

INDUSTRY COST CURVES AS A TOOL TO ANALYSE COST PERFORMANCE OF SOUTH AFRICAN MINING OPERATIONS: GOLD, PLATINUM, COAL AND DIAMONDS.

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the degree of Master of Science in Engineering.

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DECLARATION

I declare that this research report is my own, unaided work. It is being submitted to 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

Signed:

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This _____ day of _____ year _____

ABSTRACT

Since its existence, the South African mining industry has contributed significantly to the economic development of the country either directly or through the creation of linkages. In 2010 the sector accounted directly for 8.6% of Gross Domestic Product (GDP), 50% of South Africa's total merchandise exports, 13% of direct corporate tax receipts and employed 498,141 employees. The country is home to some of the world's largest mining companies and is host to several minerals that are of strategic importance to the global and national economy but unless those minerals are mined profitably then no benefit can be derived from their existence. It holds the world's largest known reserves of gold (13%), Platinum Group Metals (PGMs) (88%), chrome ore (72%), manganese ore (80%) and diamonds (12%). In 2010 it was a significant gold producer, the world's largest producer of (PGMs) (59%), manganese, chrome and vanadium. Platinum, gold, coal are the major economic contributors in the mining industry in terms of sales revenue, export earnings, job creation and remuneration earnings. Diamonds are also a key mineral commodity in the country because of their high unit value. However, the South African mining sector is faced with several challenges that threaten its productivity and hence profitability. The sector's significance and threats necessitate analysing its cost performance, and assess its profitability and sustainability as a key national economic sector.

To do this analysis, industry cost curves were used for the country's gold, platinum, coal and diamond mining sectors from 2007 to 2011. The cost curves were developed in Microsoft Excel using an algorithm that is based on error bars. The cost curves relate the unit cost of production against cumulative production from which low and high cost operations can be clearly distinguished. Important information can be derived and concluded from the industry cost curves that is useful to various industry stakeholders including shareholders, investors, management and industry analysts.

It was noted from the analysis that the mining sector's performance has been severely affected by several global and local activities during the period under review. The 2008 global financial crisis and several local challenges impacted on the sector's productivity and hence profitability and sustainability. These include industrial strikes, the Department of Mineral Resources' Section 54 safety stoppages, technical challenges associated with deep-level mining and the depletion of easily accessible mineral resources. All these challenges led to operating cost escalation resulting in profit margin squeezes. As a result, several operations were placed under care and maintenance while some capital projects were suspended. Notably due to these economic and technical challenges South Africa has dropped from being the world leader in gold production in the 1970s to fifth position in 2010.

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To my late father Joseph Mafuraha Tholanah whose presence would have been
necessary to celebrate with me my successes.
May his soul Rest in Peace.

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1 INTRODUCTION

1.1 Chapter overview

This chapter gives a background, overview and justification of the research report. The role played by South Africa in the global mining industry together with the sector's contribution to the national economy is discussed. The current challenges facing the South African mining industry are briefly discussed. Against the background of the importance of mining to the national economy and the challenges that threaten the profitability of mining operations, a justification for the use of industry cost curves to analyse the cost performance of the industry is given.

1.2 Problem statement

Mining companies publish quarterly, bi-annual and annual financial statements. Industry cost curves are developed from the data but no further detailed analysis has been done to find how industry cost curves derived from those financial and production data can be used to analyse the cost performance of mining operations over a given period. It is the aim of this report to develop industry cost curves for selected mineral commodities and use them as an input to benchmarking of new projects and relate them to cost performance of mining operations.

1.3 Background

Loneragan (2006, pp. 191) defined cost as "an expenditure or an outlay of cash, other property, capital stock, services, or the incurring of a liability therefore, identified with goods or services acquired, or with any loss incurred and measured by the amount of cash paid or payable, or the market value of other property, share capital, or services given or promised to be given in exchange". The Business Dictionary (2012) briefly defined cost as a monetary valuation of resources, risks incurred and opportunity foregone in the production and delivery of goods and services. Two main categories of costs are variable and fixed costs; variable costs being costs that vary with production volume whilst fixed costs are costs that do not vary with production volume (Musingwini, 2011). Mine operating costs are determined by various factors and mine site costs largely reflect the inherent characteristics of the orebody, its geology, grade, mining and processing methods employed, metallurgical performance of the mill, management practice and exchange rate movements. Treatment and refining charges also have a significant impact on costs, with higher charges increasing mine production costs (CHR Metals Limited, 2005).

Any mining company is in business because they have the capability of providing value to their shareholders through generating revenues that are in excess of costs. Profits are created when revenue exceeds expenditure and irrespective of the method used to determine them, costs form the basis of the profit equation (Lind, 2001). Price less the unit cost of production is profit and producers of a commodity are generally willing to supply it as long as the commodity price on the market exceeds the unit cost of production (McKinsey & Company, 2009). Economic Value Add (EVA) is a financial performance method used to calculate the true economic profit of a corporation and is used as a performance evaluation over time and is based on the idea that business must cover both the operating and capital cost (Value Based Management, 2011). One unique characteristic of mining is that mineral commodities are fungible in that there is little or no difference in product quality among producers hence mineral products are traded on international markets which means that markets determine the price, so miners are “price takers” (Gentry, 1988). This implies that to maximise value, the main factor a mining company has influence on is cost on the profit equation. Any company’s sustainability and competitiveness depend on its ability to reduce its operating and capital cost bases. This ensures that the company moves its mines down the industry cost curve, otherwise the company will not be able to weather future economic downturns and generate free cash flow after investing for growth (Anglo American Platinum Limited, 2010). Movement of costs into the lower quartile is not only beneficial to the company in terms of profitability, but it also sends a positive signal to the market and to investors that the company is pursuing a strategy of growth in value through cost reduction (Macfarlane, 2011). Cost management is the most key focus area to maximise value and low-cost production is a competitive advantage that positions a company to deliver value at every stage of the mining value chain (Agnico-Eagles Mines Limited, 2010).

Industry cost curves show ranked mine unit cash costs plotted against cumulative production. The curves show in graphical form the comparative operating cost performance of all operations in the industry and it can be thought of as an industry supply curve (World Mine Cost Data Exchange Inc., 2012a). On the cost curve, mines are ranked according to their unit costs, with lowest cost producing mines placed at the start of the horizontal axis and the highest cost producing mines on the extreme right of the horizontal axis. The width of the bar measures their production output and the height of the bar their unit cash cost (Musingwini, 2011).

Industry cost curves are a powerful tool that can be used to evaluate mineral projects, predict the behaviour of individual companies within an industry and under appropriate conditions, give indications of future prices (Torries, 1988). Under many conditions, the level of demand for a product and the cost of the next available supplier’s capacity determine the market price. Theoretically, the industry cost curve should allow companies to predict the

impact that capacity, shift in demand and inputs cost have on market prices. Economic theory suggests that production decisions made by a company are based on variable costs and the industry cost curve (Torries, 1988). According to Jaguar Mining Inc. (2010) cost curves are a useful indicator to investors and management as they provide:

1. a measure of the mine's cash margin per tonne or ounce by comparison of the cash operating cost per tonne or ounce to the commodity price;
2. the trend in costs as the mine matures; and
3. an internal benchmark of performance to allow for comparison against other mines in the industry.

New projects must aim to be within the lowest quartile cost producers so that should the commodity price decline, the project can still survive because the highest cost producers must close down first before the lowest cost producers can do so (Musingwini, 2011). In reality, costs and the resulting competitive position of a company on the cost curve are constantly changing (CHR Metals limited, 2005). As a benchmark for comparing the fortunes of individual mining companies relative to each other, the cost curve is an important analytical tool for mine management and their shareholders as well as for the banks, equity brokers and investors (VM Group, 2012).

1.4 Justification for the use of cost curves to analyse South African gold, platinum, coal and diamond mining operations

The rationale of using industry cost curves to analyse the South African mining sector is justified by its significance to both the global and local economy together with the challenges facing the mining sector. Each of these will be discussed in the following sub-sections.

1.4.1 The role of South Africa in the global mining industry

South Africa remains a major mining force, hosting some of the largest mining companies in the world and has a great comparative advantage in terms of vast mineral resource endowments. It is the wealthiest country in terms of mineral resources, with an estimated in-situ mineral resources worth US\$2.5 trillion - the largest in the world and an economically exploitable life of more than a century for non-energy mineral commodities (Department of Mineral Resources of South Africa, 2011). According to the Department of Mineral Resources of South Africa (2010), South Africa holds the world's largest known reserves of gold (13%), Platinum Group Metals (PGMs) (88%), chrome ore (72%), manganese ore (80%) and diamonds (12%). It is a significant gold producer, the world's largest producer of PGMs (59%), manganese, chrome and vanadium and a fifth largest producer of diamonds (8%). It is also a significant exporter of manganese and coal. Table 1.1 shows the contribution of South Africa to the global mining industry.

Table 1.1 South Africa's role in world's mineral reserves, production and exports

(Source: Department of Mineral Resources of South Africa, 2010)

COMMODITY	RESERVES				PRODUCTION				EXPORTS			
	Unit	Mass	%	Rank	Unit	Mass	%	Rank	Unit	Mass	%	Rank
Aluminium*		*	*	*	kt	1025			kt	538	3,1	7
Alumino-silicates	Mt	51	*	*	kt	265	60,2	1	kt	109		*
Antimony	kt	350	16,7	3	t	3 000	1,6	3	t	*	*	*
Chrome Ore	Mt	5 500	72,4	1	kt	6 762			kt	1035		
Coal	Mt	30 408	7,4	6	Mt	250,6	3,6	7	Mt	60,5	6,4	5
Copper	Mt	13	2,4	14	kt	89	*	*	kt	27	*	*
Ferro-chrome		*	*	*	kt	2 346	39,2	1	kt	2 621	56,5	1
Ferro-Mn/Fe-Si-Mn		*	*	*	kt	392	*	*	kt	411	*	*
Ferro-silicon		*	*	*	kt	148,9	2,9	6	kt	82,0	2,1	1
Fluorspar	Mt	80	17	2	kt	180	3,5	5	kt	*	*	*
Gold	t	6 000	12,7	1	t	197	7,8	5	t	180	*	*
Iron Ore	Mt	1 500	0,8	13	Mt	55,4	3,5	6	Mt	44,6	4,7	5
Lead	kt	3 000	2,1	6	kt	49	1,2	10	kt	47	1,9	14
Manganese Ore	Mt	4 000	80,0	1	kt	4 576	17,1	2	kt	3 978	26,6	2
Nickel	Mt	3,7	5,2	8	kt	34,6	2,4	12	kt	27,3	*	*
PGMs	t	70 000	87,7	1	t	271	58,7	1	t	251	*	*
Phosphate Rock	Mt	2 500	5,3	4	kt	2 237	1,4	11	kt	0	*	*
Silicon Metal		*	*	*	kt	38,6	2,8	6	kt	38,4	3,5	6
Silver		*	*	*	t	77,8	0,4	20	t	70	*	*
Titanium Minerals	Mt	71	9,8	2	kt	1 100	19,2	2		*	*	*
Uranium	kt	435	8	4	t	623	1,3	10		*	*	*
Vanadium	kt	12 000	32,0	2	kt	11,6	25,4	1	kt	11,9	*	*
Vermiculite	Mt	80	40,0	2	kt	194,3	35	1	kt	164,6	*	*
Zinc	Mt	15	3,3	8	kt	29	0,2	25	kt	5	0,1	24
Zirconium	Mt	14	25	2	kt	395	32	2		*	*	*

1.4.2 The role of mining in the South African national economy

The mining industry continues to play a significant and strategic role in the growth and development of South Africa's national economy. Despite the 2008 global financial crisis that almost crippled the mining sector, the sector still remains one of the key sectors of the economy, making a significant contribution to economic activity, job creation and foreign exchange earnings. The sector continues to be a key component of the Johannesburg Securities Exchange (JSE); as of the 27 February 2012 mining contributed 32.56% of the JSE market capitalisation (Johannesburg Securities Exchange, 2012) and continues to act as a magnet for foreign investment in the country accounting for 20% of private sector investment and 12.1% of total investment in the economy in 2010 (Chamber of Mines of South Africa, 2010). According to the Chamber of Mines of South Africa (2011) the following were contributions from the mining industry to the national economy in 2010:

1. the mining sector accounted for 8.6% in Gross Domestic Product (GDP) directly and 19% if the indirect multiplier and induced effects of mining are included;
2. about 50% of South Africa's total merchandise exports considering both primary and secondary beneficiated minerals exports;

3. employed 498,141 employees directly;
4. approximately 30% of capital inflows into the economy via the financial account of the balance of payments;
5. over 94% of the country's electricity-generating capacity;
6. about 30% of the country's liquid fuel supply;
7. about 13% of direct corporate tax receipts (R17.1 billion); and
8. substantially, as the largest contributor by value to Black Economic Empowerment (BEE) in terms of BEE transactions completed.

Beside direct contribution to the national economy, since its inception in the 19th century, the mining industry has acted as a springboard for the development of forward and backward linkages that are world class in their own right and owe their very existence to the mining sector. The clusters of industries that either supply it or use mining outputs include the energy, water services, engineering services, manufacturing, financial services, chemical and construction sectors that have gone a long way to service other sectors of the economy contributing significantly to the economic growth of the country. The government's New Growth Path (NGP) identifies mining as a key driver of the economy in creating jobs along the mining value chain, upstream and downstream industries across the country. In support of the New Growth Path of creating 5 million jobs by 2020, mining is set to create 140,000 more direct jobs by 2020 and 200,000 by 2030 (Department of Economic Development of South Africa, 2012). The New Growth Path also mentioned that the specific government's strategies is "...Accelerating exploitation of mineral reserves by ensuring an effective review of the minerals rights regime, lowering the cost of critical inputs including logistics and skills in order to stimulate private investment in the mining sector" (Department of Economic Development of South Africa, 2012, pp. 30). Towards the same goal, the 2011 – 2014 strategic plan of the Department of Mineral Resources highlights the importance of unlocking this value and enabling the industry to lead the country's NGP, recognising that "the mining industry has the potential to induce prosperous industrial clusters to support its development. These can significantly broaden economic growth, increase benefits and create decent jobs" (Department of Mineral Resources of South Africa, 2012b, pp.i). All these contributions necessitate the analysis of the industry and see whether it can still maintain its significance to both the global and national economic development. Table 1.2 shows South Africa's mineral sales and export contribution in 2010.

Table 1.2 Mineral revenue and export contribution of South Africa, 2010

(Source: Adapted from Chamber of Mines of South Africa, 2010)

COMMODITY	TOTAL SALES R 1 000	TOTAL EXPORT R 1 000
Precious metals		
Gold	53 093 147	51 037 449
PGMs	73 786 910	65 894 341
Silver	386 079	350 440
Sub- total	127 266 136	117 282 230
Base minerals		
Chrome	6 618 781	2 459 473
Copper (content)	4 369 326	1 209 297
Iron ore	43 418 606	40 148 279
Lead concentrate	696 738	696 738
Manganese	10 660 590	9 340 026
Nickel	5 984 753	4 911 462
Other metallic	474 748	178 817
Coal	73 202 529	36 746 983
Feldspar	56 204	0
Limestone & lime	2 277 270	13 279
Other non- metal	8 440 893	357 574
Miscellaneous	18 707 970	10 881 322
Sub- total	174 908 408	106 943 250
GRAND TOTAL	302 174 544	224 225 480

In 2010, PGMs became the largest component of South Africa's mining industry by sales value, with total sales of R73.79 billion, followed by coal at R73.20 billion and gold at R53.09 billion. These were the top three minerals altogether accounting for 66.2% of total mineral sales. In terms of exports, PGMs also ranked first with total export value of R65.89 billion, followed by gold with R51 billion, iron ore then coal with R36.75 billion. The total value of South Africa's mineral sales was R302.2 billion and export sales were R224.2 billion. Given their significant contribution to the industry, it is clear why industry cost curves were constructed for PGMs, gold and coal. Figure 1.1 shows remuneration earnings for individual mineral commodities in 2010.

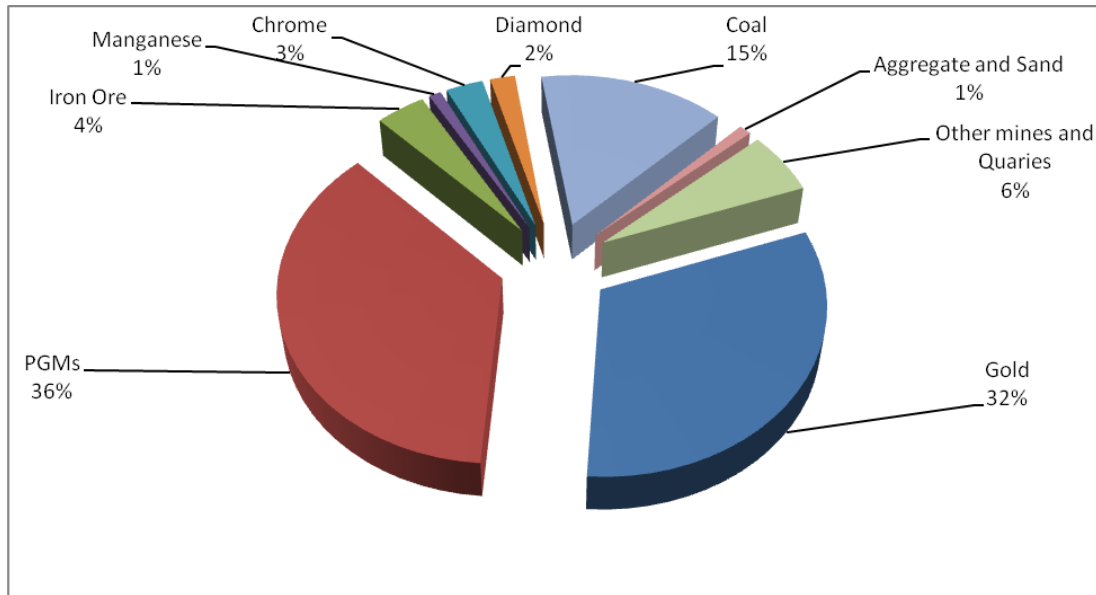


Figure 1.1 Percentage earnings on all South African mines including contractors, 2010

(Adapted from: Chamber of Mines of South Africa, 2010)

From Figure 1.1 it can be seen that PGMs ranked first in term of remuneration earnings followed by gold then coal hence the inclusion of these mineral commodities in the research. Table 1.3 shows employment contributions for the top eight and other mineral commodities in 2010.

Table 1.3 Number of employees on all mines in South Africa, 2010

(Adapted from Chamber of Mines of South Africa, 2010)

Rank	Mineral Commodity	Number of employees
1	PGMs	181 969
2	Gold	157 019
3	Coal	73 817
4	Iron Ore	18 216
5	Chrome	13 971
6	Diamonds	11 143
7	Aggregate and sand	7 001
8	Manganese	5 879
9	Other mines	29 126
	Total	498 141

From Table 1.3 it can be seen that PGMs were the biggest employer contributing 37% of the total mining industry's labour force followed by gold contributing 32% then coal contributing 15%. The industry employed a total of 498,141 people directly, and if the indirect and induced effects of mining are included, then another 500,000 jobs are estimated to exist. This is the other reason the author focussed on gold, platinum and coal in the analysis. From

Table 1.3, it can be seen that iron ore and chrome contributed more than diamonds but were not included in the analysis. However, diamonds were included as part of the study because they are a high unit value product. The reason iron ore was excluded from the analysis is that there are only two major iron ore mining companies in the country, which are, Kumba Iron Ore Limited and Assmang Iron Ore Limited. Kumba is 65% owned by Anglo American Corporation whilst Assmang is a 50: 50% Joint venture between African Rainbow Minerals Limited and Assore Limited. Under these two companies are only five operating mines which make the analysis of the iron ore mining sector using cost curves less meaningful.

1.4.3 Challenges facing the South African mining industry

Despite the strategic significance of the South African mining industry to both the global and national economy, the industry is faced with various technical, social and operational challenges that offset the benefits of high mineral commodity prices experienced from time to time. Over the past few years, there has been an increased expectation from investors, stakeholders, government and communities regarding better safety, corporate social responsibility around communities in which mines operate, environmental protection and return on investment. All these expectations are costly and impact negatively on the short term performance of the sector's profitability. Safety related mining stoppages imposed by the Department of Mineral Resources (DMR) in terms of Section 54 of the Mine Health and Safety Act, No. 29 of 1996 have been on an increase across the industry negatively impacting on the productivity of mining operations. Under this Act, the mine inspector has power to stop mining operations if he/she believes that any occurrence, practice or condition at a mine endangers or may endanger the health or safety of any person at the mine (Department of Mineral Resources of South Africa, 2012a). The mining business is perceived to be associated with super profits that all South Africans seek to benefit from the sector economically. Legislation has been developed, amended and enacted towards this goal. This drive of economic participation even prompted some political groups to call for the nationalisation of the industry that provoked a debate among industry stakeholders. The recurrent labour related strikes by employees and labour unions together with escalating electricity costs compound the problems already faced by the industry. Like any other country, South Africa's mining industry was not immune to the 2008 global financial crisis that almost crippled the sector and saw some operations being placed under care and maintenance. South Africa is also known to host the deepest gold mines in the world and the mines are highly labour intensive and require complicated and expensive extraction techniques that escalate the cost of production. Figure 1.2 shows global gold production and South Africa's gold production from 1900 to 2008.

