NYDA and NDA should be brought under the fold of SEDA or Khula depending on whether they provide mentoring service or funding. TIA under the DST should continue to help small and medium enterprises with their technology or innovation requirements and lastly the Development Bank of Southern Africa and the Land Bank under the National Treasury could provide financial and other related support to all enterprises in conjunction with IDC, NEF and Khula.

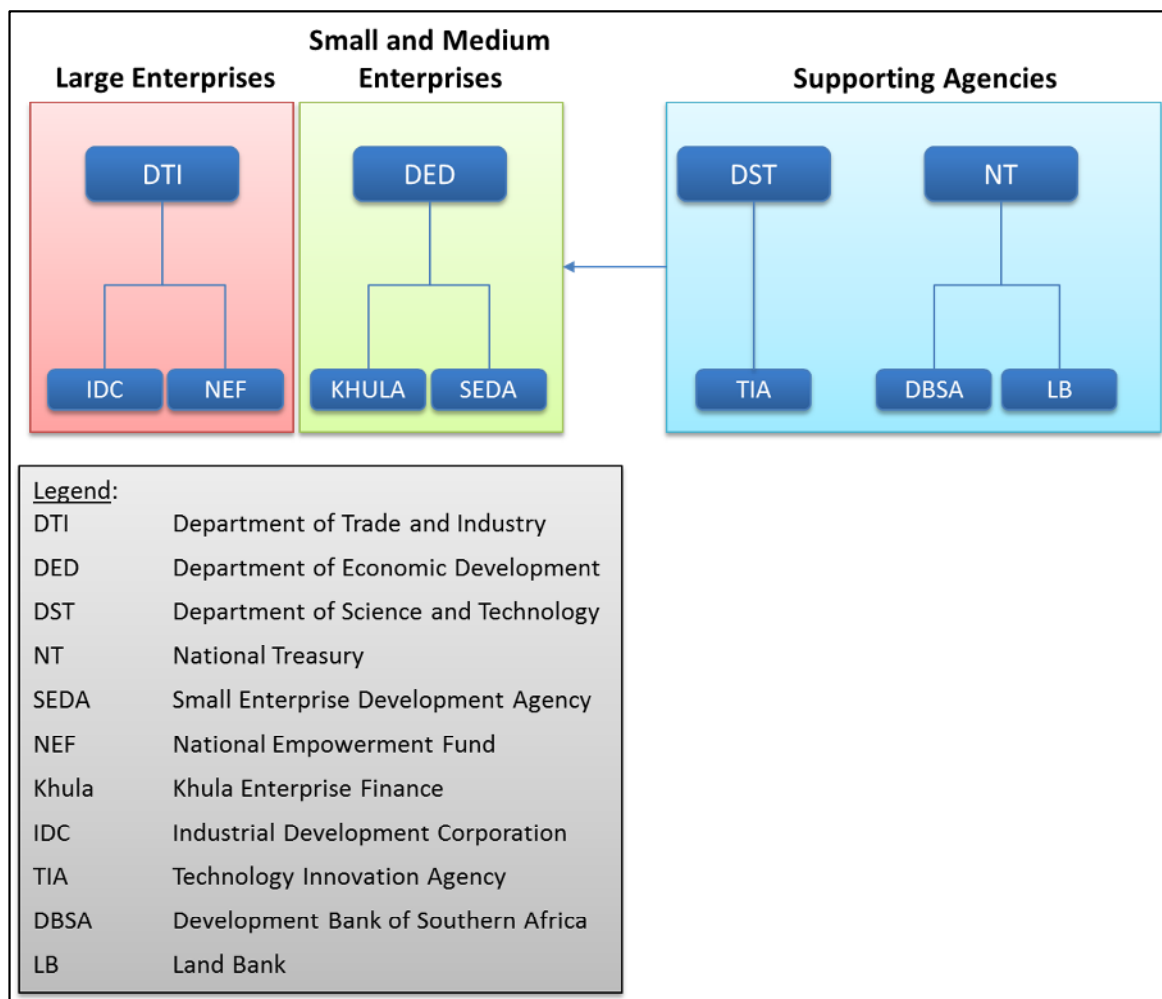


Figure 6.3: Proposed simplified structure of public enterprise development agencies in South Africa

The development and support of small and medium enterprises is important. In the second quarter of 2011 small and medium enterprises contributed 23% and 9.3% respectively towards the GDP of South Africa (see Table 6.3). In general small enterprises in South Africa have a higher contribution to GDP than medium size enterprises, but in mining the reverse is true. Perhaps the capital intensive nature of mining in South Africa and the generally poor support for small scale miners creates barriers for entry into mining (for example tertiary institutions such as Wits, UP, UJ and UNISA are not currently offering courses to capacitate small and medium enterprises in mining).

Table 6.2: Classification of large, medium and small businesses in South Africa based on annual turnover

Industry	Large (million)	Medium (million)	Small (million)
Mining and Quarrying	> R234	R60 to R234	R2 to R60
Manufacturing	> R306	R78 to R306	R2 to R78
Electricity, gas and water supply	> R306	R78 to R306	R2 to R78
Construction	> R156	R36 to R156	R2 to R36
Transport	> R156	R78 to R156	R2 to R78
Real estate and other business services	> R156	R78 to R156	R2 to R78
Community, social and personal services	> R78	R36 to R78	R2 to R36

Source: StatsSa (2011)

Table 6.3: Selected contribution of economic sectors to GDP in the second quarter of 2012 according to company size

	Large	Medium	Small
All industries	67.6%	9.3%	23.0%
Mining & Quarrying	7.3%	0.3%	0.2%
Manufacturing*	23%	3.4%	5.5%

*Includes companies involved in mineral beneficiation. Source: StatsSa (2011)

Interestingly, 8.9% contribution by small and medium enterprises in the manufacturing industry to the GDP in the second quarter of 2011 was higher than the contribution of the entire mining industry (7.8%) in the same quarter. Perhaps this demonstrates of the importance of the manufacturing sector in job creation efforts.

Even though the direct contribution of mining in the economy is smaller than that of manufacturing sector, the greatest value lies in its mining multipliers. According to CMSA (2010) the value of mining multipliers (backward, forward and lateral

linkages) in 2009 contributed 10.2% to the GDP compared to 8.8% direct contribution of mining to the GDP.

The author makes an assertion that the diversion of a portion of mining multipliers (employment and capital formation) through procurement to small and medium enterprises synergizes with the Linkage Model, especially in the context of technology intensive mines as discussed in section 6.3.6. Given that small and medium enterprises in the manufacturing sector are larger than the mining sector in terms contribution to the GDP, it is logical to infer that there is a critical mass within this sub-sector to provide mining companies or tier 1 companies with low risk products and services based on the findings of Lydall (2009) as shown in Figure 6.1.

There is also an opportunity to incentivise medium size companies in the manufacturing sector to undertake mineral beneficiation where possible (the mineral sector). For example, apart from chrome ore, phosphate rock, coal, copper and zinc, a large portion of South African minerals was exported after the first stage of beneficiation, leaving small quantities for local beneficiation in 2008 (see Table 6.4). Similarly large quantities of fabricated metals were exported in 2008, leaving very little for higher stages of beneficiation in the local economy (see Table 6.5).

According to Figure 1.2, higher stages of mineral beneficiation are labour absorptive. Therefore South Africa should be encouraging companies to participate in the second, third and fourth stages of mineral beneficiation with

principally two objectives, namely value creation and job creation. Similarly extraction efficiencies of companies operating within the first stage of mineral beneficiation should be encouraged.