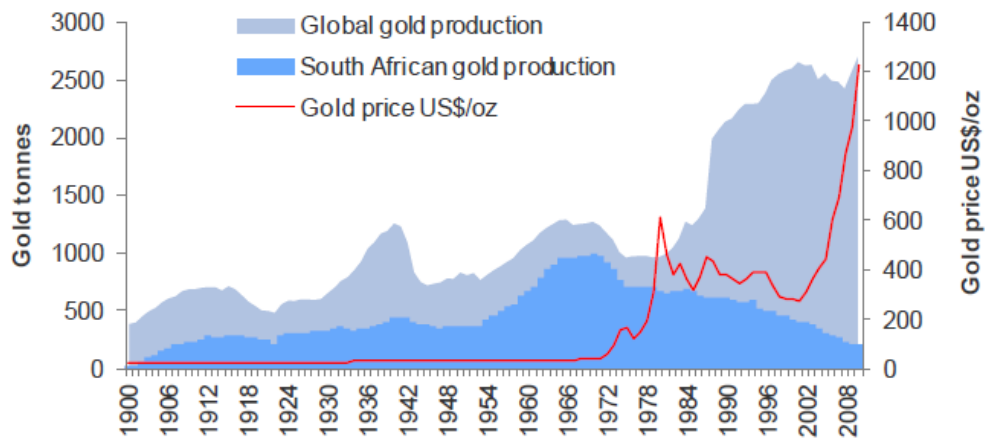


Figure 1.2 Global and South African gold production

(Source: SBG securities, 2012)

It can be seen from Figure 1.2 that even though the gold price and global gold production has been increasing from the 1970s, South Africa's production has been declining over the same period. SBG securities (2012) stated that in 1966 South African gold production amounted to 78% of global gold production but has gradually declined to 7.8% in 2010 as shown in Table 1.1.

It is against this background of challenges that one would want to know how profitable mining operations are because despite high mineral prices that are experienced from time to time, the cash margins are squeezed by various challenges facing the industry that the country may not be able to turn its comparative advantage into a competitive advantage. All of the above factors necessitate the analysis of the industry and understand its cost and profitability structure and see whether the industry is robust enough to absorb and sustain both global and local pressure and challenges. Hence the need for industry cost curve analysis in order to get a sense of the extent of the profit margin squeeze and long term sustainability of the South African mining industry.

1.5 Summary of Chapter 1 and structure of the report

South Africa continues to be a source of global mineral commodities either as raw or processed minerals. Its vast mineral resources and reserves are of strategic importance to the global economy. Nationally, the mining industry continues to be a springboard for economic development, strategically positioning the country as a competitive economy globally. PGMs, gold and coal are the major economic contributors to the mining industry as seen by their significant contribution to job creation, sales revenue and export earnings. Overall, PGMs rank first followed by gold then coal hence the use of industry cost curves to analyse the cost performance of these commodities with the addition of diamond as a high

unit value commodity. Iron ore also contributes significantly more to the industry than diamonds, but was excluded from the analysis because there are few operating iron ore mines in the country. However, the industry is faced with a lot of challenges that threaten its profitability despite high mineral commodity prices that are experienced from time to time. This necessitates analysing the industry's cost performance and see how robust and vulnerable it is to current and/or future challenges. Cost curves are a great tool to aid in that analysis.

This chapter has provided justification for the research work and defined the problem statement. The remainder of the report is structured as shown in Figure 1.3.

Chapter 2 explains how performance of the mining industry is measured including the use of cost curves as a measure of cost performance. Mining costs and their behaviour are also discussed in Chapter 2.

Chapter 3 outlines the algorithm that was used to construct the cost curves. The algorithm is based on the concept of error bars using Microsoft Excel. Industry cost curves and their analysis are shown in Chapters 4, 5, 6, and 7 for gold, platinum, coal and diamonds respectively. Conclusions and recommendations are made in Chapter 8.

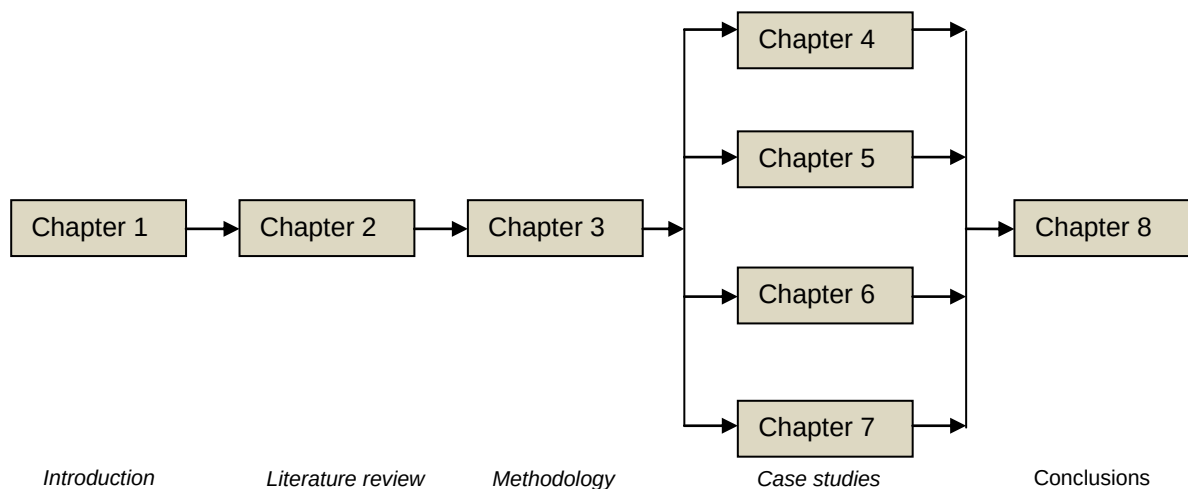


Figure 1.3 Structure of the research report

2 Literature Review

2.1 Chapter Overview

The objective of this research report is to analyse the cost performance of mining operations for the selected minerals. The word “performance” can be described in various ways so it is the aim of this chapter to describe what performance means in the context of this report as well as metrics of performance measure. Mining operating costs, their factors and behaviour are outlined together with cost cutting strategies that mining companies use to create and maximise shareholder value. The evolution, structure and use of industry cost curves as a tool to analyse the cost performance of the South African mining industry is described together with past and current work done on industry cost curves.

2.2 Performance measure in the mining industry

In the context of this research report, performance refers to value creation from the mineral asset. Stern and Pigott (2002) mentioned that the performance of a mining company is of interest to two main groups of people; shareholders and management. Shareholders want to measure how well the company is performing compared to potential or actual existing investments whilst management want to measure their performance for incentives and rewards. Both groups described above scrutinise or measure performance using a variety of metrics (Stern and Pigott, 2002). There are various operational and financial metrics that shareholders, management, investors and analysts use to measure performance of mining operations. However, in the analysis chapters focus will be given to cost performance and associated drivers because of the reasons that will be discussed in this chapter.

2.2.1 Production

Profitability at each operation is driven largely by the amount of mineral product the mine produces and the cost per unit to produce it. Since most costs at operations are fixed, the quantity of ore produced and the resulting mineral produced has a significant impact on unit costs. The objective at each operation is to operate at maximum capacity thereby reducing the cost per unit of mineral produced (High River Gold Mine Limited, 2010).

2.2.2 Net earnings

This is the net profit or loss over a period. Generating earnings enables a company to fund dividends and growth. The most measure of earnings is the Earning Before Interest, Tax, Depreciation and Amortisation (EBITDA) which is net profit or loss excluding:

- Income tax expenditure;
- Finance expenses;
- Finance income; and
- Depreciation and amortisation (including goodwill impairment charges).

EBITDA is a valuable indicator of a company's ability to generate operating cash flow that can fund its working capital needs, service debt obligations and fund capital expenditure.

2.2.3 Earnings per share

Earnings per share (EPS) is the net reported profit after tax divided by the number of issued shares in cents per share (Rudenno, 2009). Feinberg (2005) highlighted that if a company wants to increase its earnings, it can do so by merging with another company. However, if these companies do not derive Economic Value Add (EVA), the company will ultimately suffer and its share price will decline. EPS is a measure of the company's profitability and is a primary indicator in determining share price and value.

2.2.4 Total shareholder return

This is the return on investment a shareholder receives over a specified time frame and is a key indicator that is used to compare a company's share performance over time against industry competitors. Total shareholder return takes into account the share price appreciation or depreciation and dividends received.

2.2.5 Market capitalisation

A high market capitalisation is an important corporate objective, both to drive perceptions of economic success and to help companies achieve their strategic goals. It is a measure of corporate performance that reflects current performance and future expectations (Ludwig, Ringbeck and Schulte-Bockum, 2000).

2.2.6 Share price performance

Various financial and operational parameters influence future movement in the share price of a mining company including commodity price, exchange rate and production. The reserve base also influence share price movements. Exploration success is the lifeblood of any mining company either through the company's expenditure in exploration or through acquisition of exploration acreage, with known discoveries. Any discovery of new economic deposits that increases the reserve base of an operation leads to an increase in the share price as long as the market believes there is further value in the prospect (Rudenno, 2009). Larger reserves are an advantage as they represent the inventory of a company and they imply a longer potential mine life.

2.2.7 Dividend yield

Every investor wants to receive a dividend from invested capital. If a company is able to declare dividends then it has performed well and has the ability to create more value through reinvesting the cash flow into exploration or new projects thereby increasing its capital growth. A dividend yield is dividend per share divided by the share price as a percentage; the higher the yield the more attractive the stock (Rudenno, 2009). It is a measure of the simple rate of return from dividend payments.

2.2.8 Enterprise value

Rudenno (2009, pp.236) defined the Enterprise Value (EV) of a company as "its market capitalisation (share price multiplied by number of issued shares) less any net cash or, more often, plus any net debt". EV is a more accurate reflection of the market's view of the business's value. It is the value of the business as represented by the sum of the market value of the various claims on business profits and cash flows.

2.2.9 Economic Value Add (EVA)

Economic Value Add (EVA) was developed by the managing consulting company Stern Stewart Incorporated, which was founded in 1982 by Joel M Stern and G Bennett Stewart (Macfalane, 2006). It was developed as a performance management system aimed at operationalizing the idea of increasing shareholder value. EVA is net operating profit after tax less an appropriate charge for the opportunity cost of capital invested. As such, it is an estimate of the true amount by which earnings exceed or fall short of the required minimum rate of return that shareholders could get by investing in other securities of comparable risk.

Peter Drucker as quoted in Pettit (2000, pp. 2) wrote, “There is no profit unless you earn the cost of capital...” Real value is added when there is enough free cash flow available to pay shareholders or reinvest into the company’s projects that will provide returns in excess of the cost of capital. Shareholder value is created if the total market value of a company is more than the capital invested otherwise shareholder value has been destroyed. Theory suggests that EVA can be increased by earning more profit without using more capital either by cost cutting or increasing sales revenue through higher unit prices or volume. It suggests that companies should invest in new projects only when the expected return on invested capital after tax exceeds the weighted average cost of capital (Kleiman, 1999). Feinberg (2005) stated that EVA can be used as a decision making tool to ensure the creation of value and to measure performance of companies and projects.

2.3 Value creation

The main performance measure in any mining business is mineral asset value that is created as discussed before in section 2.2. Every mining operation is in business because they have the capability of creating value for their shareholders through generating revenues that are in excess of cost of production. Shareholder value is created when a business generates profits, therefore every mining operation must strive to be profitable (Musingwini, 2011). Copeland, Koller and Murrin (1994) stated that the main goal of business is to maximize shareholder value. The distinguishing and unique characteristic of a resource industry compared with any other industry is that the underlying asset is non-renewable and its value is reduced with each unit of extraction. Since the mineral resource is a wasting asset, it means there is only a single opportunity available to extract ore from the deposit in order to unlock value from the asset, so any mining operation must be managed in an optimised and cost effective manner to maximise long term value (de Jager and Minnitt, 2000). Simplistically,

$$\text{Profit} = \text{Revenue} - \text{Costs}$$

There are major technical and economic variations in the nature and cost of mining operations that are very important to the economic viability and hence the value of each operation (Lonergan, 2006). Aquarius Platinum Limited (2011) outlined several strategies that they identified to deliver shareholder value, these being to:

- optimise costs and efficiencies at existing operations to improve or maintain the position of these mines on the cost curve;
- seek growth through organic expansion or acquisition of PGM properties which are:
 1. contiguous with existing operations and capable of exploitation through existing infrastructure at low capital cost; and

2. relatively shallow, primarily Upper Group 2 (UG2) ore-bodies which lend themselves to the group's established mechanized mining techniques;
- steadily grow production from current levels to the extent that it can be done profitably, while not hesitating to cut loss making production;
 - evaluate the acquisition of other PGM properties cautiously, in terms of earnings accretion rather than potential production increases; and
 - remain a focused primary PGM producer.

Creation of value from the mineral asset is important and necessary to satisfy various stakeholders' needs. Impala Platinum Holdings Limited (2011) mentioned how various stakeholders benefit from value created from their mining business, these being:

- employees receive salaries/wages as well as share based compensation;
- shareholders receive dividends and growth on the share price;
- governments receive taxes and royalty payments;
- communities benefit through employment, job creation and socio-economic development; and
- suppliers and contractors are supported through the procurement of consumables, services and capital goods.

So it is important that mining operations are profitable through efficient and cost reduction measures. Efficiency drives productivity which maximises revenue generation from the mineral asset.

2.4 Revenue

Revenue is the money that is received from the sale of a mineral commodity and is significantly impacted by the metal price (Musingwini, 2011). Gentry (1988) mentioned that the metals industry is characterised by fungible commodities which makes miners 'price takers'. Mineral commodity prices, particularly gold, is volatile over short periods so does the revenue received. The mineral commodity price is influenced by various industry and macroeconomic factors that are beyond the control of producers.

Exchange rate movements against the US dollar also impact on revenue generated. The Financial Mail (2012) mentioned that mineral commodity prices are quoted in US dollar (USD) hence revenues received, whilst most operating costs are incurred in South African Rand (ZAR). As a result fluctuations in the exchange rate impact revenue either positively or negatively. Notwithstanding the current high gold price in US dollar terms, South African operations may fail to reap full benefits from these high prices if the South African rand is strong against the US dollar. The Financial Mail (2012) also advised that to mitigate risks in revenue fluctuations, South African companies should hedge their currency and focus on cost management which they have control over.

Volume produced, head grade and metallurgical recoveries also impact on revenue generated. Most of these factors that affect revenue are beyond the control of miners which means miners have little influence on the revenue part of the profit equation. Hence a company's competitiveness and long term sustainability depend, to a significant extent on the company's ability to reduce costs and maintain low cost, efficient operations.

2.5 Mining costs and behaviour

Operating cost is money that is spent in the production process to produce the final product (Musingwini, 2011). These costs include wages, consumable materials such as chemicals and explosives, transportation and power many of which are susceptible to inflationary and supply demand pressures. Rudenno (2009) described factors that affect operating costs and noted that they vary depending on geographical location, mining and metallurgical factors such that two mines producing identical quantities of a same resource product can have quite different operating costs; however, the order of magnitude of operating costs will often be related to size of the operation.

Low operating cost is one of the measures of a mineral project's profitability. If a mine's operating costs are lower than those of its competitors it is likely to survive commodity price squeezes. Even though future factors like price changes cannot be forecast, shareholders feel safe if their operations are in the lower quartile of the industry's cost curve. The margin between the average commodity price and the cash operating cost is an important guide to a company's ability to stay in business during commodity price downturns. Hall and Hall (2007) mentioned that significant emphasis of every mining operation is placed on cost reduction to improve economic performance because the downward price pressure reduces margins and cost cutting is seen as a best way to maintain margins. Mining operations with high operating cash costs are more risky because when commodity price falls, the operation becomes unprofitable. A low cost operation is able to generate a lot of free cash flow to finance expansionary projects, to acquire equipment and even finance acquisitions during commodity price down turns (Lonergan, 2006).

Operating costs are categorised according to their behaviour as the underlying level of activity changes, activity level being defined as production volume. In mining, costs are usually classified as fixed, variable or semi-variable costs (OneMine, 2012). Recny (nd) described the nature, behaviour and difference between the three cost categories.

2.5.1 Fixed costs

Fixed costs are costs that do not change with production volume; whether a mine produces or not these costs are still incurred to sustain production capacity. These costs are fixed only in relation to a given time period, and within a given range of activity. A radical change in a production system usually results in a new set of fixed costs (Recny, nd). Examples of fixed costs include wages and salaries (employees must still be paid even if the mine is on shutdown), pumping, ventilation, interest expense, depreciation, business license, insurance and permit fees.

2.5.2 Variable costs

Variable costs are costs that change in direct proportion to production volume; the more the production, the higher the costs. The variable cost components in a production system are usually factored linearly based on such criteria as tonnage mined or processed, manpower levels and footage drilled (Recny, nd). Examples of variable costs include materials and supplies used in the production process, transport and power.

2.5.3 Semi variable costs

These costs vary according to production volume, but not in direct proportion and are also referred to as step costs or mixed costs. For example, if volume increases by 10% the total amount of semi-variable costs may increase by more or less than 10%. Examples of semi-variable costs include maintenance costs.

Total costs are the sum of the fixed and variable costs. Variable and fixed costs are two of an assortment of cost behaviour patterns as illustrated in Figure 2.1. In reality, the classification of costs is difficult and frequently requires that some simplifying assumptions be made. Analysis of cost behaviour patterns as a function of changes in production criteria can be useful at several stages of project evaluation (Recny, nd).

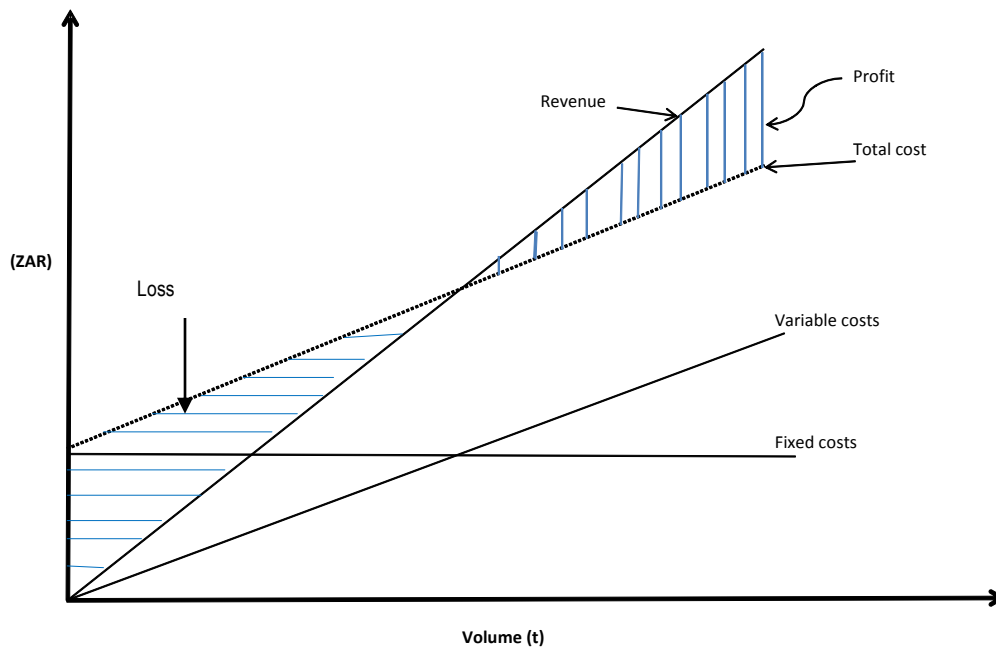


Figure 2.1 Cost-volume relationship

2.6 Factors affecting mine operating costs

Cash operating costs of mining operations vary widely and are a reflection of many factors such as the head grade (the higher the grade the better), mining methods, depth of operation (the closer to surface the cheaper), recovery rate, work labour efficiency and the use of subcontractors (Lonergan, 2006). Costs are also affected by the price of input commodities such as fuel, electricity, labour, chemical reagents, explosives, steel and concrete. The considerable increase in input costs, labour and electricity in particular, is affecting the ability of many South African mining operations to contain operating costs.

Deeper operations tend to be high cost operations because highly sophisticated infrastructure using advanced technologies are required to extract the resource sustainably and safely. As operations get deeper, refrigeration is required for ventilation which is expensive and escalates the cost of production. Deeper operations are also prone to seismicity events that disrupt production. Sophisticated and expensive rock support techniques are required for deeper operations. Materials handling (both man and rock) costs also increase as an operation gets deeper.

The type of mining employed also affects operating costs. Open pit operations tend to be lower unit cost operations than underground operations. This is because of:

- less auxiliary costs involved in open pit mining such as ventilation and rock support;

- less complex and expensive techniques required in areas of material movement, rock support and ventilation; and
- opportunity for economies of scale.

Variations in operating costs within the same type of mining either underground or surface is also influenced by the type of mining method employed, for example, room and pillar versus breast stoping. This is because some underground methods offer opportunities of mechanisation than others making them more productive because of economies of scale. The mechanisation level of a mine also affects operating costs. Mechanised operations tend to be low unit cost operations because of their associated opportunity for economies of scale. Treatment costs vary depending on the type of ore and the complexity of the onsite process, with heap leach operations generally being low cost operations (Rudenno, 2009).

Safety and health performance of a mine operation is so important to ensure profitability of the operation. Failure to provide a safe working environment and/or noncompliance with regulations and legislation could impact negatively on mine productivity. The profitability of mining operations requires the implementation of strategic and effective cost reduction measures by management.

2.7 Cost minimisation

Hall and Hall (2007 pp.10) stated that, “productivity or efficiency improvements are the best way to reduce costs but they must be achieved in the context of maximising value, that is, without impacting on the operation’s effectiveness”. Improving efficiency will often lead to cost reductions as increased productivity results in greater output being achieved using similar or less input. They also noted that there is a growing trend in the mining industry towards utilising fewer and larger productive equipment, though this can reduce the mine’s overall capacity should a major breakdown occur. Brown (2011) in Impala Platinum’s 2011 Annual Report mentioned the importance of maintaining the company’s competitive position on the cost curve through cost management focussing on two main areas:

1. ensuring the optimal usage of consumables and the implementation of cost-effective purchasing decisions for procurement of goods and services. This will assist in managing absolute costs; and
2. improving efficiencies through higher productivity, capital delivery on projects and infrastructure optimisation. This assists in containing increases in unit costs.

2.7.1 Economies of scale

Mining Man Newsletter (2012) described the principle of economies of scale and mentioned that the term economies of scale refers to the fact that usually the unit cost of production

reduces as production increases. The larger the operation the higher the absolute cost, but the lower the relative cost on a unit basis (Rudenno, 2009). For example, if a mine produces 1,000 tonnes of ore per year, it might cost \$10,000 per tonne to mine it. However, if production increases to 10 million tonnes per year it might only cost \$1,000 per tonne. The principle is very important in the mining industry- the more the mine produces, in general the less it costs to produce each tonne. Economies of scale are explained by the concept of fixed and variable costs. In the business of mining, fixed costs (especially labour and equipment) contribute significantly to the total cost of production so the more the tonnes produced means that the larger the denominator to divide fixed costs over, hence a lower unit cost. Economies of scale explain why some operations are more profitable than others in the same industry and it is one of the reasons that justify mergers between two companies producing the same product. Figure 2.2 shows a simplified cost-volume relationship to describe the principle of economies of scale, showing that as production volume increases, unit cost decreases.

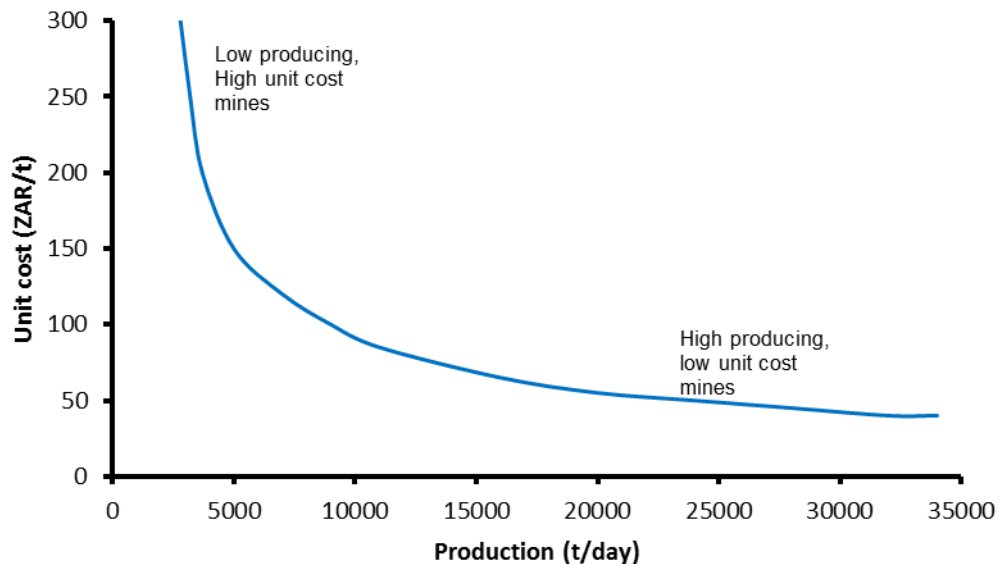


Figure 2.2 Unit cost-volume relationship

Other factors also contribute to economies of scale, including more purchasing power to get better deals from suppliers when the company is bigger, the ability to invest more capital in return for lower operating costs, and improved logistics leading to lower transport costs.

2.7.2 Asset optimisation

Anglo American Platinum Limited (2009, pp. 56) in the company's Annual Report, mentioned that "... asset optimisation initiatives over the years resulted in a decrease in the cash on-mine cost of mining and treatment of operations of R700 million or 3%, to R19,5 billion".

Asset Optimisation (AO) is a key operating agenda item for Anglo Platinum, focussed on the optimisation of the existing asset base to maximise value. The approach involves identifying and championing specific projects that are designed to contain costs and enhance value. As mentioned in the report, major initiatives include:

- the curtailment of production from high-cost shafts while expanding output from lower-cost operations where possible;
- the reorganisation of operations to match anticipated market requirements while improving productivity and costs;
- the reduction of capital, labour and stores costs through the improved utilisation of production equipment, reduced shaft infrastructure and enhanced technology; and
- reduced dependency on contractor activities.

Since its introduction, the AO strategy has resulted in improved production and reduced costs. In the same report it was stated that the company achieved savings of R4.3 billion from projects across the company and these helped to move the company down the industry cost curve.

2.8 The focus on cost as a performance measure

It is noted that several performance measures were discussed in this chapter but focus will be given to cost performance and factors that affect unit operating costs. This is because cost is the main value driver that companies can use to maximise profitability because other value drivers such as price are beyond the control of mining operators. The other reason is that financial performance measures such as share price, market capitalisation and earnings are only meaningfully comparable when companies under analysis have all their operations in the same country. In Annual Reports, financial measures are always consolidated for the whole company that if a company has operations outside South Africa, it is not possible to determine the contribution of South African operations to such financial measures. For example, comparing share price for Gold Fields and Gold One is unreliable because Gold Fields has about 50% of its operations outside South Africa whilst Gold One has all its operations in South Africa. When a company has operations in different countries, financial measures are not reflective of South African operations' contribution alone.

2.9 Industry cost curves

The evolution, definition and use of industry cost curves are discussed in detail in the following sub-sections. Dynamic cost curves are also briefly discussed.

2.9.1 *The evolution of industry cost curves*

Gentry and O'Neil (1984) noted that due to weak mineral commodity prices in the early 1980's, mining operators became increasingly cost conscious and this attitude extended into investment analysis. As a result of inaccurate price forecasts during that period, investors looked for more investment criteria, focussing increasingly on the competitive cost rankings of prospective mines. Some investors even required that new projects be in the lower cost region before committing funds into the project. Since then it has become standard practice in the mining industry to plot industry cost curves though little further analysis of the curves has been done particularly at a company and country level to explain the performance of mining operations.

2.9.2 *Definition and construction of cost curves*

CHR Metals limited (2005) defined a cost curve as a graphical plot of cumulative production for individual mines (x-axis) ranked according to unit cash cost of production (y-axis). It represents the supply curve for the industry reflecting mine site costs, metal prices, exchange rates, treatment and refining charges. Industry cost curves show in graphical form the comparative operating cost performance of all operations in the industry sample and can be thought of as an industry supply curve (World Mine Cost Data Exchange Inc., 2012d). The width of the bar represents the production and the height represents the unit cost. Mines are placed on the curve according to their unit production cost with the lowest unit cost producing mine placed at the start of the horizontal axis, and its bar stops at its production rate. The production from the next cheapest mine is then added until the highest unit cost producing mine is added at the extreme right of the horizontal axis (Musingwini, 2011). Key to constructing industry cost curves is to identify and treat the various cost items of each company consistently so as to compare like with like. The task is complicated because:

1. companies have different accounting and taxation methods; and
2. costs are usually accumulated in different ways at different stages of production within a single operation.

In consideration of these variations in financial reporting, it is important to correctly account for all cash costs to derive a meaningful and comparable cost analysis. In order to prepare a ranking of mining costs it is also necessary to first convert all individual mine costs to the same currency because companies report in different currencies.

The curve allows an individual mine to see how its unit production cost relates to its competitors. A typical industry cost curve is shown in Figure 2.3. While there are exceptions, it is clear from the cost curve that the larger producers tend to inhabit the lower quartile of

the cost curve, while the smaller producers dominate the upper quartile reiterating the advantages of the principle of economies of scale as explained before in section 2.7.1. In the middle there tends to be a mixture of small and large producers, most probably because those small producers have high grade ore whilst those large producers have low grade ore that these two end up having comparable unit cost of production.

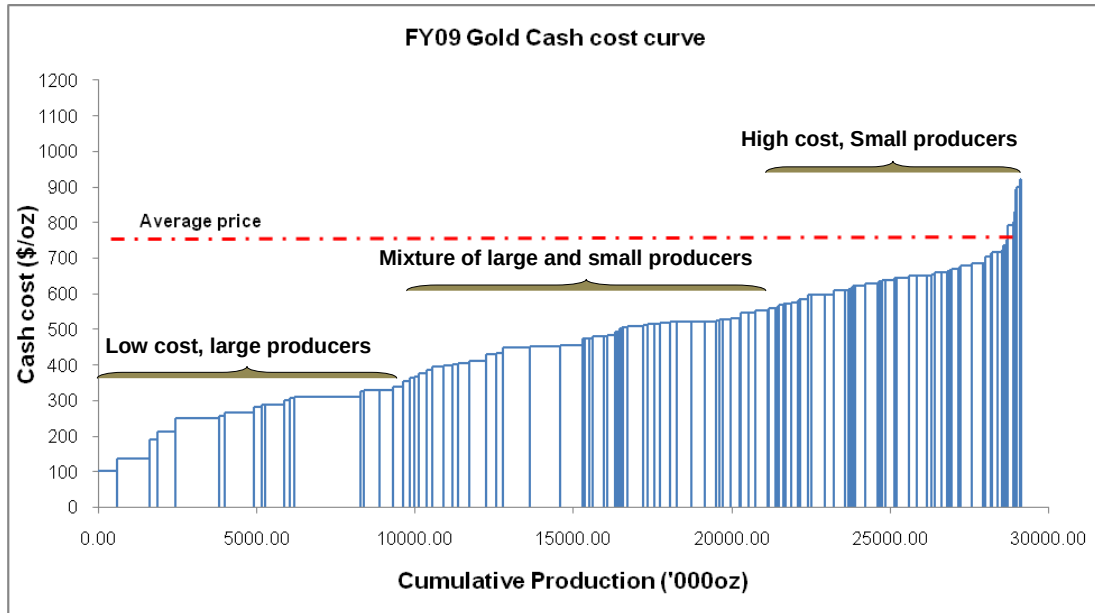


Figure 2.3 Typical cost curve

According to ABN AMRO Gold mine cost report for the first quarter of 2011 produced by (VM Group/Haliburton Commodity Research, 2011 pp.4) in their cost curves analysis on a regional basis, it stated that “in South Africa, the margin between an average South African gold mine’s production cost and the average gold price over the first quarter of 2011 fell to \$518/oz from a record \$541/oz in the previous quarter”. The report also noted that in Q1 2011 the US dollar weakened against major gold producing currencies, putting pressure on production costs for miners. However, the report stated that the South African rand weakened in the first quarter of 2011 for the first time since the first quarter of 2010 but this did not prevent South African production cash costs from rising, with average costs increasing by 5% to \$869/oz. According to their report for the second quarter of 2010, in South Africa the strong rand performance against the US dollar served to increase cost pressures but improved efficiencies helped to lower costs at the upper end of the cost curve (VM Group/Haliburton Commodity Research, 2010). VM Group/Haliburton Commodity Research (2010 pp.6) also stated that despite the improvements, “...South Africa still remains the world’s highest cost producer per ounce of gold, with average cash costs of \$739/oz, up \$118/oz from the next most expensive producing region, the rest of Africa”. However, the analysis by VM Group only shows the trend in cash cost over a period but did not go further in explaining the longer time trends and further analysing the cost structure for

South African gold mine producers. Figure 2.4 shows the trend of cash cost for Q1 2010 and Q1 2011 for South African gold mines.

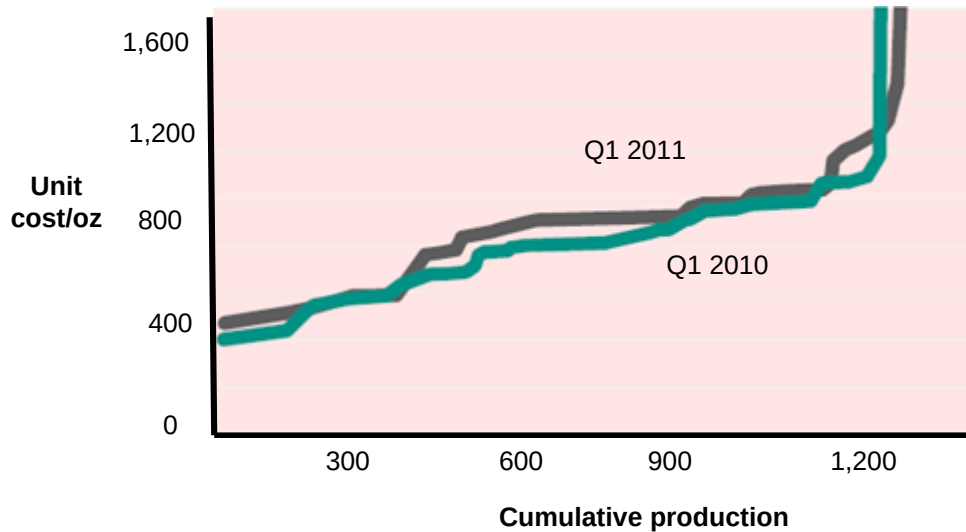


Figure 2.4 South African gold mine cost curve comparison for Q1 2011 and Q1 2010

(Source: Adapted from VM Group/Haliburton Commodity Research, 2011)

According to (World Mine Cost Data Exchange Inc., 2012c), to assist in the estimation of costs during feasibility studies, O'Hara developed a rule of thumb relating cost to production rates. The rule of thumb was developed using data from operating mines based on the exponential regression equation $Y=aX^b$ where:

- X is the independent variable upon which the cost relationship is based which is the production rate;
- a and b are constants estimated by the regression of X on Y; and
- Y is the unit cost.

The curve in Figure 2.5 was developed using actual data from over 300 mining operations in North America, Australia, Latin America, Europe and Southern Africa. The curved lines above and below the plotted mines are drawn one standard error above and below the line of best fit for the sample. Again this cost curve supports the principle of economies of scale previously discussed in section 2.7.1.

Using the curve, to estimate the range of costs expected for a particular production rate, one can go to the particular production rate per year on the X-axis and read off the range of production cost on the Y-axis corresponding to the upper and lower curves on the chart. It has been proved that there is a two thirds probability that the true cost lies between the two curves for that particular production rate per tonne (World Mine Cost Data Exchange Inc., 2012c).

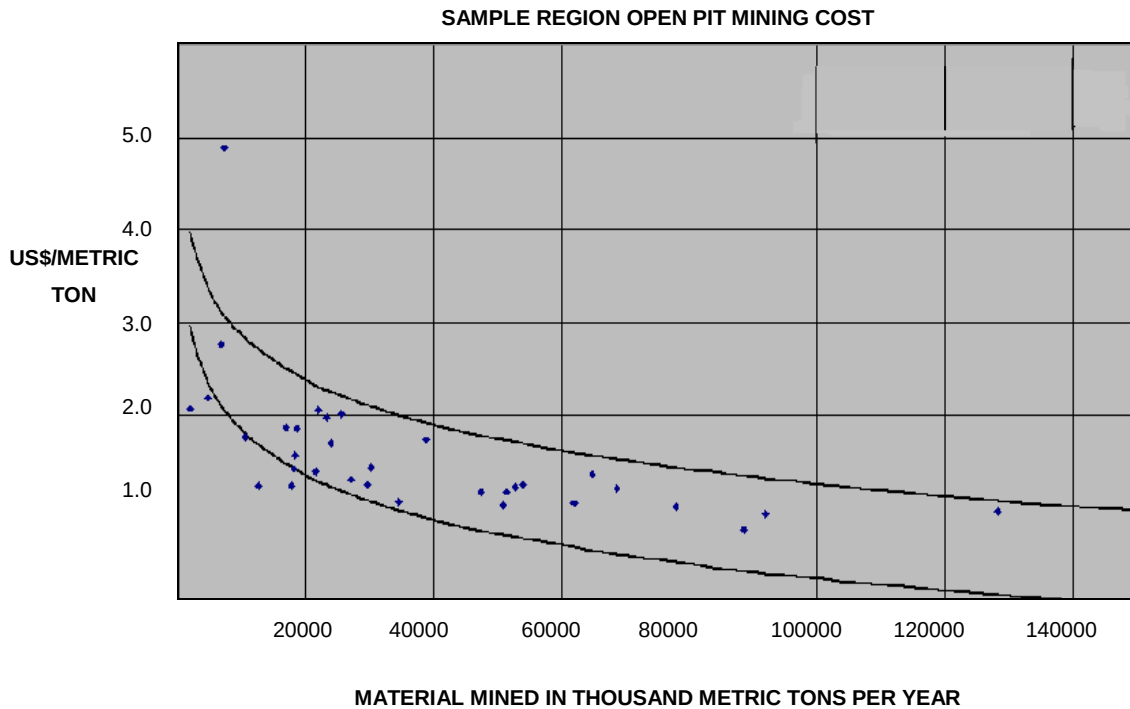


Figure 2.5 Example of O' Hara cost curve

(Source: Adapted from World Mine Cost Data Exchange Inc. (2012c))

2.9.3 Uses of industry cost curves.

Knowledge about the industry cost structure is critical so industry cost curves are an important analytical and project evaluation tool that can be used by investors, shareholders, management, lenders and industry analysts. Cost curves are important in industries like mining where most producers receive the same or similar prices for their products (Mining Man Newsletter, 2012). They are basically used to analyse the performance of the individual mines that make up an industry.

They are commonly used during feasibility studies to benchmark new projects with existing operations to see how the estimated operating costs of the new project compare with competitors already in the industry. If an operating cost is known for one type of comparable operation, then an estimate can be easily made for a similar new operation (Rudenno, 2009). Given the volatility of commodity prices, the position of an operation on the industry cost curve is important. New projects must aim to be in the lower cost quartile which means not only are their costs low compared to their competitors but also that they are less likely to be hit by price squeezes than those in the upper quartile (Musingwini, 2011). Lonergan (2006) also highlighted that mining operations are most vulnerable to price fluctuations during their development and start up stages confirming the importance of new projects to be in the

lower cost quartile to weather price squeezes. Even for operations in the producing stages their position on the cost curve has important valuation implications.

Cost curves are also used during project evaluation and as an investment decision criterion. A project that is in the lowest portion of the cost curve is likely to find alternative profitable sales. Conversely a company in the higher cost portion of the cost curve is unlikely to be able to offer a competitive price to potential new customers. Lending institutions are more likely to lend money to a project that is located in the lower cost region of the cost curve (Fawcett and Taylor, 1985). Resource industry investment analysts also use cost curves to forecast earnings from mining operations and funding institutions can use cost curves to assess project finance options and credit worthiness (World Mine Cost Data Exchange Inc., 2012b).