Table 6.4: South African production of selected minerals and metals in 2008

Mineral/metal	Global Resource Base Ranking	Production (t)	Export Quantity (t)	Local usage (t)	Export (%)	Local (%)
Chrome Ore	1	9 683 000	762 000	8 921 000	8	92
Manganese	1	5 589 000	3 572 000	2 017 000	64	36
PGMs	1	276	223	53	81	19
Gold	1	213	190	23	89	11
Fluorspar	2	299 000	276 000	23 000	92	8
Vanadium	2	20 300	12 100	8 200	60	40
Vermiculite	2	200 000	205 000	-	103	0
Titanium minerals	2	1 211 000	1 211 000	-	100	0
Phosphate Rock	4	2 287 000	-	2 287 000	0	100
Nickel	5	32 000	22 200	9 800	69	31
Coal	8	250 200 000	57 900 000	192 300 000	23	77
Zinc	8	31 400	-	31 400	0	100
Iron Ore	9	41 300 000	3 300 000	1 000 000	73	27
Copper	14	93 000	27 000	66 000	29	71

Source: DMR (2009a)

The gap between export quantities and local usage in Table 6.4 and Table 6.5 represent opportunities that can be filled by increased participation of small, medium and large enterprises within the mineral sector. A probable vehicle to capacitate these enterprises is the Linkage Model.

Table 6.5: South African production of selected beneficiated metals in 2008

Mineral/metal	Production (kt)	Export Quantity (kt)	Local usage (kt)	Export (%)	Local (%)
Ferrochromium	3 269	2 525	744	77	23
Ferro-alloys of manganese	704	626	78	89	11
Ferro-silicon	134	44.2	89.8	33	67
Silicon metal	51.7	53.5	-	103	0

Source: DMR (2009a)

6.3. The components of the Linkage Model

The proposed Linkage Model consists of the following components:

- government support;
- funding scheme for mining and mineral beneficiation research;
- development of skilled personnel to generate and support new technologies;
- involvement of Science Councils and universities in resource-based research;
- mining and mineral beneficiation research output; and
- commercialisation of mining and beneficiation research findings.

In simple terms the Linkage Model is primarily concerned with resource-based research and enterprise development. The two combine to create a symbiotic relationship between the mining industry as the primary industry, the downstream beneficiation industries and the resultant first and second tier companies. The Linkage Model, with resource-based research at its centre and enterprise development as its ultimate output is shown in Figure 6.4.

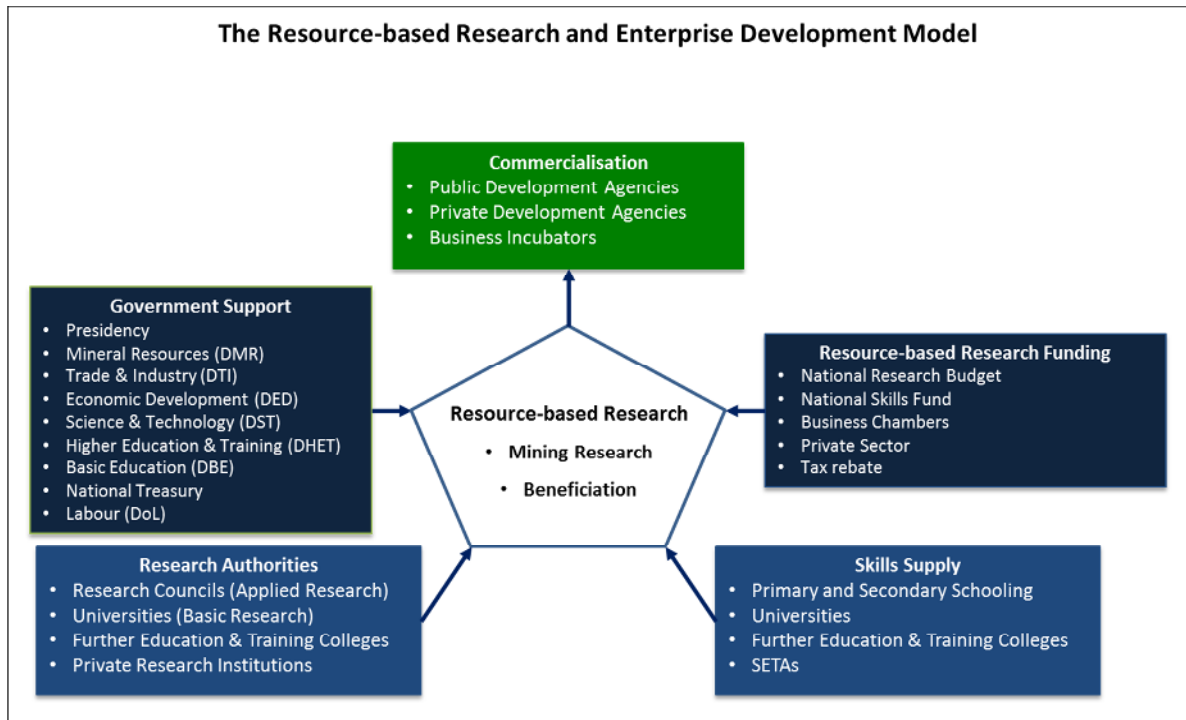


Figure 6.4: The Linkage Model

The force behind the Linkage Model should be a strong culture of resource-based research supported by coordinated activities of enterprise development agencies and capability to commercialise research findings on a continuous basis. Fortunately the culture of resource-based research in South Africa is not new; it was one of the critical success factors of economic growth in the previous century and its remnants are still evident within the Science Councils today. The envisaged Linkage Model is based on six components or pillars as discussed below.

6.3.1. Government support

The first component of the Linkage Model is the support from the government through its various departments. The strategic nature of the Linkage Model warrants the attention of the highest office in the country. For this reason, it should

be on the radar screen of the Office of the Presidency, in particular the Planning Commission. Currently the Planning Commission is considering a number of issues (economic, social, environmental and political) with a view to shape the future of South Africa.

One of the issues that the Planning Commission is looking at is to increase the social and economic value of the South African mineral endowment. It is in this respect that the Linkage Model should be regarded as one of the tools that could be used to create a stronger mineral sector characterised by profitable mines, fervent enterprise development and significant mineral beneficiation in line with the government's Mineral Beneficiation Strategy. To achieve this feat, there has to be a synergy of policies from various government departments under the guidance of the Planning Commission in the Office of the Presidency (see Figure 6.4).

In this regard, the role of the Department of Mineral Resources (DMR) will be to create an environment where there is sufficient space and adequate number of mines to undertake mining and metallurgical (first stage of mineral beneficiation) research with the view of developing usable technologies. The DMR should also ensure that there are sufficient quantities of mined minerals in the country for local beneficiation.

In the long term, the DMR should use African Exploration Mining & Finance Corporation (AEMFC), the State mining company, to support research in mining and metallurgy. In this instance, the DMR will have to allocate mineral resources with high Ricardian rents to AEMFC, similar to Luossavaara-Kiirunavaara

Aktiebolag (LKAB) in Sweden. AEMFC will then reciprocate by opening its doors to Science Councils and universities to undertake R&D on its mines. Part of the Ricardian rent can be used to fund R&D while the economic rent will be used for the normal operation of the company. However there is always a risk that Ricardian rents could be abused by political elites, therefore the National Treasury should put in place mechanisms that will ensure that such rents are directed to their rightful recipients or are disburse for research in the mineral sector.