Cost curves can also be used by government to clearly identify the profitability of mining operations within the country and determine the amount of economic rents being derived from the operations. Torries (1998) defined economic rent as the amount of profit that can be taxed away without affecting decisions of the project investor. It is the difference between price and total unit production costs including the cost of capital plus a minimum rate of return on investment. Economic rents are very important to government because they form the basis of determining the amount of taxes that can be charged to mining companies without altering investment decisions. Accurate identification and quantification of economic rent is important for maximum economic development and efficient allocation of resources within the country. Economic theory suggests that rents are a market signal for new companies to enter an industry until such rents no longer exist (Torries, 1998) hence industry cost curves are important to understand the economics of the industry. They clearly show the profitability of the industry by comparing the price and unit cost and then prompt government to charge economic rent and possibly introduce super taxes.

Industry cost curves can also be used to determine commodity price in times of market oversupply. In situations of oversupply, price is influenced by the break-even cost of the highest-cost producers whose product is necessary to satisfy demand. Under such circumstances the cost curve represents the industry supply curve and the point on the curve where the cash break-even cost curve intersects the demand curve defines a reasonable market price of the particular commodity. McKinsey & Company (2009) noted that industry cost curves are fundamental in analysing the dynamics of pricing. Producers of a commodity are generally willing to supply it as long as the price is greater than the cost of production and it is the cost curve that determines which business units' products can be priced competitively and in which market segments. It described a cost curve as a standard microeconomic graph that maps a product's available capacity incrementally in order of

increasing cost. Under many conditions, the level of demand for a particular product and the cost of the next available supplier's capacity determine the market price of that product. Theoretically, the industry cost curve allows companies to predict the impact of that capacity, shifts in demand and input costs have on market prices. McKinsey & Company (2009) also mentioned that given the complex nature of markets, before the 1980's when cost curves were not in use most businesses relied on "... a gut-level approach to pricing". Hence industry cost curves are an important microeconomic pricing analysis tool.

Cost curves are also used for comparison purposes to identify high and low unit cost operations. A company with various operations can construct a cost curve and see how the various operations compare to each other. Plotting cost curves over a period allows a company to observe the trend in costs as the mine matures. This will assist management to make informed decisions of either disposing unprofitable operations or implement cost management and improvement strategies. A recent case where a decision was made to dispose high cost operations involved DRD gold which decided to sell its Blyvooruitzicht (Blyvoor) underground operation to concentrate on low cost treatment of surface tailings (Business Day, 2012). The comparison of mining operations can also be done on a national, regional and international level to identify high and low cost producing countries or regions.

Cost curves can also be used in the financial analysis of mergers and acquisitions. Osae, Fauconnier, and Webber-Youngman (2011) highlighted that the high mineral commodity prices experienced in the previous decade promoted mergers and acquisitions to position companies to gain bigger economies of scale and diversification. As part of the economic analysis of a company to be acquired or merged with, it is important to analyse the company's costs and identify how the particular company is ranked on the industry cost curve in comparison to the acquiring company. This will ensure that the merger or acquisition not only adds production but also creates value. There are various risks associated with acquisitions that require proper and accurate valuation and cost curves can be used for that purpose. Rudenno (2009) mentioned that in hostile bids, companies usually provide incomplete information and are reluctant to give truly sensitive information. Although salient factors are provided, they are often averages over longer time frames, or a group figure that has less detail with missing important factors. This offers the investor with a limited look at the impact of different assumptions on valuations.

2.9.4 *Dynamic cost curves*

In reality, costs, and the resulting competitive position of mines on the industry cost curve are constantly changing (CHR Metals limited, 2005). The relative position of specific operations on the cost curve constantly changes from time to time.

2.10 Conclusion

It is the objective of every mining business to derive and maximise shareholder value and that value is created when revenue generated is in excess of cost of production. There are various metrics used to assess the performance of mining operations but focus will be given to cost performance and factors that drives costs. Profitability is one other important performance measure and is a factor of revenue and cost. Revenue generated from a particular operation is much a reflection of the inherent characteristics of the ore body and the prevailing economic conditions which are beyond the control of mining operators. The ability of an operation to implement cost cutting strategies gives it a competitive advantage to generate higher profit margins than the rest of its industry peers and move its mines down the industry cost curve.

Given the importance of mining to the South African economy as discussed in section 1.4, it is important to analyse the industry' cost performance and understand its profitability. An industry cost curve plots unit cost of production against cumulative production and provides that capability of analysing the cost performance and hence the profitability of the mining industry. Industry cost curves are an important tool that can be used by investors and lenders to assess the cost performance of mining companies. They have always been used by a number of research companies but with limited focus particularly in explaining the cost performance of mining operations. Their use in analysing the cost performance of South African mining operations is the objective of this report. The algorithm that was used to construct the cost curves is fully described in the following chapter.

3 Data sources and industry cost curve algorithm

3.1 Chapter overview

This chapter describes the methodology that the author used to collect data and to construct the cost curves that have been used for the analysis. The algorithm is the same for constructing industry cost curves at mine or company level. In this report cost curves were only constructed at a mine and company level.

3.2 Input data sources

A list of South African mining companies listed on the Johannesburg Securities Exchange (or listed elsewhere but with operations in South Africa) with comprehensive Annual Reports was compiled for gold, platinum, coal and diamonds. Annual Reports for these companies for the period 2007 to 2011 were obtained from the public domain from which a database of producing mines was created. The period 2007 to 2011 for the analysis was selected because it gives a good overall outline of the mining industry, that is, how the industry performed before, during and after the 2008 global financial crisis. From the Annual Reports, production and unit cash cost data was extracted to construct the cost curves. As shown in section 1.4, gold, platinum and coal are the major contributors to the South African mining industry hence the focus of this report to these minerals. Diamond was included because of its high unit value. Companies that produced these minerals as by-products were excluded from the analysis together with mines still in the feasibility and start-up phases. Although there are other gold, platinum, coal and diamonds companies not listed on the JSE, it can be assumed and concluded that those companies listed represent the South African mining industry. This implies that any analysis and conclusions made are assumed to be representative of the South African mining industry.

3.2.1 Basis of reporting of costs and cost curve construction

Only cash operating costs were used to construct cost curves because they are the costs that determine future actions of either new or existing operations. Past capital expenditures were not considered because they are sunk costs that do not influence future decisions of existing operations (Torries, 1998). Another reason is that total cash cost of production can be estimated fairly accurately so that a reliable database can be developed for the construction of cost curves (Gentry and O'Neil 1984). Additionally, cash costs are important because a mining company is considered to be financially viable if it is solvent in the short term by being cash positive to ensure long term profitability. Cash costs are costs that

represent actual monetary outflow and non-cash costs such as depreciation and amortisation do not directly represent such outflows but are permissible deductions from revenue, the sole impact of which is to reduce the income tax liability. The cash cost of production includes:

- direct mining costs;
- direct processing costs;
- general administration costs;
- other onsite charges; and
- royalties.

Cash costs used in this analysis are exclusive of capital expenditure; development and stay-in-business capital expenditure. Such other costs that are capitalised and excluded from the analysis include, exploration expenditure to extend the mineral deposit already being mined and costs related to property acquisitions and mineral and surface rights. These costs were excluded because some companies do not report them on a per mine basis. Rather they are reported as a consolidated figure for the whole company such that estimating these costs for each mine is difficult.

Joint ventures (JVs) are common in the mining industry particularly for large-scale operations and there are variations in reporting among JV companies. Some mines report only what is attributed to their company, that is, on the basis of their share value whilst other companies report both what is attributed to them and on a 100% basis so for comparable purposes, data reported on a 100% basis was used for the analysis.

For gold mines' analysis, production in ounces and unit cost per ounce produced were used. For platinum mines, production in tonnes milled and cost per tonne were used for analysis. This is because unlike gold mines, not all platinum mines are vertically integrated from mining to refining. Some junior platinum mining companies without smelters and refineries only produce concentrate and matte and not the final PGM product. This means that these companies have different assessment points of the cost structure and report at different stages of the mining value chain either concentrate, matte or refined PGM. Comparing platinum operations basing on cost per ounces produced was also impractical because platinum producers have different prill split reporting preferences (4E or 6E). Musingwini (2009) described the prill split system as used in platinum mining and mentioned that the prill split is classified as a 4E (alternatively known as a 3E+ Au prill split) prill split if it reports on the elements platinum (Pt), palladium (Pd), rhodium (Rh) and gold (Au), whilst a 6E prill split (alternatively known as a 5E+Au prill split) reports on the elements Pt, Pd, Rh, iridium (Ir), ruthenium (Ru) and Au. Additionally, platinum is mined as part of a basket of a group of metals with each metal being priced differently to others and base metals are also produced as by-products. Hence a meaningful common basis for comparison to accommodate the

junior producers and the basket of metals produced as by-products was the 'tonnes milled' since all companies report on tonnes milled and unit cost per tonne milled. Besides, mining and concentrating costs for platinum companies altogether account for about 80% of the total unit cost per refined ounce which makes analysis based on mining and concentrating costs to be reasonable. In cases where only the total cash operating cost was given, the unit cash cost was calculated by dividing the total cash operating costs by the production. However, cost analysis at milled production provides a view of a company's performance even though it disregards the effect of grade which is a key value lever.

For coal and diamonds analysis, industry cost curves were constructed at company level only. Production for each company was the sum of the company's individual mines in tonnes treated or carats produced for coal and diamonds respectively whilst the unit operating cost was calculated as a quotient of operating cost (revenue-operating profit) and production (tonnes treated or carats produced). This is because most coal and diamonds companies never reported operating cost for individual mines which made the construction of industry cost curves for coal and diamonds at mine level impossible. The reader is cautioned that cash costs are only one component of total costs which in addition to cash costs would include depreciation, depletion, amortization, reclamation and closure costs.

3.3 Cost curve algorithm

To construct cost curves one has to be familiar with Microsoft Excel and below is an algorithm based on the concept of error bars that the author used to construct cost curves in Microsoft Excel:

1. Compile raw data (production in tonnes treated or ounce/carats produced and cash costs per ounce/carat produced or per tonne treated) from company Annual Reports. Sort the data to arrange mines or companies in ascending order of unit cash costs and use the data to compile a table like the one shown in Table 3.1.

Table 3.1 Input data for cost curve construction

Mine/Company	Production	Cumulative production	Unit cost	X-Error	Y-Error	Y-Error
Name	'000oz	'000oz	US\$/oz	(-)	(-)	(+)
Mine 1	120	120	240	120	240	199
Mine 2	500	620	439	500	439	161
Mine 3	768	1388	600	768	600	150
Mine 4	1500	2888	750	1500	750	50
Mine 5	100	2988	800	100	800	-800

The columns from left to right are described as:

<i>Mine/ company</i>	name of Mine n or Company n;
<i>Production</i>	production in tonnes treated, ounces or carats produced by Mine n or Company n;
<i>Cumulative production</i>	this forms the X-axis of the curve and is calculated by adding the production of a particular mine or company to the total production of the previous mines or companies in the list. Mathematically, cumulative production = (production of Mine n) + (production of mine n-1) + ... + (production of Mine 1);
<i>Unit cost</i>	unit cost of Mine n or Company n as reported in the Annual Report or calculated. This forms the Y-axis of the cost curve;
<i>X-error (-)</i>	production of Mine n or Company n;
<i>Y-error (-)</i>	unit cost of Mine n or Company n; and
<i>Y-error (+)</i>	unit cost of Mine (n+1) or Company (n+1) less the unit cost of Mine n or Company n.

2. Use the Microsoft Excel chart wizard to create XY scatter points, from the data range of cumulative production for X-axis and unit cost for Y-axis to get a display similar to the one shown in Figure 3.1.

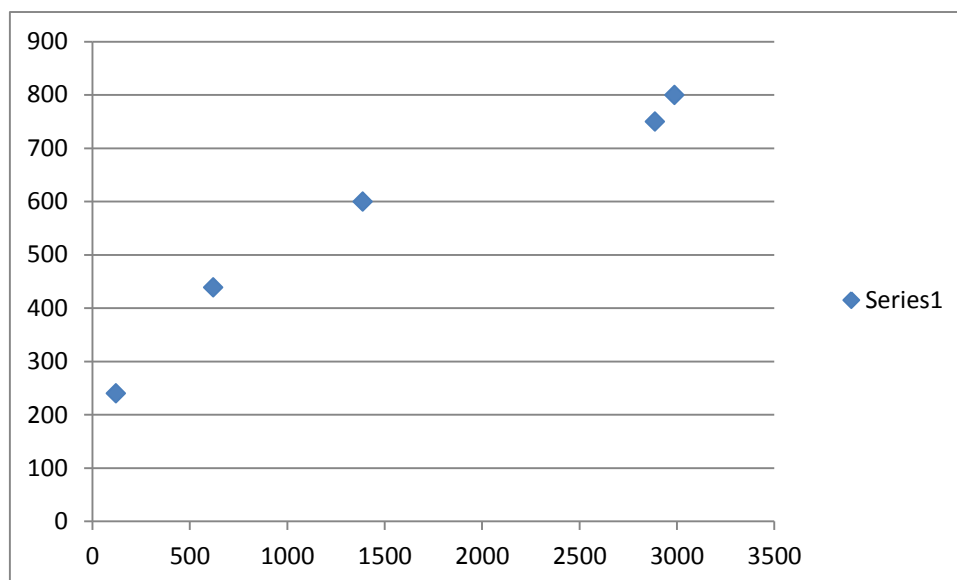


Figure 3.1 Scatter points plot 1

3. Delete the legend and gridlines, then format the plot area and chart area to any fill colour of choice to obtain a display as shown in Figure 3.2 below.

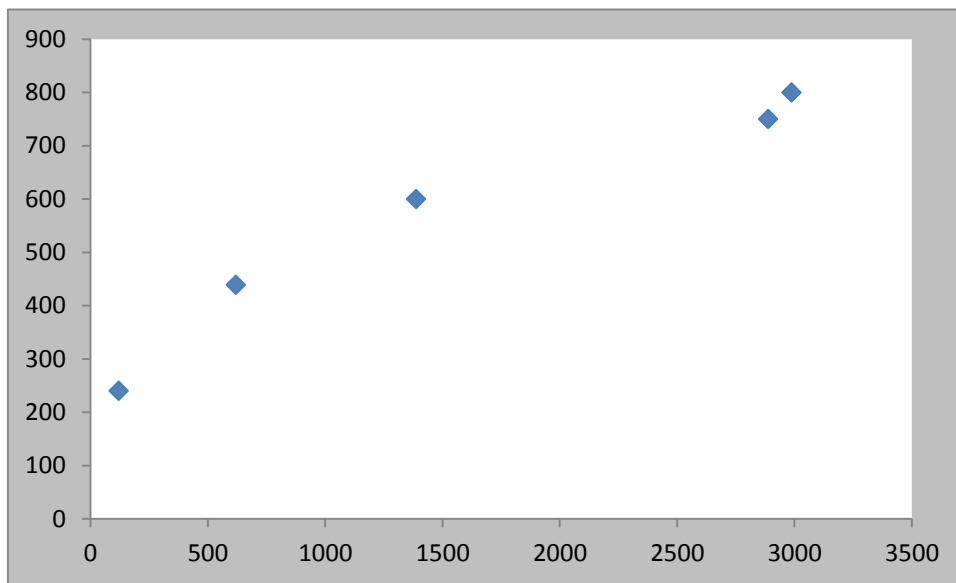


Figure 3.2 Scatter points plot 2

4. Click inside the plot area. On the “layout” menu tab, click the “Error bars” tab and select “Error bars with standard error”. Right click on the X-Axis, format axis and under “Axis options” set “minimum fixed” to zero to get the view as shown in Figure 3.3.

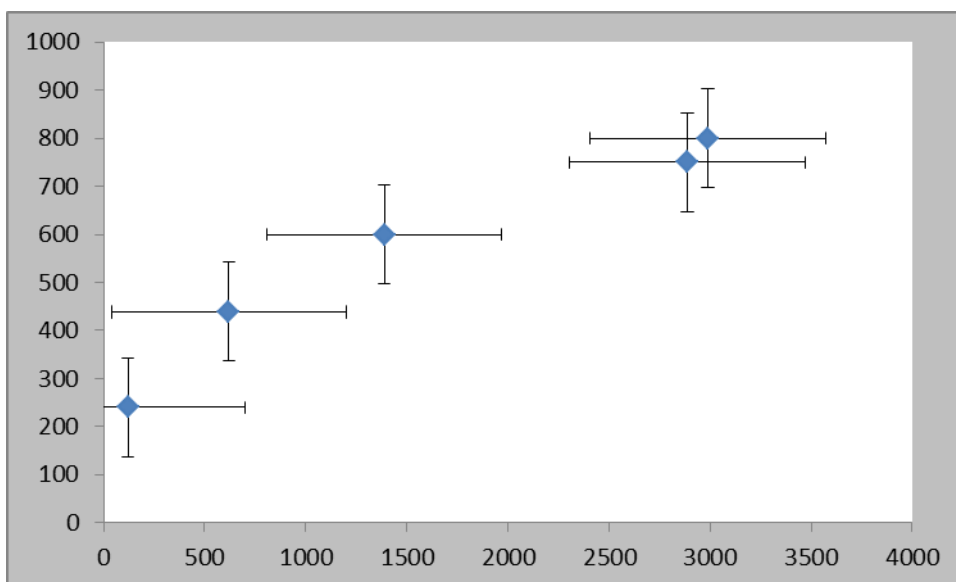


Figure 3.3 Error bars

5. Selecting any one of the horizontal error bars in the plot area, right click on it then select “ format error bars” and set the following parameters for the horizontal error bars:

- Direction – minus (negative error only);
 - End style – no cap (to have smooth corners for the bars); and
 - Error amount – select custom and specify value; from Table 3.1 select data under column “X-Error (-)” for negative error value and leave the positive error value space blank, click OK then close the dialogue box.
6. Selecting any one of the vertical error bars in the plot area, right click on it then select “format error bars” and set the following parameters for the vertical error bars:
- Direction – both (positive and negative error)
 - End style – no cap (to have smooth corners for the bars)
 - Error amount – select custom and specify value; from Table 3.1 select data under column “Y-Error (-)” for negative error value and under column “Y-Error (+)” for positive error value, click OK then close the dialogue box.

The result should be a curve similar to the one in Figure 3.4

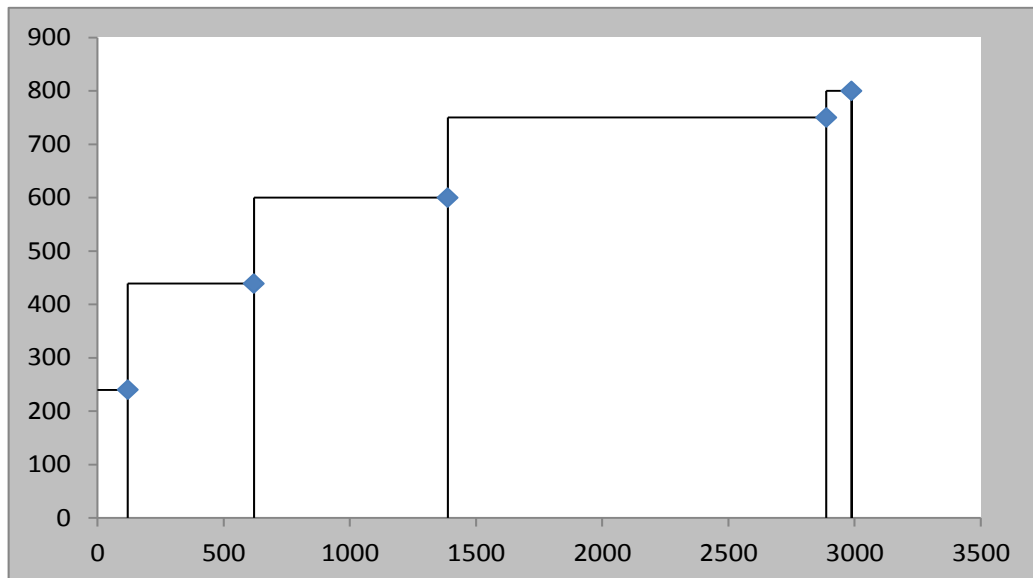


Figure 3.4 Cost curve

7. Select the markers on the bars; right click then select option “Format data series”. Under “marker options” format “marker type” to none, then close the dialogue box;
8. Under ‘layout’ menu tab the chart title, axis titles and any other formatting can be done to one’s own preferences; and
9. To label the bars according to the corresponding mine or company names, download Rob Bovey’s XY Chart Labeller available from <http://appspro.com> and run the installation script. Close the Microsoft Excel file after installing the XY Chart Labeller. On re-opening the file the “XY Chart Labeller” menu tab will appear on the main menu. Click on the tab and a dialogue box appears prompting the user to select the cells with the mine or company names. A typical cost curve should look

like one shown in Figure 3.5. The dotted line is simply drawn to indicate the average price.