With regard to the industrial sector, the Department of Trade and Industry (DTI) will have to take the lead in ensuring the attainment of appropriated research outputs with regard to second, third and fourth stages of mineral beneficiation. In addition, measures should be put in place to ensure that the level of import component of capital goods in the mines is progressively reduced. However the government and public will have to safeguard against the stealth introduction of import substitution policies.

The roles of DMR and DTI within the Linkage Model will be supported by the Department of Science and Technology (DST) since it is charged with the mandate to ensure sufficient level of R&D in South Africa. Successful execution of this mandate depends on the creation and maintenance of knowledge banks, coordination of various research aspects (scientific, social and economic), provision of research facilities, and provision of funding through the National Research Foundation (NRF).

In addition, the National Treasury in conjunction with the DST and other government departments must embark on a campaign to inform the public about various trade incentives⁴⁶ and the provisions of the Income Tax of 1962 that stipulates that companies which have registered their R&D with DST are eligible for a tax rebate of up to 150% with respect to their R&D expenditure. In Australia there were 5 630 companies in 2004 that were using R&D tax concessions, which varied between 125% and 175% of R&D expenditure (Australian Government, 2007). In comparison, only 301 South African companies applied to be on R&D tax incentive programme by the end of 2009 (DST, 2010).

The force behind R&D is human capital. To ensure a long term sustainability of the Linkage Model, the country will have to produce adequate number of skilled people. To achieve this, the education system under the auspices of the Department of Basic Education (DBE) and the Department of Higher Education and Training (DHET) will have to produce the right quantity and quality of graduates. In particular the education system under DBE will have to put measures in place to improve mathematics and physical science pass rates at matric level from a low base of 5.1% and 5.8% respectively in 2005.

6.3.2. Resource-based research funding

Funding in research is very important. While the government through NRF under the DST provides grants for research in general, it will be in the interest of South Africa to increase the total research fund pool. Currently the government aims to

⁴⁶ Some of these incentives are mentioned in the Industrial Policy Action Plan (IPAP) 2012/2013 – 2014/2015 document.

increase the research budget from the base level of 0.93% of GDP in 2010 to 1.5% and 2% of GDP by 2014 and 2018 respectively. This is noteworthy because according to the DST, the 2010 level of R&D funding does not support economic growth in South Africa (DST, 2010).

The mandate of the DST is very broad and cuts across all sectors of the economy. To secure adequate level of funding for the Linkage Model, authorities will have to look elsewhere for funds. Other than the National Research Budget, there are other potential sources of research funds such as the National Skill Fund, private sector funding and tax rebates.

The National Skills Fund is made up of the money from skill development levy collected under the Skill Development Act (SDA) of 1998 by the South African Revenue Service (SARS). According to SDA, companies with annual turnover of more than R0.5 million are supposed to pay 1% of their payroll to Sector Education and Training Authority (SETA) in their respective industries while employees contribute another 1% to make a total of 2%. A 20% of the SDA levy collected by SARS is paid into the National Skills Fund while the 80% is disbursed equitably to the respective SETAs.

Regrettably money paid into the National Skills Fund grew to R5 billion between 2005 and 2010 despite South Africa suffering from chronic shortage of skills and high unemployment (Pressly, 2010). Nonetheless, SDA presents an ideal opportunity to fund the Linkage Model in two ways. Firstly part of the money accumulated in the National Skills Fund could be used as a seed-fund for the

Linkage Model. Secondly 20% of the skills development levy collected by Mining Qualification Authority (a mining industry SETA) could be used to fund subsequent activities within the Linkage Model. Furthermore other SETAs in the industrial sector could divert anything between 0% and 20% of their National Skill Fund portion into the Linkage Model depending on their involvement.

As part of their social responsibility, private sector companies may contribute funds to towards the activities of the Linkage Model in exchange for discounted rates on solutions and technologies therefrom. This is not unique though; established mining companies tend to provide funds for R&D from time to time. For example De Beers in conjunction with ISCOR developed DMS technology for recovering diamonds in the 1940s; Jubilee Platinum collaborated with Mintek in developing ConRoast furnaces to treat PGM ores with high chromite content; AngloGold Ashanti is collaborating with Mintek in the AuTek Project in search for new uses of gold; and Gold Fields have donated money to build Mine Design Laboratory at Wits.

Business chambers can also play a role in encouraging their members to participate in the Linkage Model activities. In the past the CMSA, through COMRO, was central to the development of mining technologies such as the underground refrigeration, underground ventilation systems, portable rock-drills, and hydro-power. In the early 1990s when COMRO reduced its staff complement, some of those retrenched staff started their own companies using the knowledge accumulated within the COMRO over the years. To this effect, companies such as Hydro Power Equipment (hydro-power), Joules Technology (hydro-power), Turgis

(hydro-power and mining services), TLC Software (hydro-power software and instrumentation), and Bluhm Burton Engineering (cooling and ventilation) were established (Pogue, 2008). A move that is beneficial to the economy and membership roll of business chambers.

The government can also incentivise companies through tax rebates and public funding to undertake R&D outside formal programmes of the Linkage Model provided such technologies are in the national interest (e.g. employment creation or more corporate taxes in the future). However care should be taken to develop appropriate policies as it has been found that tax rebates and public funding can counter each other's effectiveness if one of them is too attractive. To this effect, it was found that the government funding of R&D in private companies was effective if pegged between 10% and 20% of the overall R&D fund. The government funding below 10% was found to be discouraging to R&D initiatives while the funding above 20% was found to have an effect of replacing private sector funding or creating dependency on public money (Guellec and Van Pottelsberghe De La Potterie, 2003).

6.3.3. Skills supply

Availability of adequate quantity and quality of skills to undertake research, product and service development, and business development (including entrepreneurship) is very important for the success of the Linkage Model. The preparation for such skills starts from basic education and goes all the way to tertiary education.

It was shown earlier that the South African education system is not producing enough learners with mathematics and physical sciences at matric level. These two subjects are a prerequisite for learners intending to study science and engineering which in turn are core disciplines in the Linkage Model. Even more alarming is the fact that South Africa is producing doctorate degrees at a slower rate than its competitors in the mineral sector (see Table 6.6), a factor that reinforces the status of South Africa as the net importer of technology in the mineral sector.

Table 6.6: Number of doctoral graduates in 2007

Country	Graduates per 1 000 000*	Population**	2007 Graduates
Chile	13	16 600 000	216
South Africa	26	47 900 000	1 274
Mexico	28	106 500 000	2 982
Turkey	48	74 000 000	3 552
Brazil	52	189 300 000	9 844
Japan	132	127 700 000	16 856
Canada	140	32 900 000	4 606
France	172	61 700 000	10 612
New Zealand	179	4 200 000	752
USA	201	302 200 000	60 742
Norway	208	4 700 000	978
Australia	264	21 000 000	5 544
UK	288	61 000 000	17 568
Germany	297	82 300 000	24 443
Finland	375	5 300 000	1 988
Sweden	427	9 100 000	3 886

Source: *ASSAf (2010); **2007 World Population Data Sheet

In 2007 South Africa produced 1 274 doctorates compared to an estimated figure of 60 742 in USA, 24 443 in Germany, 16 856 in Japan, 5 544 in Australia, etc. as shown in Table 6.6. Among the countries shown in Table 6.6, South Africa had the second of smallest doctorate ratio per one million people. Apart from Mexico,

Turkey and New Zealand, the rest of the countries listed in Table 6.6 are direct or potential competitors of South Africa in supplying goods and services to the mineral sector. Up to 2007 the South African production of doctorates was not enough to start changing the procurement pattern of the mining industry highlighted by Lombard and Stadler (1980), Tregenna (2007), and Lydall (2009).

For example in 2007 there were 1 274 doctoral graduates in South Africa and only 92 of them graduated in the category of engineering sciences, materials and technologies. Out of the 92 graduates, 28 and 17 of them were in the field of electrical and electronic engineering, and mechanical engineering respectively. These two fields of study consistently produce a large number of doctoral graduates (ASSAf 2010). In the corresponding period, Wits produced only 1 doctoral graduate in mining engineering (see Table 6.7), pointing to a possible capacity problem with respect to the envisaged resource-based research.

Table 6.7: Mining engineering doctoral statistics at Wits University

Year	Registered PhD	PhD Graduates
2005	10	1
2006	16	2
2007	16	1
2008	14	2
2009	14	0
2010	16	2

Source: Wits University School of Mining Engineering (2011)

ASSAf (2010) provided a number of recommendations to overcome the problem of low numbers of PhD graduates. One of the recommendations was to increase the number of full-time doctorate students by increasing annual allowances to a level

that will not adversely affect their financial well-being while undertaking full-time studies. With limited funds available, it will be the issue of how authorities can increase the research fund pool for the resource-based research. Failure to do this, the country will not be able to competitively increase the level of home grown research, leading to the reinforcement of the problem of high import capital component in the South African mining industry.

To create a sustainable pipeline of resource-based researchers, product and service developers, and entrepreneurs in South Africa schools, colleges, universities, and SETAs will have to produce graduates with the right set of skills. Colleges and SETAs are important in the sense that they are supposed to produce artisans and technicians who are supposed to support technology used in research and subsequently in enterprises. SETAs in particular are established, among others, to formalise training and recognise years of experience in the workplace.

The downside is that very few SETAs function optimally, while the pass rate at colleges is very low. There are approximately 50 public colleges in South Africa where candidates sit for the National Certificate examinations at level two and three. The pass rate of the National Certificate examinations at level three in 2008 and 2009 was 9.56% and 12.4% respectively. Similarly the pass rate of the National Certificate examinations at level two in 2007, 2008, and 2009 was 11.39%, 7.59% and 9.6% respectively (Blaine, 2011). This situation exacerbates the skill shortage problem, particularly those of artisans and technicians that are supposed to support the development and maintenance of technology.

In addition to technicians and artisans, another requisite skill is that of researchers. Primarily universities are responsible for producing researchers. In South Africa, the onus mainly falls on Wits and UP to produce relevant doctoral, masters and first degree graduates for the South African mining industry. Naturally this pool of graduates is a lot smaller than that of technicians and artisans and has to be shared between R&D, technical, and management streams in the mining industry. Because of the economics, many first degree graduates would rather be in management positions with few enrolling for masters and doctoral programmes in technical fields. The problem with this situation is that the number of people with doctorate degrees in the country correlates well with the economic growth (ASSAf, 2010). For South Africa to be competitive in the mineral sector, it will need to produce enough people with technical masters and doctoral degrees to work in the mineral sector industries, universities and Science Councils.

6.3.4. Research authorities

Science Councils, universities and private research institutions have a crucial role to play in the Linkage Model. South Africa has some of the best universities in Africa and Science Councils capable of undertaking resource-based research on a large scale. Work done by Science Councils is discussed elsewhere in this report.

Despite the success of Science Councils in the past, there is a lot that has to be done if the reliance of mining on imported goods is to be reduced and meaningful job opportunities are to be created. The gap between the status quo and the desired state where ample jobs would be created because of the research in the mineral sector creates an opportunity for tripartite collaboration between private

sector, universities and Science Councils. Close collaboration between Science Councils and universities will lead to young graduates appreciating the value and benefits of choosing careers in research. Through the Linkage Model, the salaries of young researchers could be supplemented in order to bring them in line with their counterparts on the mines or in factories.

Science Councils must also be refocused to undertake more fundamental research and less of commercial projects. For this to happen, the government must increase the research budget allocation for Science Councils. Currently these institutions are undertaking commercial projects in private and public sectors to stay viable. Figure 6.5 shows a split between government funding and income due to commercial activity of Science Councils from 2007 to 2010. The author is of the view that fundamental research will lead to breakthrough technologies that could put South Africa in a good light internationally.

With respect to private research institutions, their participation in the resource-based research is not new though. COMRO was actively engaged in various research projects between 1965 and 1992 in all areas that impacted on gold and coal mining. While it is acknowledged that knowledge created in the private sector is private, some form of knowledge exchange between public and private research organisations should be encouraged. This is crucial when it is considered that the private sector is more likely to commercialise research outputs than public institutions.

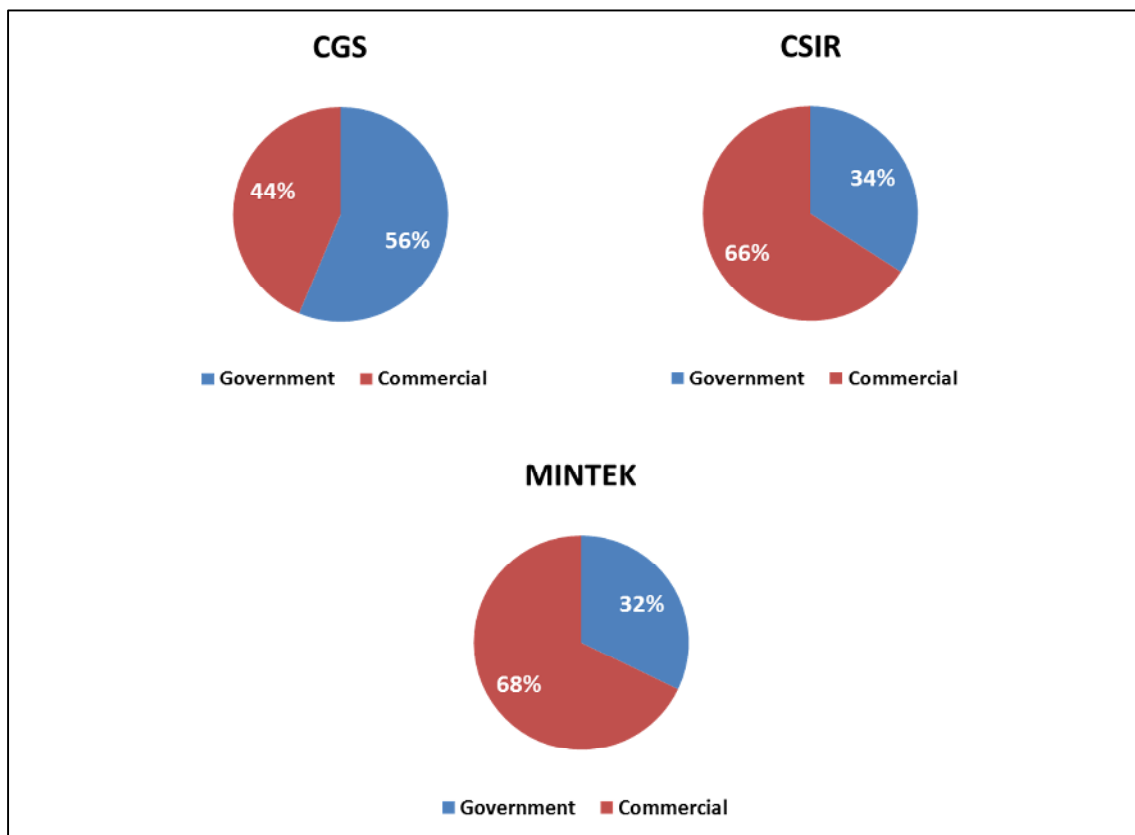


Figure 6.5: Split between government funding and commercial income of Science Councils from 2007 to 2010
 Sources: Annual reports of Mintek, CGS and CSIR

6.3.5. Mining research and beneficiation

The ability to develop and eventually commercialise research findings is important. To be competitive, South Africa needs safe and healthy, profitable and efficient mines and strong downstream industries, a feat that can be achieved through long term investment in research.