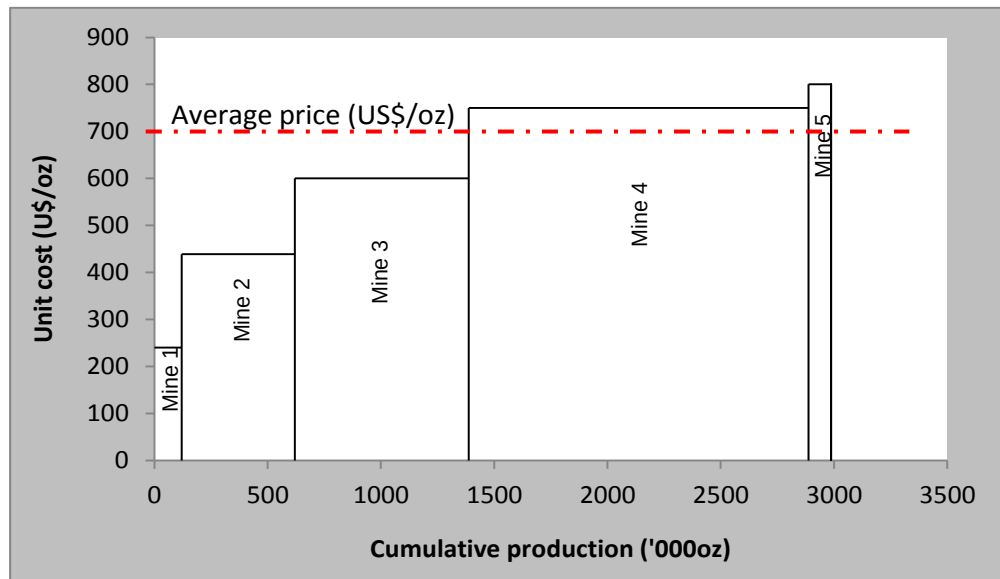


Figure 3.5 Typical cost curve

From Figure 3.5 above, considering a price of US\$700/oz it can be seen that Mine 1 is the lowest unit cost operation with the largest profit margin whilst Mine 5 is the highest unit cost operation. The unit cost of Mines 4 and 5 exceed the price which implies no profit or value is being created by these operations.

3.4 Conclusion

It is evident from this chapter that the construction of industry cost curves is a simple process that can be done with basic Microsoft Excel skills. To create an accurate and comparable database, care should be taken in the collection of data to have a dependable industry analysis. Even though cash costs form part of the total costs they provide a good indication of a company's financial performance and its ability to generate free-cash flow to reinvest into capital projects. Using this methodology, four case studies for gold, platinum, coal and diamonds were done. The results and the analysis of the particular operations using industry cost curves are presented in the proceeding chapters.

4 Gold mining industry cost curves

4.1 Introduction

Gold is a major commodity in the South African mining industry as outlined in section 1.4 hence the use of industry cost curves to analyse gold mining operations. The gold industry is a mature industry that dates back over a century and has contributed significantly to the economic development of the country since its existence. In 2010 gold ranked second in remuneration earnings, total export earnings and employment figures. Over the same period, it was third in total sales value and the country has significant in-situ reserves that are of strategic importance to the global mineral industry. It accounted for about 2% of GDP (if multipliers and induced effects are included). However, the gold industry's profitability and survival is threatened by various economic and technical challenges that will be discussed in this chapter.

4.2 Gold mining companies listed on the Johannesburg Securities Exchange

According to the Johannesburg Securities Exchange (2012) there are 14 gold mining companies that are listed on the JSE namely:

1. AngloGold Ashanti Limited (AGA);
2. Central Rand Gold Limited (CRG);
3. DRD Gold Limited (DRD);
4. Great Basin Gold Limited;
5. Gold Fields Limited (GF);
6. Gold One International Limited (Gold1);
7. Harmony Gold Mining Company Limited (HG);
8. Simmer and Jack Mines Limited;
9. Village Main Reef Limited (VMR);
10. Witwatersrand Consolidated Gold Resources Limited;
11. Pan African Resources (PAN);
12. Rand Gold Resources;
13. Pamodzi Gold; and
14. JCI.

As mentioned before in section 3.2 that only companies with comprehensive Annual Reports that are available in the public domain together with operations in production were used for this report a total of seven were selected. The following companies were excluded from the analysis and the accompanying reasons for their exclusion are given below:

- Witwatersrand Consolidated Gold Resources Limited is in the business of acquiring, preserving, evaluating, trading and developing prospecting rights for exploration and investment purposes. The company is not involved in mine production activities (Witwatersrand Consolidated Gold Resources, 2012);
- Great Basin Gold Limited has one operation in South Africa, Burnstone mine which started operating in 2010 with its revenue and operating costs being recognised starting Q1 2011 (Great Basin Gold Limited, 2011);
- Simmer and Jack Mines Limited's production and financial reports were not accessible on the company's website www.simmers.co.za by the time of data collection;
- For the period under review Central Rand Gold Limited was not in stable commercial production. It acquired mining rights for its operation in 2008 and started underground trial mining in 2009. Commercial production was anticipated to begin in 2010 but according to the company's 2011 Annual Report, the first two footwall-accessed stopes were mined in 2011. This disqualified it for comparable analysis;
- Rand Gold Resources is listed on the JSE but all its current operations are outside South Africa (Rand Gold Resources, 2012); and
- Pamodzi gold and Johannesburg Consolidated Investment Company Limited (JCI) are under suspension from the JSE (Johannesburg Securities Exchange, 2012).

4.3 Gold mines cost curves and their analysis

Figure 4.1 to Figure 4.5 below show the gold cost curves for the year 2007 to 2011 respectively for the operating mines. Different colours are used to represent mines of different companies while mines of the same company share the same colour. According to Kitco (2012) the cumulative average gold price was US\$ 695/oz in 2007 which is shown as a red dotted line in Figure 4.1. Figure 4.1 to Figure 4.5 were developed from data in Appendix 10.1 to Appendix 10.5 respectively.

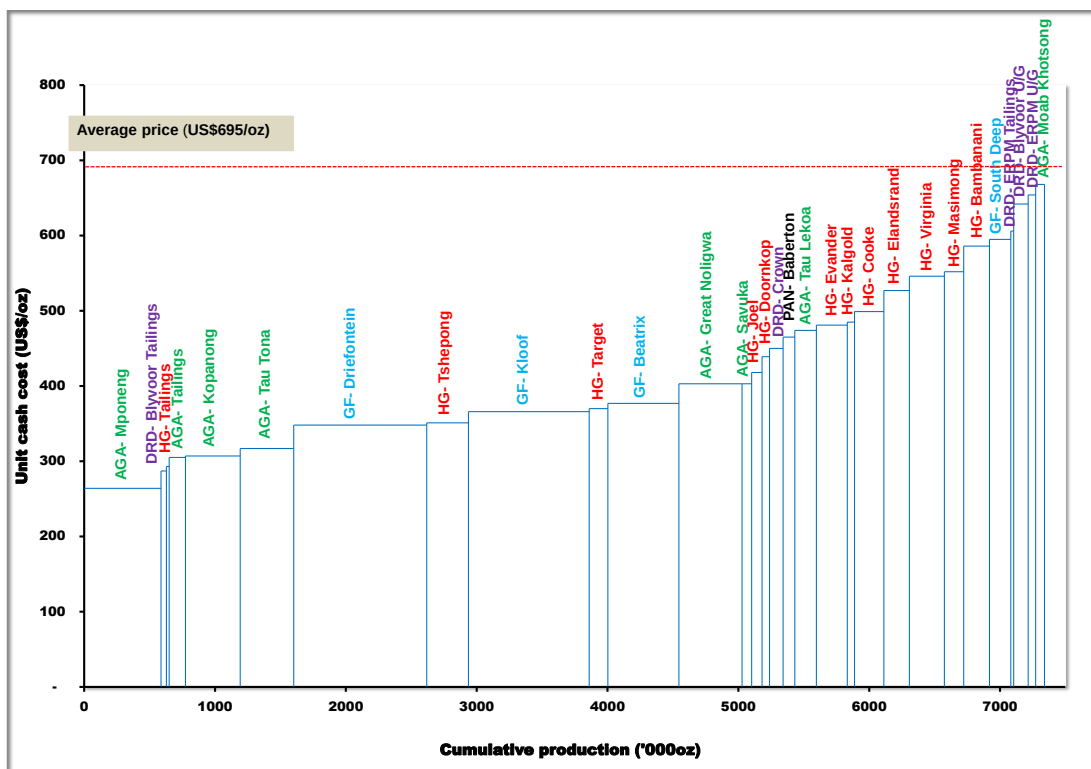


Figure 4.1 Gold mines cost curve for FY2007

(Sources: AngloGold Ashanti Limited, 2007; Gold Fields Limited, 2007; Pan African Resources Plc, 2007; Harmony Gold Limited, 2007; and DRD Gold Limited, 2007)

According to Kitco (2012) the cumulative average gold price was US\$871.96/oz in 2008. This average price is shown as a red dotted line in Figure 4.2.

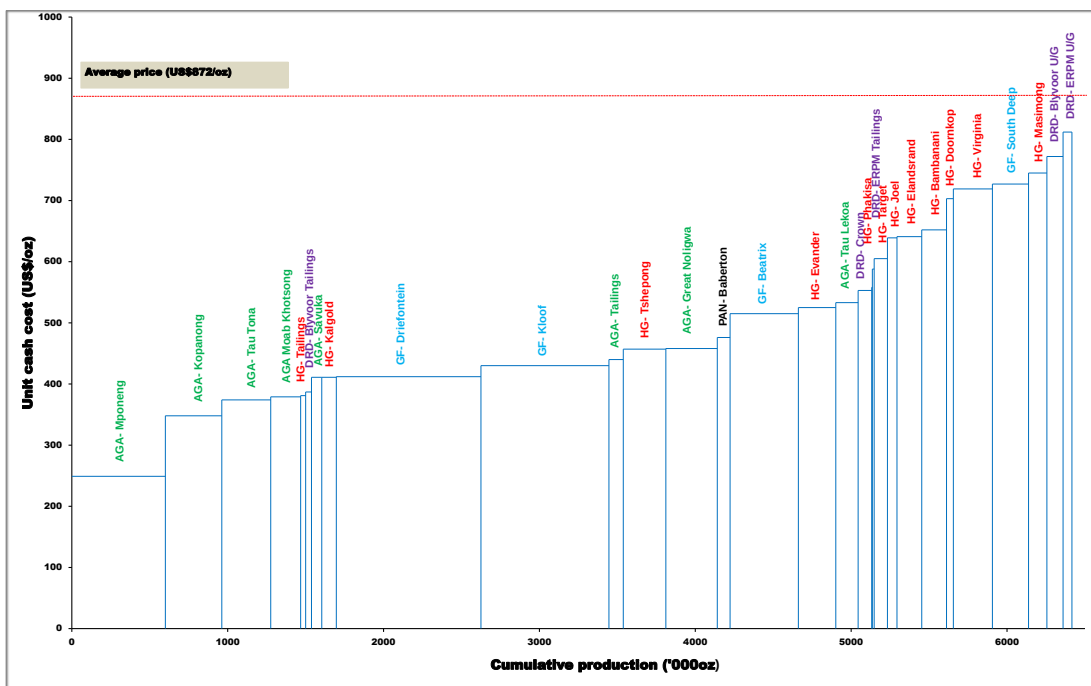


Figure 4.2 Gold mines cost curve for FY2008

(Sources: AngloGold Ashanti Limited, 2008; Gold Fields Limited, 2008; Pan African Resources Plc, 2008; Harmony Gold Limited, 2008; and DRD Gold Limited, 2008)

According to Kitco (2012) the cumulative average gold price was US\$972.35/oz in 2009. This average price is shown as a red dotted line in Figure 4.3.

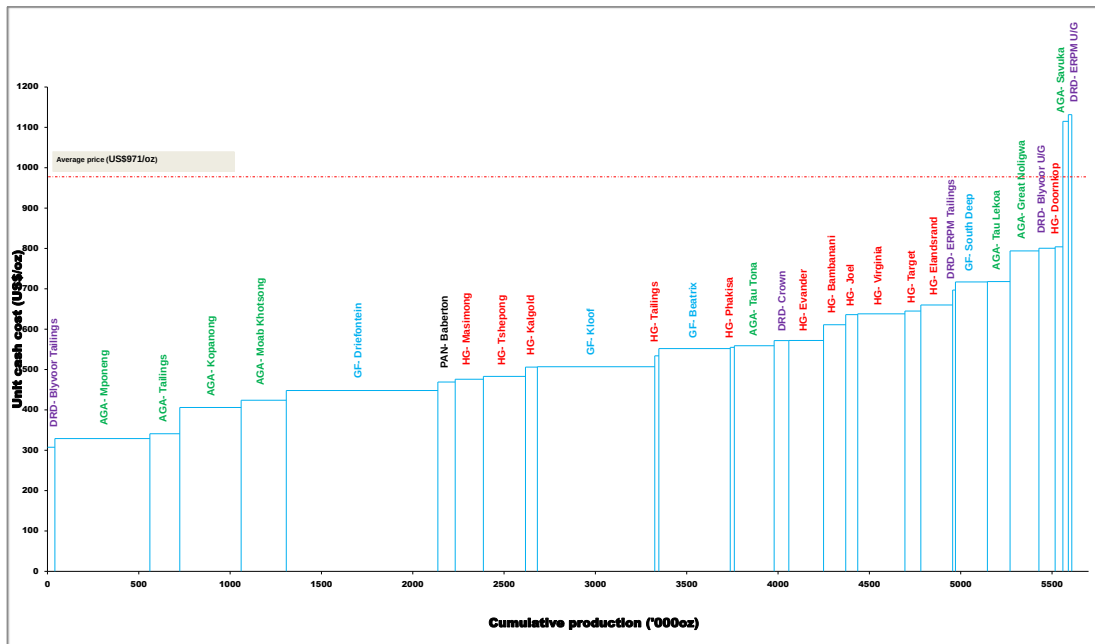


Figure 4.3 Gold mines cost curve for FY2009

(Sources: AngloGold Ashanti Limited, 2009; Gold Fields Limited, 2009; Pan African Resources Plc, 2009; Harmony Gold Limited, 2009; and DRD Gold Limited, 2009)

According to Kitco (2012) the cumulative average gold price was US\$1224.53/oz in 2010. This average price is shown as a red dotted line in Figure 4.4.

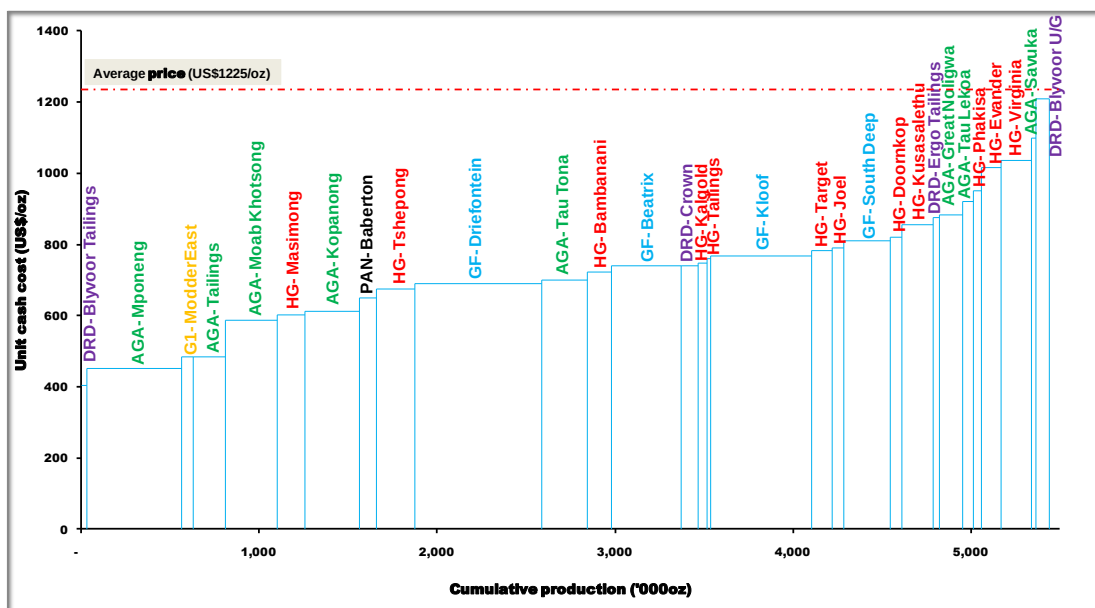


Figure 4.4 Gold mines cost curve for FY2010

(Sources: AngloGold Ashanti Limited, 2010; Gold Fields Limited, 2010; Pan African Resources Plc, 2010; Harmony Gold Limited, 2010; DRD Gold Limited, 2010; and Gold One International Limited, 2010)

According to Kitco (2012) the cumulative average gold price was US\$1571.52/oz in 2011. This average price is shown as a red dotted line in Figure 4.5.

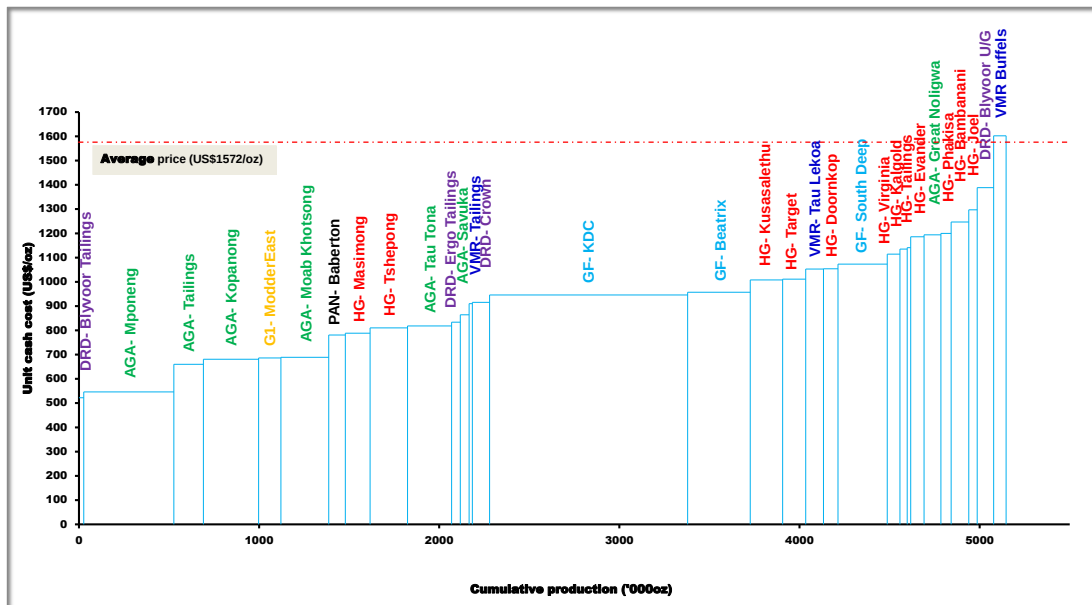


Figure 4.5 Gold mines cost curve for FY2011

(Sources: AngloGold Ashanti Limited, 2011; Gold Fields Limited, 2011; Pan African Resources Plc, 2011; Harmony Gold Limited, 2011; DRD Gold Limited, 2011; Village Main Reef Limited, 2011; and Gold One International Limited, 2011)

4.3.1 Production

It is clear from Figure 4.1 to Figure 4.5 that all the cost curves resemble a typical cost curve shown in Figure 2.3, where the lowest half is occupied by large gold producing mines and the upper half by low gold producing mines supporting the principle of economies of scale explained before in section 2.7.1. Dividing the mines into quartiles based on total mines, the production contribution of each quartile is shown in Table 4.1. Each column shows each quartile's contribution as a percentage from 2007 to 2011.

Table 4.1: Contribution of each quartile to total annual production

Quarter	2007	2008	2009	2010	2011
Q1	38%	26%	41%	30%	32%
Q2	34%	47%	30%	35%	37%
Q3	16%	11%	18%	24%	19%
Q4	12%	16%	11%	12%	12%

As shown in Table 4.1, in 2007 and 2009 production decreased from the first quartile to the fourth quartile. This is explained by the principle of economies of scale already discussed before. In 2008, 2010 and 2011 the second quartile has the highest contribution. This is also evident from Figure 2.3 that the second quartile has a mixture of high and low production

mines as explained before in section 2.9.2. It is also clear from Table 4.1 that the third and fourth quartiles together contributed less or equal to the first quartile's contribution because these operations fail to benefit from economies of scale.