A well-executed mineral-based research project should lead to the creation of new jobs. Fortunately all the building blocks for mineral-based research are in place in South Africa. For example there are established Science Councils, universities, and development agencies which can be used to support the Linkage Model. What

seem to be lacking is adequate skills, appropriate research policy, and public and private sector willingness to invest in fundamental and exploratory research.

The resource-based research envisaged in this report should lead to development of new technologies that will unlock the potential within the South African mineral resources. A point in case is the South African gold mining sector. While production has been declining to the extent that countries such as China and Australia have overtaken South Africa as the leading producers of gold, the country still has the largest known gold resources in the world (Brown, 2010). Unmined gold resources in South Africa are locked in underground pillars; unmined marginal ground that fell below the cut-off grade at some stage in the past; deep deposits (beyond 3km deep) in the Witwatersrand basin; unprocessed slimes dams; and in the deposits of the Bushveld Complex. These resources can be converted into mineable reserves through investments into new mining and metallurgical methods, including new industrial applications of gold (new demand), subject to commodity price movement and risk adjusted price of capital.

Currently gold is used almost exclusively for investment and jewellery purposes, but work is underway to find alternative large scale application of gold. Mintek has been collaborating with AngloGold Ashanti (and Harmony in the past) in the AuTek project to find new industrial applications of gold in areas of catalysis, nanotechnology and biomedical science (Mintek, 2010).

Recently AngloGold Ashanti has embarked on a five year project to develop an automated continuous mining process aimed at unlocking gold resources as deep

as 5km below surface. To achieve the terms of the project, AngloGold Ashanti has assembled a group of innovators, researchers and academics around the world. It is envisaged that this project will replace the cyclic operation of underground gold mining and the need for people to work in dangerous stopes, with a continuous automated mining technology (Creamer, 2011).

Similarly there had been development in the PGM front. For example Mintek and DTI were instrumental in the development of auto-catalysis industry in South Africa.

The capacity of South Africa to undertake research in the mineral sector is notable. However there is an ever present risk of falling further behind the leading countries based on the country's inadequate administration of the basic education and low production of doctorates. In addition, South Africa has established a number of public development agencies but has failed to inculcate high rate of entrepreneurial activity among its citizens compared to other BRICS countries despite having an environment where it is easier to establish and close businesses compared to India and Brazil (Timm, 2011).

To take mining and mineral beneficiation research to a level where \$2.5 trillion worth of unmined mineral resources can benefit South African citizens, the above mentioned deficiencies will have to be addressed.

6.3.6. Commercialisation of research findings

The research findings should naturally bring an improvement in the way people do things and generally there is a monetary value attached to such improvement. To realise the monetary value of the improvement, research findings have to be commercialised. Failure to commercialise research findings could lead to a loss of future revenues. For example, many of the novel mechanisation technologies used in coal mines today originated in the commandist countries (mainly USSR). However, lack of commercialisation capacity in the commandist countries led to Western companies seizing the opportunity to commercialise their mechanisation research findings. The consequences of this action were that Western economies benefited substantially more than commandist economies despite the latter being responsible for the ideas in the first place (Wagner and Fettweis, 2001).

To avoid repeating mistakes of the commandist countries, it is important to establish a bridge between R&D and commerce through enterprise linkage such that viable economic clusters around the mineral sector are created. In a free market world, meaningful job opportunities will arise if research findings are commercialised cost effectively.

Factors of production such as land, labour, capital and entrepreneurship are crucial in the commercialisation of research findings. To transform research findings into commercial technology, funding, enterprise development and requisite business skills have to be in place. Development agencies, SETAs and institutions of higher learning are best suited in this regard to impart the necessary technical and business skills.

A suitable model for start-up enterprises wishing to develop new technologies or improve existing technologies is business incubation. The business incubation model, particularly the one that focuses on technology, started in the late 1950s at the Massachusetts Institute of Technology (MIT) in USA. The survival rate of start-up businesses that went through the MIT business incubator model in USA was over 90% compared to 3% survival rate of start-up businesses within the first five years of their operation globally. Business incubators were also successful in Norway and Japan. In South Africa, although not used extensively, business incubators achieved 78% survival rate in start-up businesses after three years of operation (Leeuw, 2005).

The business incubation model entails start-up companies entering the three to four year incubation programme with only a viable business concept and exiting (graduating) as fully fledged companies. In the context of the Linkage Model, the same model could be used to commercialise research outputs of university graduates. For example the School of Mining Engineering at Wits could collaborate with Wits University Business School (WBS) and one of the Science Councils in a manner that a PhD graduate in mining could be given business skills or be linked with other WBS graduates to commercialise his/her research findings. Through TIA, a Science Council concern could be used to convert research findings into functional technologies. The seed funds for the incubated entities could be provided by Khula for which both WBS and Khula would take equity in the incubated entities and upon graduation (exiting the programme) the equity could be sold for profit.

While the majority of small and medium enterprises in South Africa are not technology enterprises, there are clear advantages of focusing on technology-based business incubators or similar programmes in the Linkage Model. According to Hirschman (1958), the intensity of linkages (*IL*) within the economy is proportional to the technology usage (*TU*) in the primary industry (*PI*), giving rise to the following expression:

$$IL \propto TU_{PI}$$

It therefore follows that the technology usage ratio in a particular period can be determined by the following equation:

$$TU_{ratio} = \frac{CT}{PE} \quad \text{Eq 1.}$$

Where: **CT** is the cost of technology or the annual procurement expenditure relating to a particular technology; and

PE is the industry total annual procurement expenditure;

The **TU_{ratio}** value of one (1) is an indication of a sheer dominance of a particular technology in the market, whereas the value of zero (0) is an indication of a technology not in use⁴⁷.

Take a case of portable rock-drills in gold mines. The value of **TU_{ratio}** between 1900 and 1933 increased as more mines accepted the use of rock-drills, with full

⁴⁷ Note that the appropriate level **TU_{ratio}** has not been quantified scientifically

acceptance achieved in 1933. There is a likelihood that rock-drill TU_{ratio} continued to increase beyond full acceptance as production and safety pressures demanded better models. Similarly the TU_{ratio} of individual components of a rock-drill can be assessed in much the same way if rock-drill OEMs were to be regarded as an industry.

The increase in TU_{ratio} is generally accompanied by an increase in the number of job opportunities. According to Walker and Minnitt (2006), the number of companies involved per unit component increases exponentially as one moves from the mines (primary industry) to first tier companies and then to second tier companies, pointing to a case of job creation potential due to technology intensive primary industries that require more components to function than less technology intensive primary industries.

Handel (2003) in Figure 6.6 shows employment growth in USA between 1948 and 2000. The growth in employment coincided with the rise in productivity, mechanisation and proliferation of computers in USA, suggesting that there is a close correlation between employment growth and technology in the workplace. However Handel warned against making such conclusions.