4.3.2 Low unit cost gold operations

Since it came into full production in 2010, Modder East has always been in the first quartile of the cost curve as shown in Figure 4.4 and Figure 4.5. This is possibly because:

1. it is a relatively new underground operation which supports the idea already discussed in section 2.9.3 that new operations must aim to be in the low cost quartile of the cost curve to survive profit margin squeezes;
2. it is a shallow operation compared to its peers with production at 300 to 500m below surface, making it the shallowest underground mine in the mines under review;
3. it is fully mechanised so the haulage cost of ore to surface is lower compared to deep operations with hoisting facilities. Mechanised operations tend to be low unit cost as discussed before in section 2.6; and
4. the operation came into production just when the industry was recovering from the 2008 global financial crisis and when the gold price was on an upward trend.

However, the mine moved from the third position in 2010 to fifth position of the cost curve in 2011 possibly because of increased depth of operation which increases the hauling distance to surface.

Kopanong, Mponeng and Moab Khotsong have always maintained their positions in the first quartile of the cost curve. Mponeng and Moab Khotsong are low unit cost operations most importantly because of their high head grades of above 9g/t for the whole period under review. In addition Moab Khotsong is one of the newest mines in the country taking advantage of relatively new infrastructure with less maintenance costs. Moab Khotsong moved from being the highest unit cost mine in 2007 to the first quartile the following year. The high head grades coupled with their relatively high production will ensure that the two operations can maintain their positions in the first quartile of the cost curve.

Despite its low production, Barberton is a relatively low unit cost mine which moved down the curve from the second quartile in 2008 to the first quartile in 2009. This is because of its high average head grade which gives it a competitive advantage and has been averaging above 10g/t since 2009 far above the total mines' average head grade of 4g/t. Another reason is that Barberton is the birthplace of Biological Oxidation (BIOX[®]) processing technology for over 15 years now. BIOX is known to have better recovery rates, less capital costs, less operating cost per ton milled, less environmental costs, less technical risks and low level of technical skills to operate compared to conventional extraction processes used in most

operations. Barberton is still used as the training facility for all BIOX[®] plants globally. Barberton has been generally moving down the industry cost curve from the third quartile in 2007 to the first quartile in 2011. It is expected to remain a relatively low unit cost operation because of its high head grade and less costly BIOX processing technology.

Tailings treatment operations tend to have low unit cost of operation compared to underground mines despite their low head grades and production. This is because of no mining costs being associated with these operations. This is evident as Blyvooruitzicht (Blyvoor)'s tailings and AngloGold's tailings treatment operations have always maintained their positions in the first quartile of the industry cost curve.

Masimong was in the fourth quartile in 2007 and 2008 before moving down to the second quartile in 2009 to 2011. One of the reasons it moved down the curve is that an intensive cost restructuring process and people transformation programme was implemented at the mine with positive results noticed beginning end of 2007. The people program started at Tshepong then Masimong and was based on an aspect of transformation initiative involving the devolvement of responsibility to self-directed work teams, with specific emphasis to safety, team building and productivity. This resulted in improved employee productivity and better efficiencies at both operations and made Masimong to be Harmony Gold's lowest unit cost operation in South Africa followed by Tshepong since 2009. As the restructuring programme becomes full complete, these mines are expected to remain Harmony Gold's low unit cost mines. Evander progressed from the third quartile in 2009 to the fourth quartile in 2010 and possibly that is the reason that Harmony gold disposed the mine.

4.3.3 High unit cost gold operations

Great Noligwa moved from the second quartile in 2008 to the last quartile in 2009 till 2011 because the operation is a mature mine near its end of economic life. The mining method has been recently shifted from conventional mining to pillar extraction because the mine has reached its boundary limits. As expected when a mine progresses towards closure, Great Noligwa's production has been on a gradual decline from 483,000 ounces in 2007 to 94,000 ounces in 2011. At this declining rate coupled with its little opportunity to significantly increase its production base, the mine is expected to maintain its position in the last quartile of the industry cost until it closes.

Savuka is one of AngloGold Ashanti's two highest unit cost mines mainly because of its relatively low production and extreme deep operations. The mine was affected by a serious seismic event in May 2009 which lowered its production capacity. In 2007 it was said to be the deepest mine in the world which naturally would make it a high cost operation and most

prone to seismic events as explained before in section 2.6. In 2008 before the seismic event it was in the low cost quartile producing 66,000 ounces but after the seismic event in 2009 it slipped to the fourth quartile in 2009 producing 22,000 ounces. This shows that as a mine's production decreases its unit cost increases and vice versa because as Savuka ramped up production in 2010 it moved down the curve from the fourth to the second quartile in 2011. This is again because of the principle of economies of scale. As it fully recovers from the seismic event damages and stabilises production, Savuka is expected to remain in the second quartile where it was before the seismic event. This seismicity also shows the complications associated with mining from deep levels as is the case with South Africa gold mining.

DRD's East Rand Proprietary Mines (ERPM) underground mine has always been one of the highest unit cost producer at the bottom of the cost curve until it was placed under care and maintenance in 2009. The main reason it was a high cost operation was increasingly underground water as the pumping infrastructure failed to cope with the rising water levels. The mine had a R102.7 million before tax loss in 2007 and the capital and operating costs of additional pumping infrastructure and maintaining the workforce at full pay (whilst pumping for 12 months) were high that the company decided to place the mine under care and maintenance till to date. Despite the current favourable gold price, the cost of resuscitating ERPM underground operation is still too high beyond the means of the company. This implies that there are little prospects of reopening the operation unless the gold price increases above the current level. DRD's Blyvooruitzicht (Blyvoor) underground mine has been the highest cost operation for the company.

Since 2008, Kalgold mine has been gradually moving up the industry cost curve from the first quartile in 2008 to the fourth quartile in 2011. This is mainly because of its relatively low production for an open pit mine; with a maximum production of 93,000 ounces since 2007. This relatively low production coupled with low average head grade of 1g/t makes it an equally high unit cost operation when compared to underground operations.

South Deep, the newly acquired Gold fields' operation has always been the highest unit cost operation for the company and has been reporting a net loss from 2007 to 2010. This is mainly because the operation is still a developing asset that is ramping up production and most of its infrastructure in 2007 and 2008 was still incomplete which caused lack of production flexibility. That impacted on its ability to produce but as the mine progresses to stable state production targeted in 2013, its production has been increasing from 163,000 ounces in 2007 to 273,000 ounces in 2011. As a result of increased production South Deep moved down the industry cost curve from the last quartile in 2009 to the third quartile in 2010

as it gained from economies of scale. As it reaches stable production it is expected to be in the middle of the gold industry cost curve.

Buffelsfontein (Buffels) mine was the highest unit cost operation in 2011. It was affected by a seismic event in May 2010 that led to the closure of operations for 19 days. The decrease in production at Buffels mine led to a substantial operating loss of R138.9 million that the company decided to implement a cost restructuring plan requiring a complete overhaul of the operation. This led to the development of a zero-based operational and cost plan in June 2011. It is expected that the operations are capable of meeting the required breakeven production in 2012 and be profitable thereafter.

4.4 Gold mining companies cost curves and their analysis

Company cost curves for gold were constructed from total production and weighted averages for unit cash cost from the operating mines in the analysis. The production of a particular company was calculated from the total production of the individual mines in the analysis whilst the unit cash cost were weighted averages calculated as:

$$\text{Unit cash cost} = \frac{\sum (\text{mine 1's production} \times \text{mine 1's unit cost}, \text{mine 2's production} \times \text{mine 2's unit cost}, \dots)}{\sum (\text{mine 1's production}, \text{mine 2's production}, \dots)}$$

This is because most gold companies in South Africa have many operations outside the country whose contribution is included in the consolidated Annual Report so using data from consolidated reports is not representative of the South African gold mining sector. Figures 4.6 to 4.10 show gold companies industry cost curves from 2007 to 2011 respectively. The average gold price as shown in Figures 4.6 to 4.10 were the Kitco (2012) average gold prices as used in Figures 4.1 to 4.5. Figure 4.6 to Figure 4.10 were developed from data in Appendix 10.1 to Appendix 10.5 respectively.

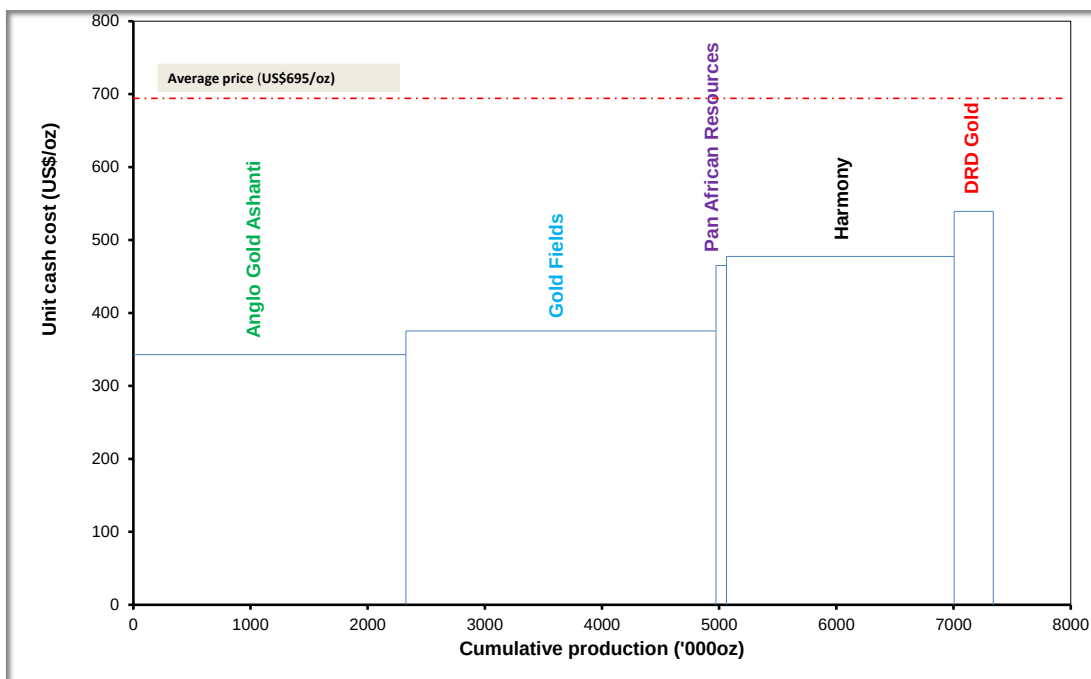


Figure 4.6 Gold companies cost curve for FY2007

(Sources: AngloGold Ashanti Limited, 2007; Gold Fields Limited, 2007; Pan African Resources Plc, 2007; Harmony Gold Limited, 2007; and DRD Gold Limited, 2007)

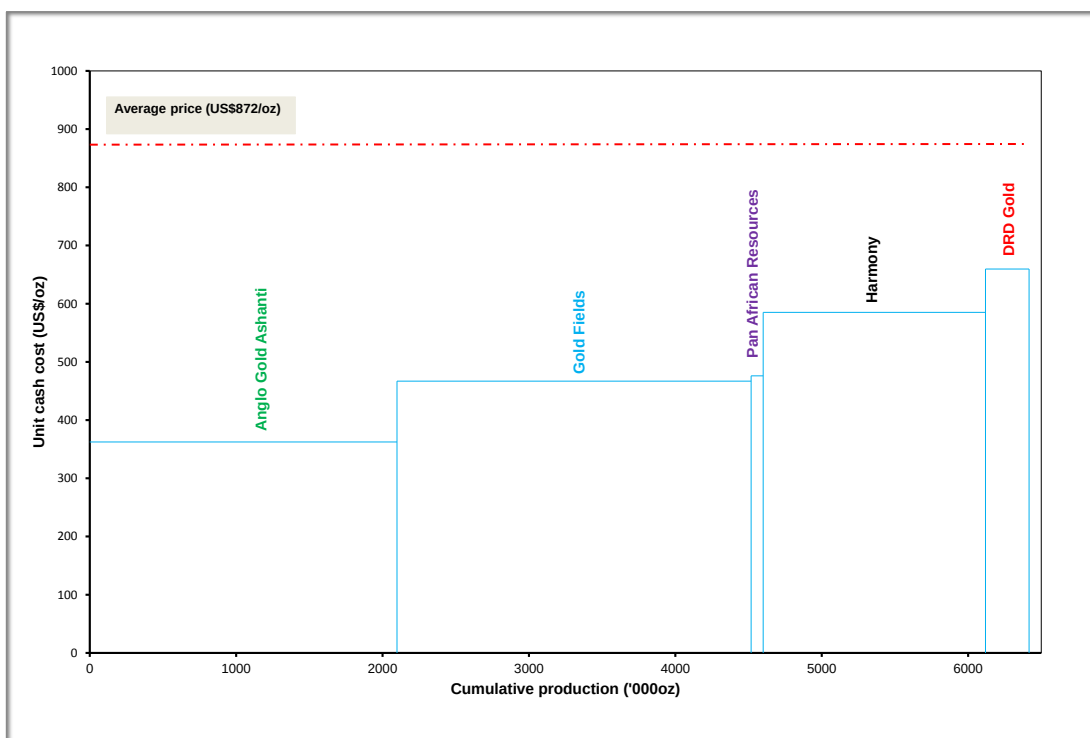


Figure 4.7 Gold companies cost curve for FY2008

(Sources: AngloGold Ashanti Limited, 2008; Gold Fields Limited, 2008; Pan African Resources Plc, 2008; Harmony Gold Limited, 2008; and DRD Gold Limited, 2008)

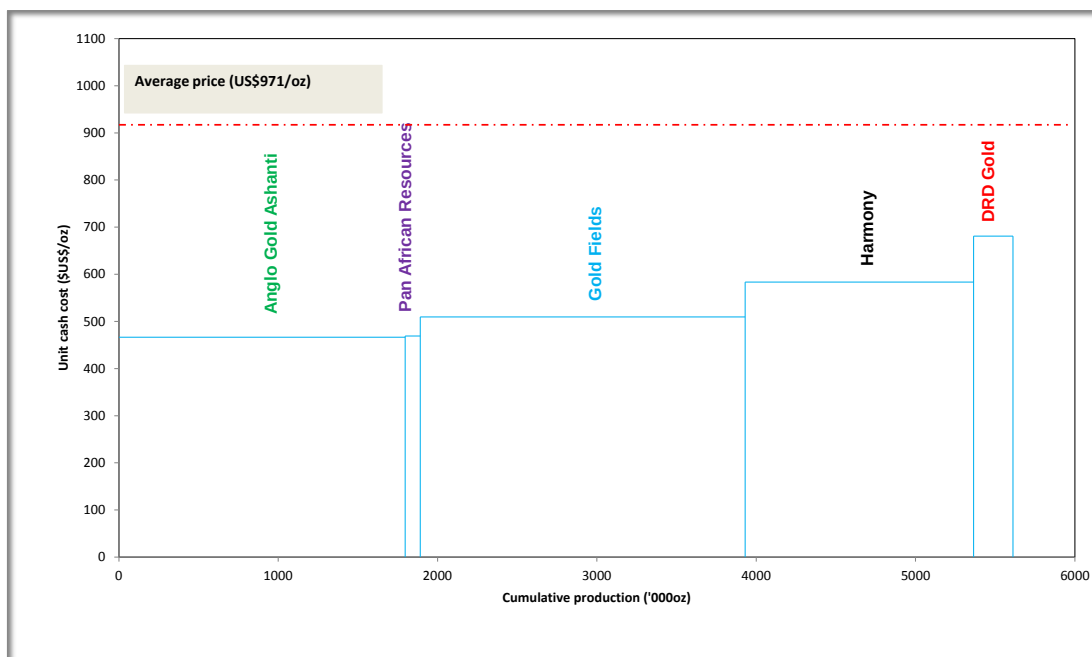


Figure 4.8 Gold companies cost curve for FY2009

(Sources: AngloGold Ashanti Limited, 2009; Gold Fields Limited, 2009; Pan African Resources Plc, 2009; Harmony Gold Limited, 2009; and DRD Gold Limited, 2009)

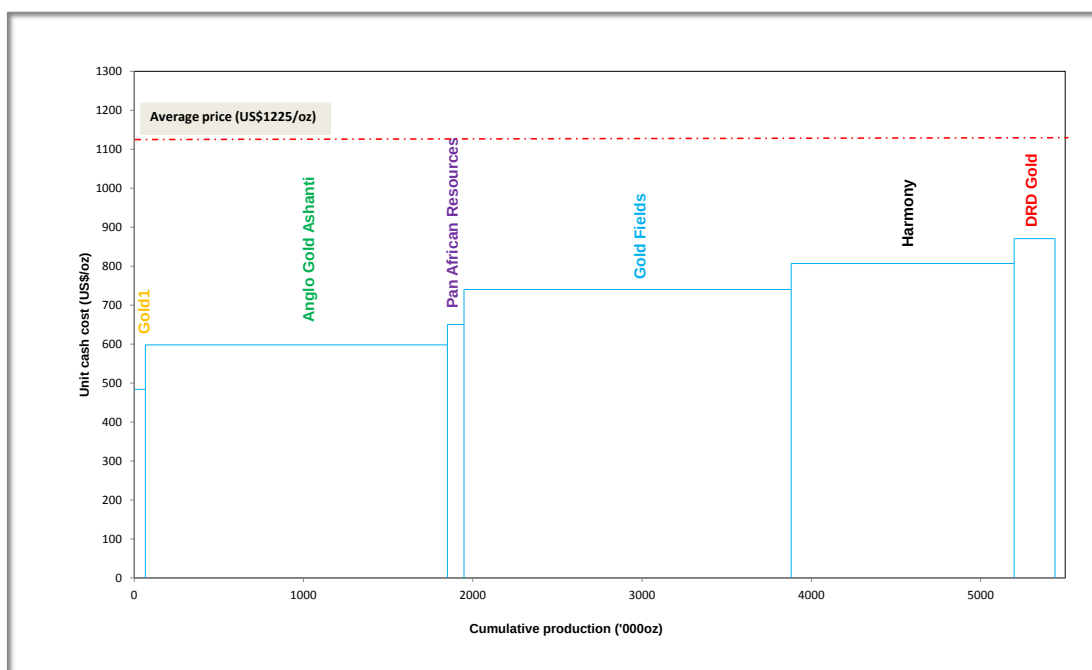


Figure 4.9 Gold companies cost curve for FY2010

(Sources: AngloGold Ashanti Limited, 2010; Gold Fields Limited, 2010; Pan African Resources Plc, 2010; Harmony Gold Limited, 2010; DRD Gold Limited, 2010; Gold One International Limited, 2010)

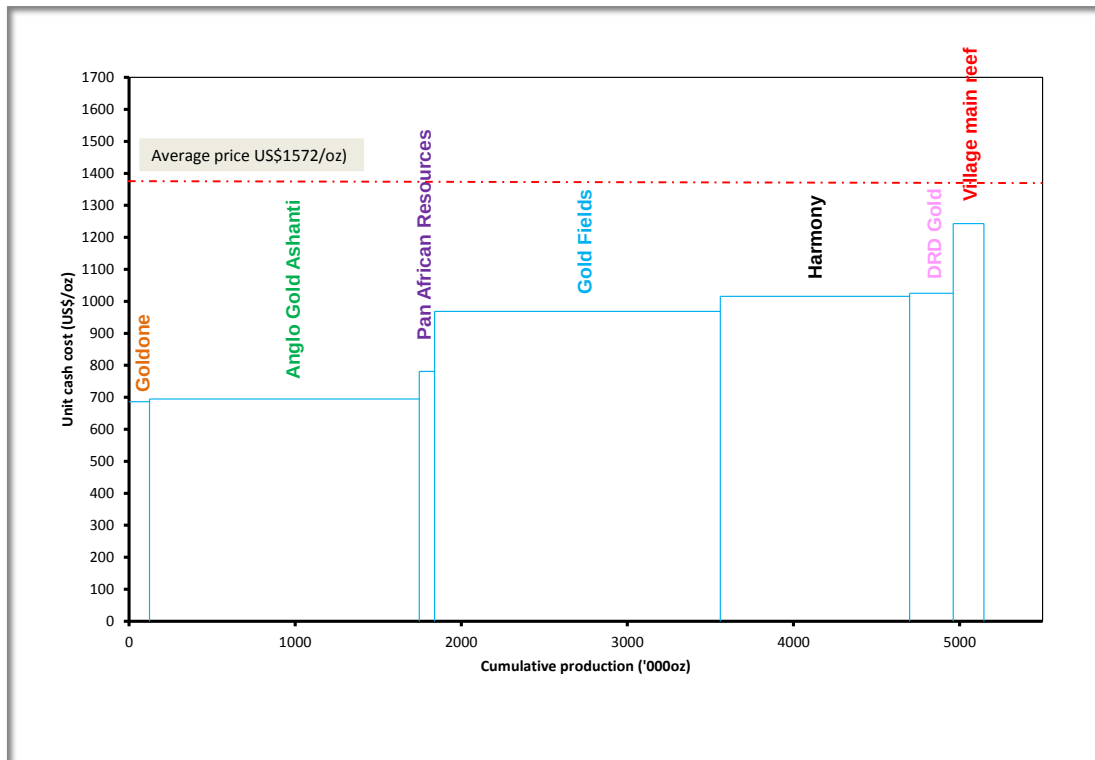


Figure 4.10 Gold companies cost curve for FY2011

(Sources: AngloGold Ashanti Limited, 2011; Gold Fields Limited, 2011; Pan African Resources Plc, 2011; Harmony Gold Limited, 2011; DRD Gold Limited, 2011; Gold One International Limited, 2011; and Village Main Reef Limited, 2011)

At a company level it is important to note that a company's total production does not significantly determine its position on the industry cost curve. Small and junior companies are not always in the high cost quartile of the curve. Junior companies such as Pan African Resources and Gold One are lower cost companies compared to Gold Fields and Harmony gold which are big producers. This is because:

- small companies are easier to manage than large companies. Cost cutting measures can be easily implemented in smaller companies hence they can be low unit cost operations compared to big companies;
- junior companies tend to operate single or fewer mines implying that decision-making cascades much more efficiently from executive levels to lowest operating levels; and
- large companies have large corporate offices with large executive staff complements than smaller companies. These corporate head offices incur high running costs through high administrative costs and executives' salaries.