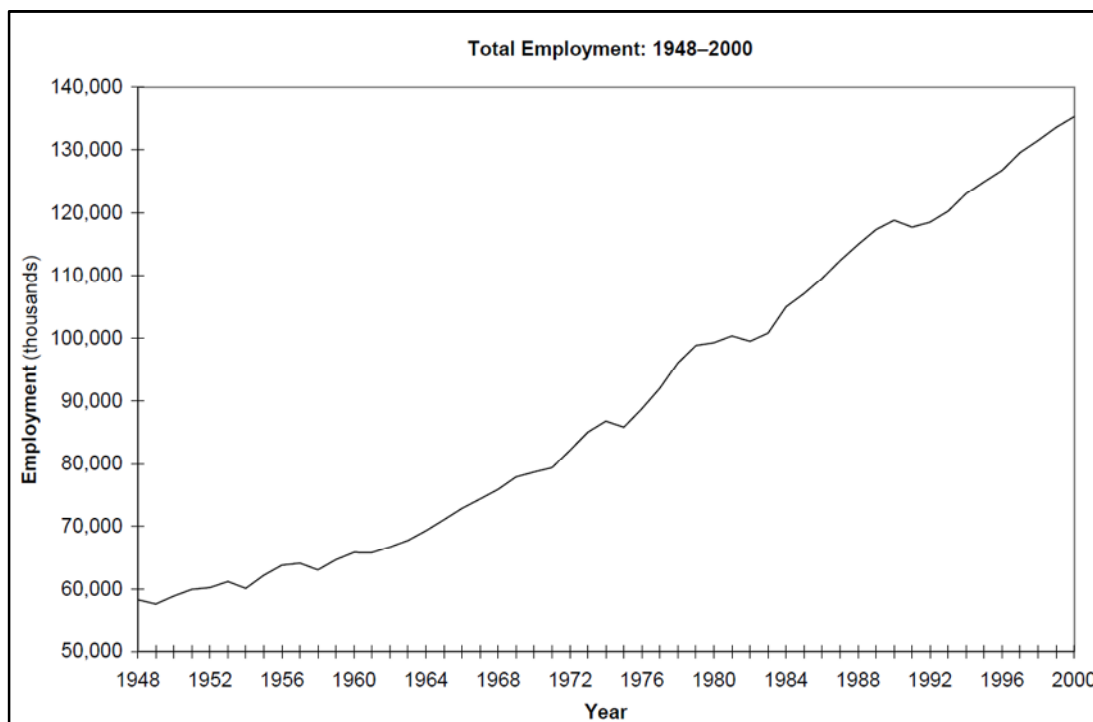


Figure 6.6: Employment growth in USA between 1948 and 2000
Source: Handel (2003)

Jared Bernstein⁴⁸, in line with Handel (2003), produced graph shown in Figure 6.7 that depicts the relationship between productivity and employment. There has been a strong positive correlation between productivity growth and employment growth in USA from 1947 until about 2000. Thereafter the two graphs have diverged with productivity continuing on the growth trajectory while employment growth plateaued.

According to Bernstein, the divergence between employment and productivity as from 2000 is due to USA firms importing cheaper input goods and outsourcing production activities (particularly manufacturing) to countries with cheaper labour. This act has undermined local employment opportunities while at same maintaining growth in productivity of local firms.

⁴⁸ <http://jaredbernsteinblog.com/about/>

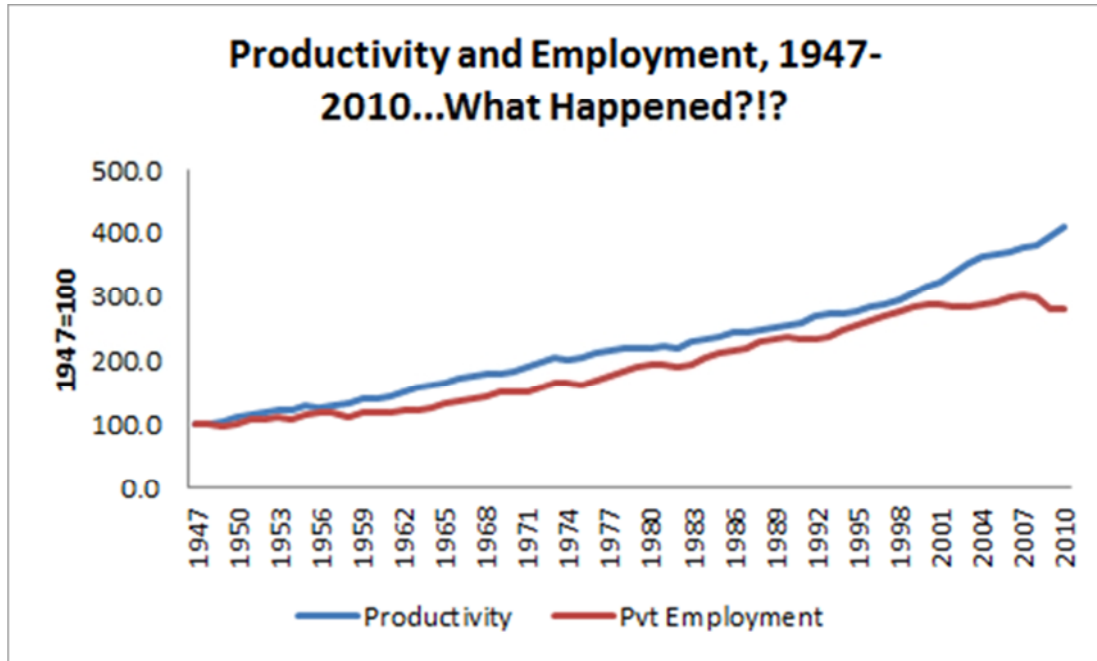


Figure 6.7: Relationship between productivity and employment in USA from 1947 to 2010⁴⁹

Another possible explanation is the type of technology that has emerged after 2000. Before 2000 the focus was significantly on mechanisation and automation. After 2000 there was a significant shift among OECD⁵⁰ countries towards the services sector driven by growth in the information, technology and communication (ICT) sector (OECD, 2007).

In contrary, the focus of this report is on the mining and industrial technologies characterised by mechanisation and automation. Based on Walker and Minnitt (2006) and Lydall (2009), the implication is that mines with high technology intensity (high-tech mines) have a greater potential of creating external job opportunities than conventional mines. A typical underground section of a PGM mine has a higher technology intensity than a typical underground section of a

⁴⁹ Source: <http://jaredbernsteinblog.com/another-explanation-for-the-productivityemployment-split/>.

Accessed on 01 May 2012

⁵⁰ Organisation for Economic Co-operation and Development

gold mine but less technologically intensive than a typical underground section of a coal mine. The intensity of technology becomes even more pronounced in metallurgical sections, with PGM mines being more complex because of the extraction of typically four platinum group elements (PGEs) and other metals.

To illustrate the importance of technology intensive mines in the economy, Lydall (2009) has estimated that a single PGM mine with a capacity of 200 000 tons per month can consume up to 100 000 assemblies from 2 000 to 5 000 firms. It can therefore be stated that the number of employment opportunities in the mining and supporting industries is proportional to the level of technology usage by individual mines. Employment opportunities (**EO**) in the economy can be estimated by the following equation:

$$EO = \frac{P_{PI} \times UPT}{k} + EO_{initial} \pm OE_{PI} \quad Eq 2.$$

Where: P_{PI} is the annual production of the primary industry;

UPT is the unit price of a specific technology;

$EO_{initial}$ is employment opportunities due to initial capital investment;

OE_{PI} is the change in employment opportunities in the primary industry; and

k is the average cost of creating one employment opportunity to produce additional unit of technology after the initial capital investment.

According to Derby (2011), the cost of creating one employment in the industrial sector in the large enterprise category in South Africa varies from R260 000 to R3 million, depending on the nature of investment, i.e. marginal increases or new capital investments. It is however unclear about the cost of creating one employment in the small and medium enterprise category in South Africa⁵¹.

It should be noted though that there is a high likelihood that the number of employment opportunities (OE_{PI}) in the primary industry could decrease as new technologies are assimilated into work routines. The relationship between job opportunities and technology is not linear as there are a number of factors that impact on the intensity of usage of technology in the mines. Some of these factors are discussed briefly below.

- **Depth of a mine**

Deep mines face a different set of geotechnical and logistical challenges compared to shallow mines. The challenges of deep mining generally compel mines to rely on proven low-tech conventional mining methods as opposed to shallow mines which seek to achieve higher level of efficiencies through the use of new technologies. In South Africa, gold mines are generally deeper than PGM mines.

⁵¹ Potential area of research in the future

- **Geology of a mine**

The hardness, corrosive levels, abrasiveness, dip and discontinuity of underground reefs and surrounding strata, especially in gold mines, have in the past discouraged attempts to introduce higher levels of mechanisation. The CMSA in the 1980s championed a ten year mechanisation research project in gold mines which failed to revolutionise underground gold mining methods. Nonetheless the research gave mine operators a better understanding of the ambient underground environment.

PGM mines, although prone to discontinuities, generally have dips and corrosive levels that are amenable to mechanisation, although not yet to the level of coal and base metal mines. Particular advantages of coal and base metals mines are, firstly, production largely takes place inside the orebody and thereby limiting the amount of waste mined. Secondly, the thickness of the orebody places less restriction on the size of equipment used. It should be noted that manufacturing of smaller mechanised units for mining application demand higher developmental capital. Thirdly, ore mined tends to be softer, especially coal, compared to mineralised rock strata in gold and PGM mines, thereby prolonging the life of equipment and components used.

- **Social factors**

Social factors can facilitate or discourage the use of technology in organisations. Organisational social factors are made up of “skill

requirements, job assignments, task design, structure, work integration, information flow, decision-making processes, and reward systems” (Lin and Chen, 2000: p43). They are also influenced by individual’s character, and horizontal and vertical relationships within the organisation. The individual’s character is influenced by attitude, skills level, education and beliefs, whereas vertical relationships are influenced by the attitude of management and supervisors, and horizontal relationships are influenced by peer pressure (Lin and Chen, 2000).

The complex nature of organisational social factors plays a significant role in the successful assimilation of technology in the work place. In particular, the attitude of senior management and the age of a firm are critical success factors in so far as the implementation of technology is concerned (Lin and Chen, 2000).

While it appears as if there is no significant difference between the attitudes of senior managers of gold and PGM mines, the age difference does however come into play between these two mining sectors.

- **Union attitude towards technology**

According to Peitchinis (1983, p116), attitudes of trade unions towards technological innovation vary based on circumstances, that is “positive attitudes exist in industries which have recorded expanding employment, even though significant technological changes take place in them; the attitudes are negative in industries which experience declining employment,

even though technological changes in them may be sporadic and minimal; and an attitude of indifference prevails amongst unions whose members have not been affected by technological or any other changes”.

In line with Peitchinis, Dowrick and Spencer (1994) analysed the attitudes of trade unions based on the level on which they operate and concluded that national level unions tend to view technology in the workplace in much more favourable terms than industry level unions provided it leads to the creation of employment across industries. Industry level unions, on the other hand tend to disdain technologies that will lead to retrenchment of its members even if more employment is created elsewhere in the economy, but they would support technologies that create employment within their own industries.

In the South African context, National Union of Mineworkers (NUM) is a mining industry union. Based on the conclusion of Dowrick and Spencer (1994), it would be expected that NUM would resist attempts to introduce a job-shedding technologies in the mines and support those that create employment. Indeed according to Baleni (2009) NUM views technical innovations in metallurgy in a positive light because they render previously unprofitable deposits payable, whereas mechanisation (especially underground) is viewed negatively because of its tendency to reduce labour in mining. Furthermore NUM does not “...believe that it is the absence of technology that has failed mineworkers but rather the prevalent attitudes and mind-set that mining is inherently a risky and dangerous industry”

(Baleni, 2009). The implication is that trade unions, in particular NUM, prefer labour intensive mining environment as opposed to high usage of technology that would adversely affect its membership.

In conclusion it can be said that the repercussion of commercialising research findings is likely to be the reduction of employment opportunities in the mines and related beneficiation factories. On the other hand the upside of commercialising research findings is the potential increase in production and creation of employment opportunities in supporting industries. In addition there is also a possibility that new technologies developed for the mineral sectors can find their way into other sectors of the economy, resulting in organic and quantitative growth of companies. However the biggest hurdles are, firstly the creation of enabling environment to develop and nurture the requisite skill to research, develop and commercialise research findings, and secondly the willingness to implement the Linkage Model.

6.4. The implementation of the Linkage Model

Government departments and other stakeholders mentioned or implied in Figure 6.4 will primarily form the core of a team that will look into the best way of translating the Linkage Model into a resource-based research and enterprise development institution in South Africa. The institutionalised Linkage Model will be known as the Linkage Initiative.

The successful implementation of the Linkage Initiative will rest on the effectiveness of its steering committee outlined in Figure 6.8. Due to the envisaged

strategic and multi-disciplinary nature of the Linkage Initiative, stemming from the Linkage Model, it will be ideal if its operations could be coordinated by the Planning Commission. Ideally the chairperson of the steering committee should be a senior official at the Director General level in the office of the Planning Commission. This is appropriate because one of the issues that the Planning Commission is looking at is to increase the social and economic value of the South African mineral endowment.

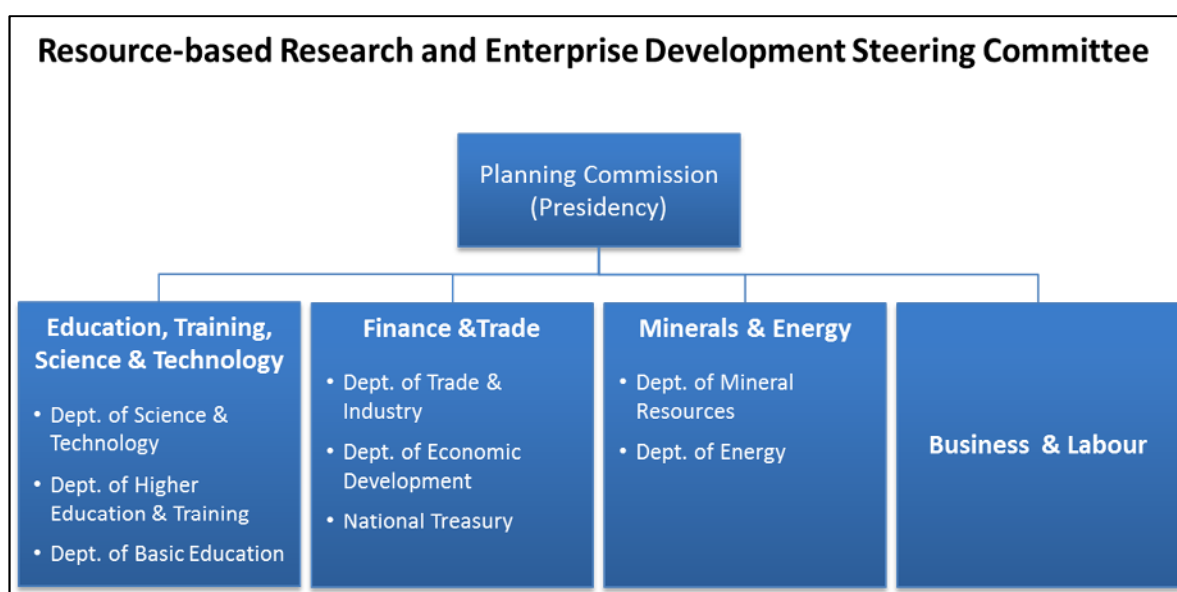


Figure 6.8: Proposed composition of the steering committee responsible for the Linkage Initiative