4.4.1 Gold One International Limited

Since Gold One's Modder East mine came into commercial production in 2010 it has continued to be the lowest unit cost company. This is because of its relatively new, shallow

and single producing mine with relatively new operating equipment and infrastructure as already discussed in section 4.3.2.

4.4.2 *Pan African Resources*

Pan African Resources (PAN) was primarily an exploration company until 2007 when it acquired 74% of the Barberton mines from Meterox thus refocusing the company from being an exploration company to being a mid-tier gold producer in the country. PAN slightly moved its position down on the industry cost curve in 2009 and is currently positioned in the low cost region of the gold industry cost curve. PAN acquired Evander mine from Harmony gold in 2012 which was in the fourth quartile of the cost curve, higher than its current Barberton mine which was in the first quartile of the cost curve. This acquisition is likely to move the company up from the first quartile to the second quartile of the industry cost curve from 2012 going forward. This is an example of where mergers and acquisitions of mineral assets may only increase a company's production without much value-add to the company.

4.4.3 *AngloGold Ashanti Limited*

AngloGold Ashanti (AGA) continues to be a low unit cost company because most of its operations are in stable state of production except Great Noligwa which is towards the end of its production life. AGA's highest unit cost operations since 2008 were Great Noligwa and Tau Lekoa with the exception of Savuka which experienced a seismic event in 2009 but has since moved up to the second quartile in 2011. AGA has a strategy of benchmarking its operations on a total cost basis below the broader industry's mean to protect returns in times of price downturns. Once an operation exceeds the benchmark, even though it is still profitable, the company regards it as a high cost operation and it is sold. This is not surprising that Tau Lekoa was sold to Village Main Reef Limited in 2011. AGA's current highest unit cost producer is Great Noligwa which is in the fourth quartile of the industry cost curve with most of AGA's operations ranked in the first half of the cost curve. This, coupled with its declining production from 483,000 ounces in 2007 to 94,000 ounces in 2011 favours it to be the next target of disposal.

4.4.4 *Harmony Gold Limited*

Harmony Gold (HG) continues to be a relatively high unit cost company from 2007 to 2011. Most of Harmony's operations are in the second half of the industry cost curve mostly because the company restructures marginal and aging deep-level mines acquired from other companies. Most mines acquired by Harmony are leveraged and tend to be marginal mines nearing the end of their economic lives. Mines nearing the end of their economic lives have

several disadvantages including high infrastructural and environmental liabilities that escalate the cost of production.

As discussed before in section 4.3.2, Harmony did a cost restructuring process and people transformation program at its Tshepong and Masimong mines since 2007 and if that is done on all Harmony's operations, the company may move itself slightly down the industry cost curve to become one of the industry's low unit cost and competitive company. Most of Harmony's mature operations have a number of growth projects to sustain their production and extend their life of mine which might also ensure the company's long term competitiveness. Kusasalethu, Doornkop and Phakisa are among Harmony' mines with growth projects that if successful will see these operations going down the industry cost curve. To remain competitive, Harmony Gold's strategy is to increase its production from outside South Africa as seen by its recent sale of Evander to commit the capital in the development of projects in Papua New Guinea.

4.4.5 Gold Fields Limited

Gold Fields (GF) implemented a comprehensive Business Process Re-engineering (BPR) in its South African and international operations. BPR involved the optimisation of its mine's organisational and cost structures and production process among others. In its South African operations, the initiative included mechanisation of all its flat-end development to improve safety and reduce development costs which reduced its operating costs by R840 million in 2011. This will ensure the company continues to be competitive despite its deep operations. The second phase of the initiative included the amalgamation of Driefontein and Kloof's infrastructure to form Kloof-Driefontein Complex (KDC). This was done to improve operational and financial efficiencies subsequently reducing overhead costs of these mature operations. The amalgamation is also expected to arrest Gold Fields' declining production and maintain its production. Before its amalgamation with Kloof, Driefontein has always been the highest gold producing mine in South Africa and Gold Fields' lowest unit cost operation in the country. Hence this strategy is expected to reduce the mine's unit operating cost and subsequently move the company down the industry cost curve as it benefits from greater economies of scale.

4.4.6 DRD Gold Limited

DRD Gold continues to be in the high unit cost quartile of the industry cost curve. The overall unit cost of production is escalated by underground operations that for the past 3 to 4 years the company decided to decrease its involvement in risky deep-level underground mining and increase its focus on treating mine dumps. This resulted in ERPM underground mine

being placed under care and maintenance in 2009 and the decision to sell Blyvooruitzicht underground operation in 2011 so that the company could focus primarily on the treatment of tailings dumps which the company seems to be effective at. Re-constructing the industry cost curve with the exclusion of DRD's Blyvooruitzicht underground, it can be concluded that Blyvooruitzicht mine distorts DRD's cost structure and profitability.

Table 4.2 shows the average unit cash cost and ranking of companies if DRD's tailings and underground operations are analysed separately. The columns show years and each company's weighted average unit cash cost. The companies are arranged in ascending order of unit cash cost. Each company has a distinct colour which can be traced as it moves up/down the industry cost curve from one year to another, for example, PAN stepped up in 2007, 2008 and 2009 and GF stepped down in 2008.

Table 4.2 Ranking with DRD's tailings and underground separate

2007 (US\$/oz)	2008 (US\$/oz)	2009 (US\$/oz)	2010 (US\$/oz)	2011 (US\$/oz)
			484	686
343	362	466	598	694
375	467	469	650	781
431	476	507	711	831
465	511	510	740	968
477	585	584	807	1016
646	786	859	1209	1243
				1388

Key

	Gold One		Pan African Resources
	Anglo Gold Ashanti		Harmony
	Gold Fields		DRD Gold u/g
	DRD Gold surface		Village Main Reef

It can be seen from Table 4.2 that separating DRD's tailings treatment operations from its underground operation positions DRD as a medium cost company moving from the fourth to the second quartile of the company cost curve. This justifies the decision made by DRD Gold to cease ERPM underground activities and dispose its Blyvooruitzicht (Blyvoor) underground mine. Hence it is expected that from 2012 after the sale of Blyvoor mine, DRD will be in the second half of the company industry cost curve. DRD's underground operations have always reported negative operating margins except in 2008, offsetting the company's profitability. In 2011 the company reported a net loss of R415.4 million but since consolidating its surface operations it reported an operating profit of R162.2 million in the first quarter of 2012. This shows that the company is set to be a profitable and competitive company after disposing

underground operations. Blyvoor's sale agreement to Village Main Reef is in the final stages and will be completed this year.

4.4.7 Village Main Reef Limited

In 2011 Village Main Reef (VMR) was the highest unit cost gold company most probably because of acquiring operations that are nearing their end of production life. Operations nearing their end of production lives tend to be high cost operations because of increased depths, marginal resources and reserves and high maintenance cost of old infrastructure. The company acquired both AngloGold Ashanti's Tau Lekoa and Simmer and Jack's Buffelsfontein gold mines in 2011 which are old assets nearing their end of production lives with high costs of production. With the current production, Tau Lekoa's expected Life of Mine is five years and it was one of AngloGold Ashanti's highest cost operations before its acquisition. There is no doubt that with its current acquisition strategy, the company will continue to be in the highest unit cost quartile of the gold companies industry cost curve.

4.4.8 Production analysis

Figure 4.11 shows the production in thousand ounces for individual gold mining companies for the period 2007 to 2011.

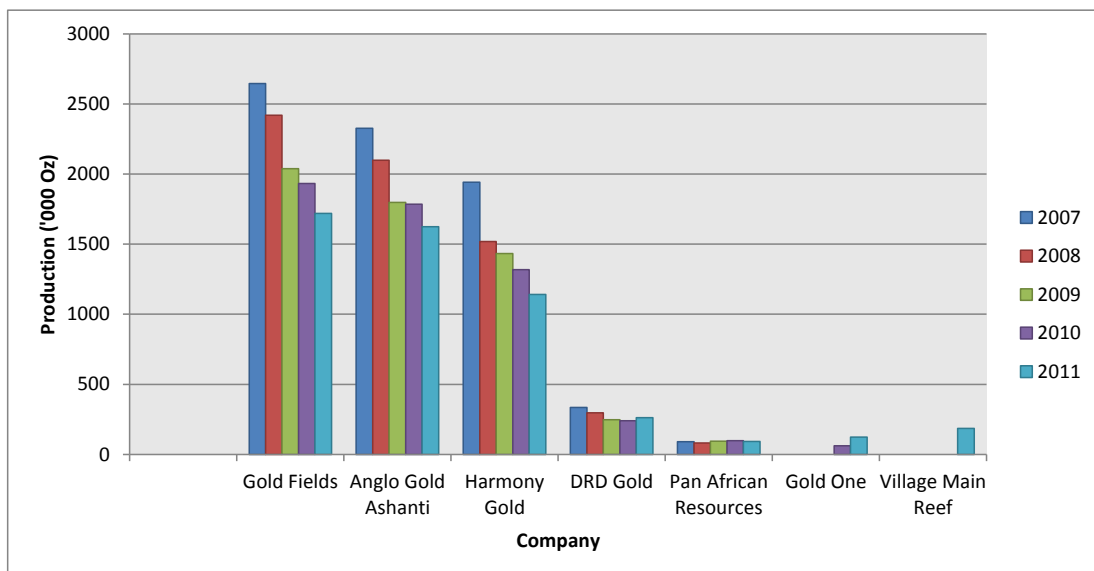


Figure 4.11 Production from 2007 to 2011

From Figure 4.11, it can be seen that production for Gold Fields, AngloGold Ashanti, and Harmony Gold has been declining progressively from 2007 to 2011. DRD's production has been also on a decrease since 2007 until 2011 when it increased by 2.7%. This production decrease led to the total production for all the companies declining by 30% from 7,340,000

ounces in 2007 to 5,147,000 ounces in 2011. From these companies' performance it can be concluded that the overall South African gold production is declining. This decline in production is attributed to the following reasons:

1. Depth of operation- gold in South Africa is being produced from increasing depths from the seemingly inexhaustible Witwatersrand's reefs and mature mines with no new projects coming into production. From the operations under analysis, based on 2011 data, the average mine was 2,469m deep, being one of the reasons that production is declining while costs are increasing. The impact of mining depth to operating cost was discussed in section 2.6.
2. Electricity supply- high electricity costs have been a concern for the South African mining industry contributing significantly to profit margin squeezes. In addition to the cost, Eskom has been failing to supply mining operations with uninterrupted electricity that resulted in production stoppages and some mines having to complement with expensive generators. In 2007 and 2008 in particular, Eskom experienced capacity problems that it was supplying the mining industry at a level around 90% of its contractual obligations. This led to shafts and mining areas with high electricity consumption being closed down;
3. Safety stoppages- Zero incident/accident tolerance by the DMR led to strict implementation of Section 54 of the Mine Health & Safety Act resulting in an increase in safety stoppages for the entire mining industry. This is affecting productivity of mining operations; and
4. Industrial action- over the past few years there has been an increase in labour unions related strikes mainly for wage increases which also impacted on the mines' capacity to meet their planned production.

All the above factors are restraining gold mines to operate at their full capacity contributing to profit margin squeezes. These challenges are forcing gold mining companies to place non-profitable operations on care and maintenance, for example, DRD's ERPM underground mine.

4.4.9 A comparison of gold price and total gold production

Figure 4.12 shows the trend in total gold production and the average gold price for the period under review.

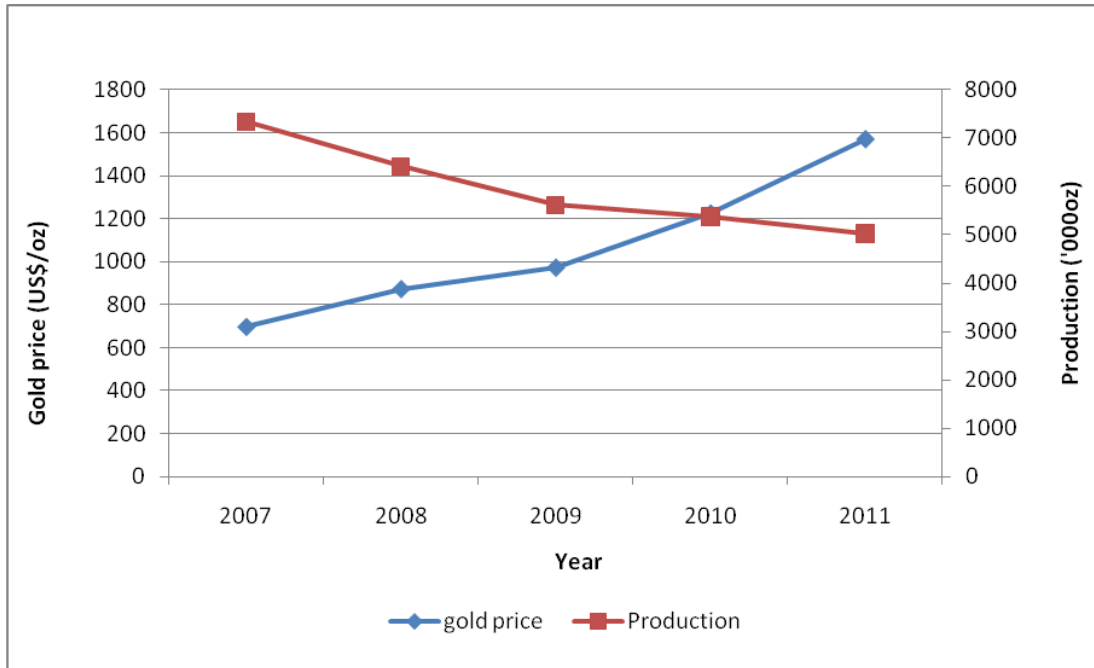


Figure 4.12 Gold price vs production

Figure 4.12 shows that as the gold price is increasing, total production from gold mines is declining over the same period. This means that despite the general increasing trend of gold price from 2007 to 2011, the South African gold mining industry has not benefited much from the high prices because of falling production over the same period. Despite the great comparative advantage that South Africa has in terms of vast mineral resource endowment, the country is failing to convert that to a competitive advantage. This trend shows that South Africa is gradually losing its position as a global gold producer, and if in future the gold price declines, production is likely to significant decline as most available reserves will not be economical. This graph compares well with Figure 1.2 which shows South African gold production declining against increasing gold price and global gold production since the early 1970s.

4.4.10 A comparison of gold price and average unit cash cost

Figure 4.13 shows the trend in the gold price and the unit cash cost of production in US\$/ounce.

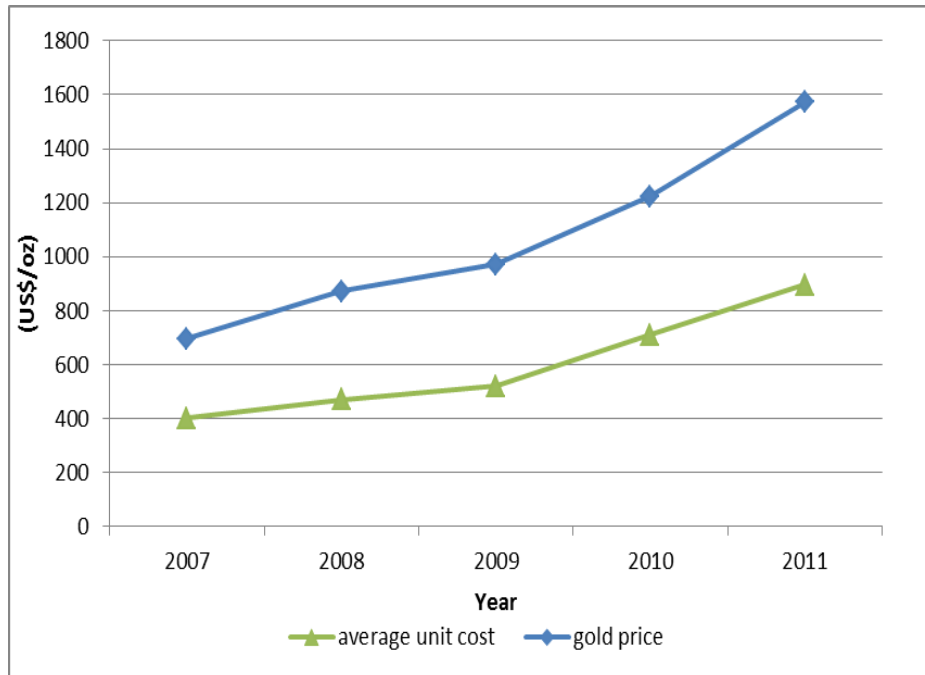


Figure 4.13 Gold price vs unit cost

From Figure 4.13 it is clear that both the gold price and unit cash cost are increasing at nearly the same rate. Considering only cash costs, it can be concluded that the gold industry is profitable but because most gold mines are mature it is possible that they are incurring high sustaining capital expenditure. Considering this possible high capital expenditure together with cash costs, it is likely that most operations are operating at break even. Due to volatility in gold price, a decrease in gold price in future will squeeze profit margins and threaten the viability of most operations. Even though cost cutting measures are implemented, the response of cost trend will not change rapidly that some mines will be unprofitable.

4.4.11 A comparison of gold production and unit cash cost

Figure 4.14 shows the trend of gold production and average unit cash cost over the period 2007 to 2011.

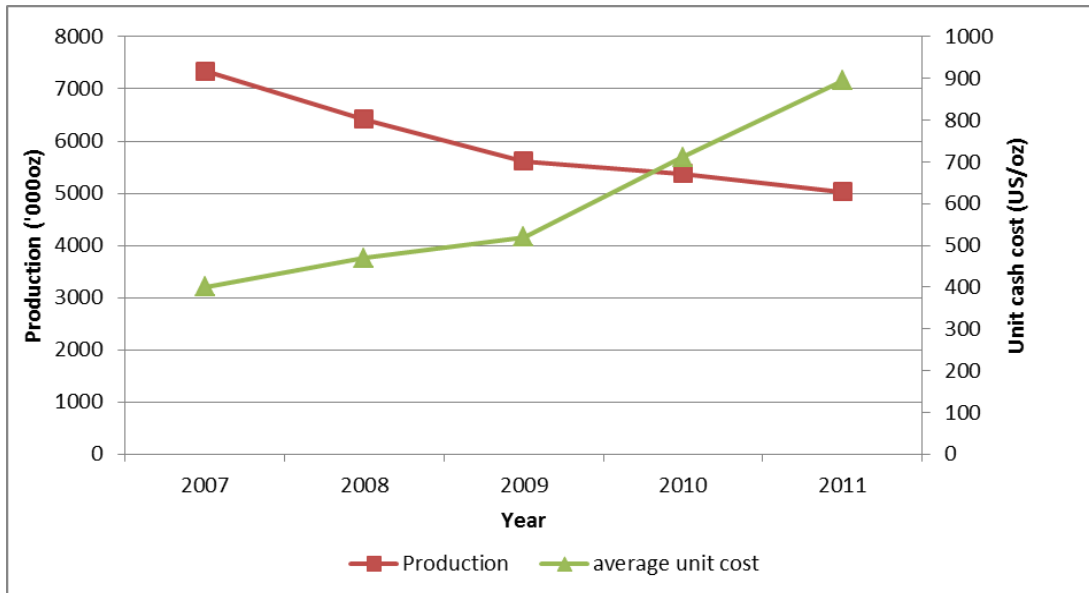


Figure 4.14 Gold production vs unit cash cost

It is seen from Figure 4.14 that as the production is declining the average unit cash cost of production is increasing. This is explained by the principle of economies of scale previously discussed in section 2.7.1 that as production declines, unit cost increases. Figure 4.14 compares well with Figure 2.2 and Figure 2.5.