The steering committee will be made up of senior officials from the government, business and labour sectors. The steering committee will be divided into the following clusters:

- Education, Training, Science and Technology;
- Finance and Trade;
- Minerals and Energy; and

- Business and Labour

All government departments identified under different clusters will not necessarily be required right from the inception of the steering committee. For example, the Department of Energy may not participate at the beginning but as the coverage of the Linkage Model expands to include research and beneficiation of oil and gas, it may be prudent for it to become a member of the steering committee. Similarly other departments may be included or excluded when the need arises.

All appointed public servants under different clusters serving in the steering committee will be senior officials at the Director General level. Similarly business and labour representatives will have to be on a level where they are able to take decisions on behalf of their constituents. Most importantly business representatives should be biased towards entrepreneurship. This is to ensure that the focus is turned towards enterprise development, which is required for commercialisation of research findings.

While the steering committee will be providing direction in so far as resource-based R&D is concerned, the real activities of the Linkage Initiative will be executed by representatives of agents identified in Figure 6.4.

6.5. Concluding remarks

The economy of South Africa was built on the strength of its mining industry and going forward, the economy could be enlarged on the basis of its mineral endowment given that it has the largest known mineral resources (excluding oil

and gas) by value. Currently nations of mining regions which include Australia, Chile, Zimbabwe and Zambia want to get more from their minerals. This global situation represents an ideal opportunity for South Africa to come up with its own brand of harnessing more value from its mineral endowment. This plausible brand for South Africa could be the Linkage Model.

The aim of the Linkage Model is to develop new mining technologies, products and services through R&D while simultaneously promoting local beneficiation of mined minerals. The envisaged Linkage Model will consist of six components which are political and administrative support from the government; adequate funding for resource-based research activities; availability of skilled personnel to undertake R&D and commercialisation of research findings; adequately resourced research agencies which include universities and Science Councils; mining and mineral beneficiation research output; and the ability to commercialise research findings through enterprise development models.

Due to the strategic nature of the Linkage Model, it is proposed that the implementation thereof be driven by a steering committee comprised of government departments, labour representatives and business representatives. In particular, the latter should be biased towards representatives of entrepreneurship organisations due to the emphasis on the commercialisation of research findings as the ultimate output of the Linkage Model.

Members of the steering committee must comprise of government officials at the Director General level with the Director General of the Planning Commission as

the head, particularly considering how well the Linkage Model resonates with the National Development Plan of 2011. In the same manner, representatives of business and labour cluster should be leaders from their respective formations with the mandate to make strategic decisions.

Ultimately the success of the Linkage Model will be measured by the global competitiveness of the mineral sector and the number of employment opportunities created in the economy with the view of reducing poverty, unemployment and inequality in South Africa.

7. CONCLUSION

South Africa is endowed with abundant minerals. In 2008 there were 53 different minerals mined from approximately 1 515 mines in the country. This is despite a long history of mining dating as far back as 1000 years ago when copper was mined in Phalaborwa and residents of Mapungubwe trading with other civilisations in iron, copper and gold. Notwithstanding, the modern history of mining in South Africa can be regarded as having started in 1846 when the British introduced the modern European style of mining at Koperberg in Namaqualand.

The first significant interest of Europeans in South Africa as a mining destination came in 1870 when diamond bearing kimberlite pipes were discovered in Kimberley. This discovery was so significant that South Africa replaced Brazil as an important source of diamonds for the Europeans. The discovery of gold in the Witwatersrand basin in 1886 cemented the status of South Africa as a mining destination. Gold from South Africa was also used by the Bank of England to support the value of the pound.

Gold in the Witwatersrand basin was instrumental for the economic growth of South Africa. Unfortunately Africans and other races (except Europeans) were excluded from this economic growth. The legacy of this exclusion and subsequent Apartheid policies precipitated one of the highest unequal societies in the world with the average gini coefficient of 0.578 between 2000 and 2010. Social grants were singled out as a factor that has kept the gini coefficient of South Africa from

reaching embarrassing levels. In addition South Africa had unemployment rate that hovered at approximately 25% in the past decade.

One of the solutions to bridge the inequality gap and reduce the high unemployment rate is to use the connectedness of the mining industry in the economy to create employment opportunities. The vehicle proposed in this document is the Resource-based Research and Enterprise Development Model or the Linkage Model in short. The Linkage Model is based on the 1958 backward and forward linkage theory of Hirschman. The premise of the Linkage Model is that the mining industry is strong enough to induce job opportunities in other industries. This is not farfetched because in the past mining led to the establishment of towns and cities, the Johannesburg Stock Exchange, and factories to manufacture explosives, rock-drills, drilling bits, ferrosilicon and hydro-power equipment among others.

The envisaged Linkage Model is based on six components, namely government support; funding for mining and beneficiation research; research authorities; skills supply; mining and mineral beneficiation research; and commercialisation of research findings. The aim of the Linkage Model is not only to create competitive industries in South Africa, it also aims to reduce poverty, unemployment and inequality..

To create significant employment opportunities, mines and other industries in the mineral sector will have to be technologically intensive. The downside of this approach is that jobs could be lost in the mining and other primary industries due

to the incorporation of technology in work routines. However, technology intensive primary industries like mines tend to demand a large quantity of different components from other industries compared to low technology intensive primary industries. As it is, the South African mining industry procures most of its capital goods internationally. Should South Africa manage to change this procurement pattern, the combination of domestic procurement and technology intensive primary industries could lead to significant employment opportunities.

Given that mines are capital intensive, the hope of many jobs being created in the mining industry going forward is misplaced. A plausible solution is to focus on creating job opportunities in the labour absorptive industrial and services sectors. This can be achieved by implementing the Linkage Model in totality. The government through its various departments must be fully committed to the success of the Linkage Model. There has to be enough funding from the government and private sector to make the model work. In addition, there has to be enough researchers and research facilities that can be used for mining and beneficiation research. This can be achieved through the cooperation of Science Councils, universities and private sector.

Ultimately, the Linkage Model must lead to the commercialisation of research findings. Commercialisation can be achieved by using development agencies in conjunction with other models such as business incubation. The advantage of business incubation is that it gives a researcher/entrepreneur time to perfect his/her invention and business model while it provides the necessary support during the early days of a business.

The relevance of the Linkage Model does not only lie in its resonance with the National Development Plan of 2011 produced by the Planning Commission, it also provides a plausible alternative solution to the call for nationalisation of mines. The solution entails remedying structural problems in the South African economy such as the poor administration of basic and post matric education; low number of doctorates per capita in South Africa compared to its international competitors; low research output in mining; low capacity to develop and manufacture products based on research findings; and low entrepreneurial activity. The endemic nature of these structural problems requires long term political and corporate commitment.

The Linkage Model is not unique though. There are other mineral sector based initiatives that seek to address issues of poverty, unemployment and inequality in South Africa and the Linkage Model should be regarded as part of these initiatives.

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