4.5 Conclusion

South Africa hosts several gold companies some of which are registered on other International Stock Exchanges with regional and global operations. All South African gold industry cost curves show a structure of a typical industry cost curve shown in Figure 2.3 where the first half is dominated by large production mines and the lower production mines inhabit the second half. It has been shown from the cost curves that the relative position of mines and companies on the curve is dynamic from one year to another as mines mature and implement various cost management strategies.

Despite the great in-situ gold reserves in the country, that wealth in the ground does not actually seem to represent wealth being generated from the mining operations because the mining industry is performing below its capacity. Production has been gradually decreasing

over the period under review that the country is slowly losing its position as a global gold producer. The depth of South African gold mines that triggers seismic accidents contributes significantly to the industry's low producing capacity. Head grade and production profile of the mine also affect the cost performance and competitive position of a gold mine on the cost curve. As a result of these factors, successful cost saving and restructuring strategies are the only way to underpin long term sustainability and productivity of the gold mining industry. Among the strategies include:

1. merging infrastructure to reduce overheads and maintain production, for example, merging of Kloof and Driefontein mines to form KDC;
2. revitalising mines by mining reefs below infrastructure to maintain production and extend the life of mine, Most Harmony Gold's operations have expansion projects to extend their life of mine including Kusasalethu, Doornkop and Phakisa mines; and,
3. full mechanization of operations to improve safety and productivity. The mechanisation of flat-end development by Gold Fields is a case in point.

The challenges facing South African gold mining operations together with declining reserves and high costs inherent with mature operations, is causing some companies to begin focussing on producing from outside the country. In the long term, gold production from South Africa is going to continue declining unless new greenfield deposits are discovered and developed.

5 Platinum mining industry cost curves

5.1 Introduction

Platinum is a relatively scarce commodity with about 80% of the world's known resource in South Africa and its supply continues to be constrained. In 2010 platinum was the major contributor to the South African mining industry. As mentioned in section 1.4, it ranked first in total export earnings, remuneration earnings, employment figures and total sales revenue and the country hosts the largest known reserves of the mineral with over 50% of the world's production coming from South Africa (Table 1.1). The PGM industry is set to maintain its position as the mining industry's major contributor particularly in view of the anticipated demand caused by stricter carbon emission legislation in the automotive industry globally, which is likely to see demand exceeding supply. However, the current low platinum prices are a major threat to the long term profitability and sustainability of the platinum sector. Like gold, the platinum mining sector is not immune from economic and operational challenges facing the mining industry that threatens its profitability. The prevailing low platinum prices and these other challenges require that platinum mine operations in the country be cost effectively managed to ensure their profitability. Therefore the dynamics of the South African platinum industry is instrumental to meet the increasing demand for PGMs hence the use of industry cost curves to analyse the sector.

5.2 Platinum mining companies listed on the Johannesburg Securities Exchange

According to the Johannesburg Securities Exchange (2012) the following platinum mining companies are listed on the JSE:

1. Anglo Platinum Limited (ANG);
2. Lonmin Platinum (LON);
3. Impala Platinum Holdings Limited (IMP);
4. African Rainbow Minerals (ARM);
5. Eastern Platinum Limited (EP);
6. Northam Platinum Limited (NTH);
7. Aquarius Platinum Limited (AQM);
8. Jubilee Platinum Limited (JBM);
9. Atlatsa/ Anooraq Resources (ARQ);
10. Bauba Platinum Limited;
11. Platfields Limited (PF);
12. Royal Bafokeng Platinum Limited (RB);
13. Wesizwe Platinum Limited (WSP); and

14. Platimin Limited (PTM).

As mentioned in section 3.2 only companies with operating mines and available Annual Reports were used in the analysis. The following companies were excluded either because their operations were still in feasibility, project or development stage or because they focus on mineral exploration:

- Wesizwe Platinum Limited has two projects that are still in their construction stages namely, the Bakubung Platinum mine and Maseve (Wesizwe Platinum Limited, 2011) ;
- Jubilee is involved in the exploration and development of mineral assets with its advanced project, Tjate still in the feasibility stage (Jubilee Platinum Limited, 2012);
- Platfields Limited is an exploration company with a vision to develop and bring its projects into operation in the future (Platfield Limited, 2012);
- Bauba Platinum Limited is an exploration company with an intention of establishing a mine in the future (Baub Platinum Limited, 2012); and
- Platmin's Pilanesberg Platinum Mine is still in build-up stage and its full production target date has been delayed to 2012 because of complicated geology in the open pit (Platimin Limited, 2010).

Anooraq Resources started reporting Bokoni mine's results from 2009 after acquiring (51%) from AngloPlat in 2009. It changed its name to Atlatsa in May 2012.

5.3 Platinum mines cost curves and their analysis

Figure 5.1 to Figure 5.5 show platinum mines cost curves from 2007 to 2011 and were developed from data in Appendix 10.6 to Appendix 10.10 respectively. Like gold cost curves, different colours are used to represent mines of different companies while mines of the same company share the same colour. Unlike gold mines' cost curves, it was not meaningful to show the platinum prices because analysis was done considering tonnes milled while platinum price is in per ounces produced.

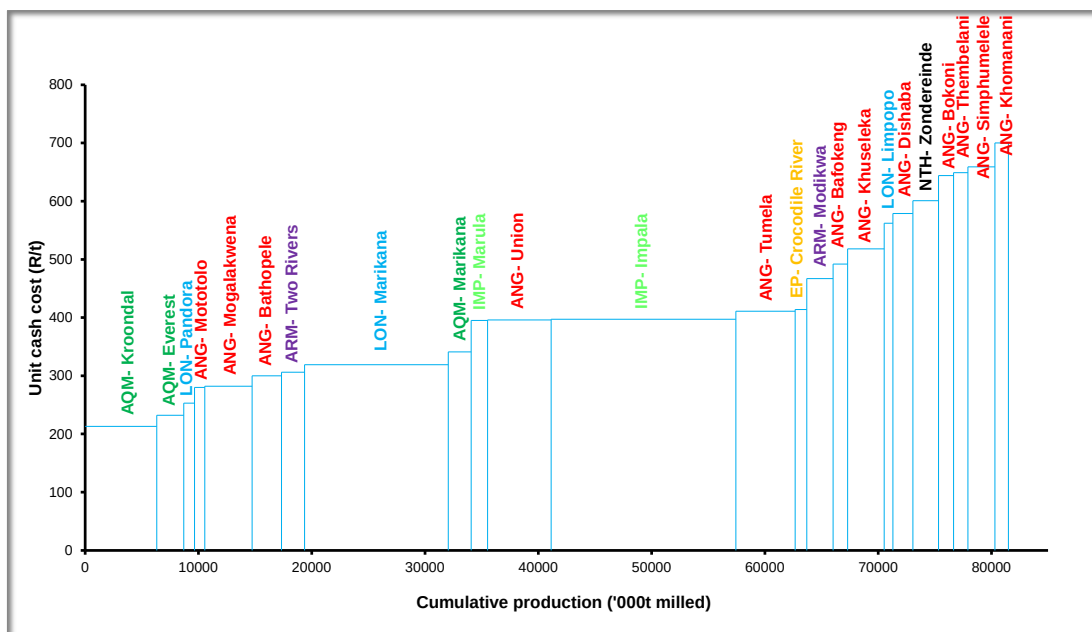


Figure 5.1 Platinum mines cost curve for 2007

(Sources: Anglo American Platinum Limited, 2007; Aquarius Platinum Limited, 2007; Lonmin Plc, 2007; Impala Platinum Holdings Limited, 2007; African Rainbow Minerals, 2007; Northam Platinum Limited, 2007; and Eastern Platinum Limited, 2007)

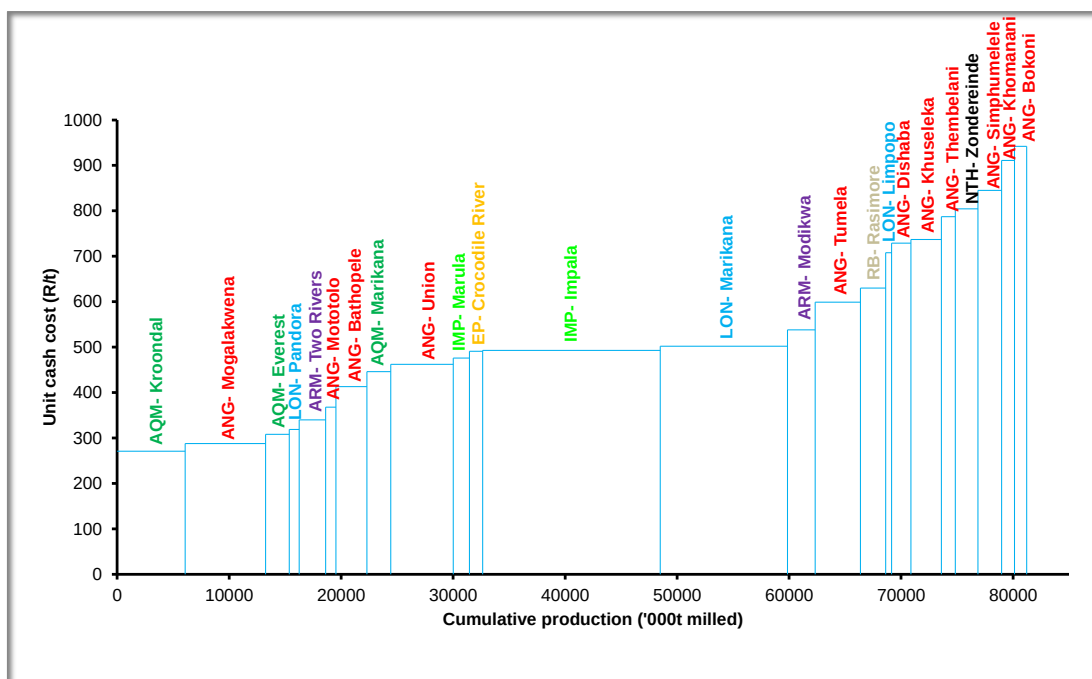


Figure 5.2 Platinum mines cost curve for 2008

(Sources: Anglo American Platinum Limited, 2008; Aquarius Platinum Limited, 2008; Lonmin Plc, 2008; Impala Platinum Holdings Limited, 2008; African Rainbow Minerals, 2008; Northam Platinum Limited, 2008; Royal Bafokeng Platinum Limited, 2010; and Eastern Platinum Limited, 2008)

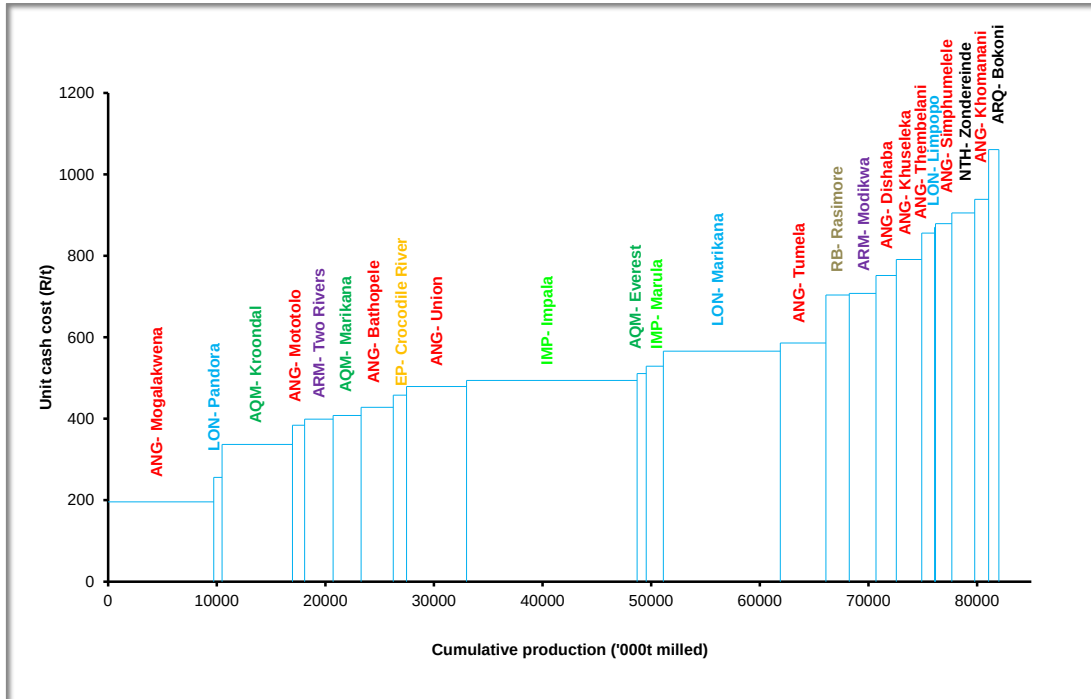


Figure 5.3 Platinum mines cost curve for 2009

(Sources: Anglo American Platinum Limited, 2009; Aquarius Platinum Limited, 2009; Lonmin Plc, 2009; Impala Platinum Holdings Limited, 2009; African Rainbow Minerals, 2009; Northam Platinum Limited, 2009; Anoroaq Resources Corporation, 2009; Royal Bafokeng Platinum Limited, 2010; and Eastern Platinum Limited, 2009)

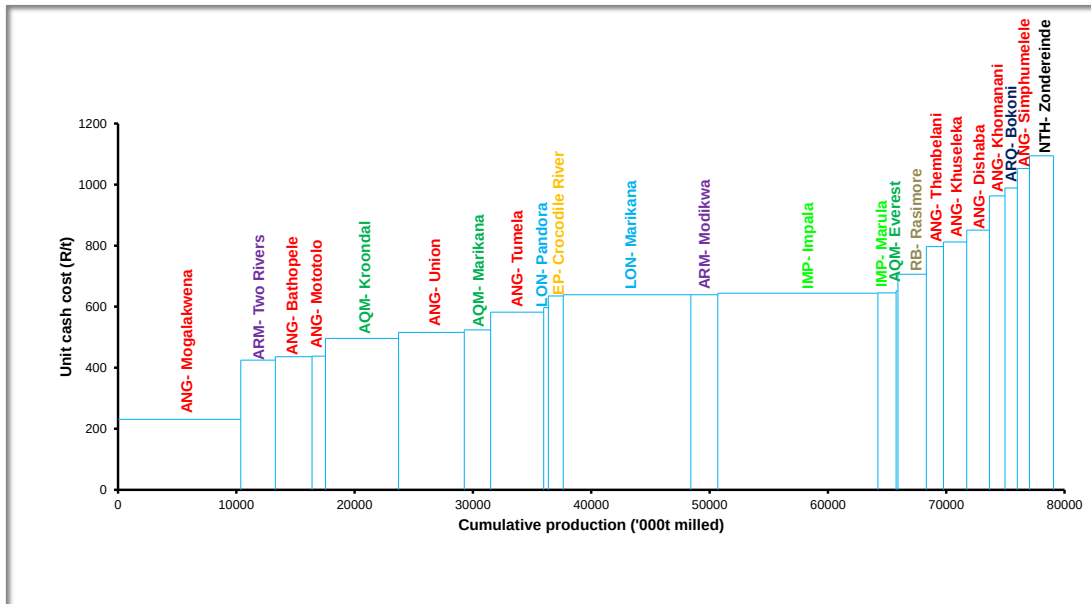


Figure 5.4 Platinum mines cost curve for 2010

(Sources: Anglo American Platinum Limited, 2010; Aquarius Platinum Limited, 2010; Lonmin Plc, 2010; Impala Platinum Holdings Limited, 2010; African Rainbow Minerals, 2010; Northam Platinum Limited, 2010; Anoroaq Resource Corporation, 2010; Royal Bafokeng Platinum Limited, 2010; and Eastern Platinum Limited, 2010)

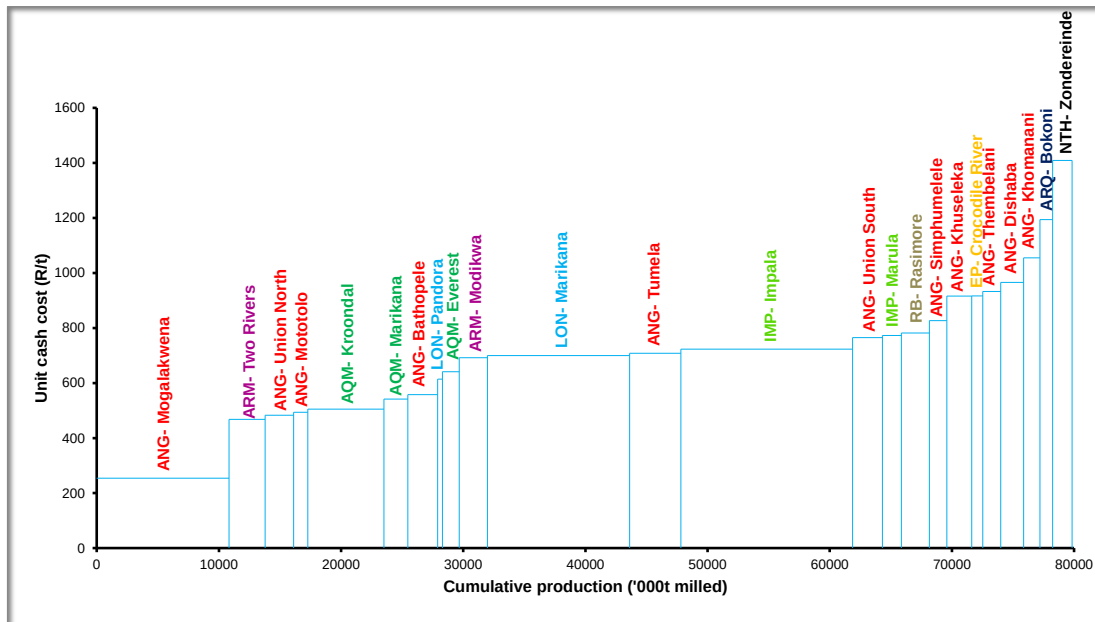


Figure 5.5 Platinum mines cost curve for 2011

(Sources: Anglo American Platinum Limited, 2011; Aquarius Platinum Limited, 2011; Lonmin Plc, 2011; Impala Platinum Holdings Limited, 2011; African Rainbow Minerals, 2011; Northam Platinum Limited, 2011; Anoroaq Resources Corporation, 2011; Royal Bafokeng Platinum Limited, 2011; and Eastern Platinum Limited, 2011)

It can be seen that all the platinum mines cost curves resemble a typical industry cost curve (Figure 2.3) where the extreme right hand side is dominated by small production platinum mines. However, the difference with all these curves is that the second quartile accounts for more production than the first mainly because of Impala mine with all 14 operating shafts consolidated into a single unit.

Unlike gold mines, platinum operations have generally been stable, maintaining their respective positions on the industry cost curve. Kroondal, Mototolo, Two Rivers and Mogalakwena mines have always maintained their positions in the first quartile of the cost curve. Consistently at the extreme end of the cost curve were Dishaba, Simphumelele, Thembelani, Khomanani, Zondereinde and Bokoni mines. These have always been highest unit cost operations from 2007 to 2011. A summary analysis and explanation of why these mines are low and high unit cost platinum operations is shown in Table 5.1 based on 2011 data.

Table 5.1 A summary analysis of low unit cost and high unit cost platinum operations

MINE	MAXIMUM DEPTH OF OPERATION	MINING METHOD	MECHANIZATION LEVEL
LOW UNIT COST OPERATIONS			
Mogalakwena	240m	Open pit	Mechanized open pit
Kroondal	450m	Room & Pillar	Mechanized
Mototolo	450m	Room & Pillar	Fully mechanized
Two Rivers	250m	Room & Pillar	Fully mechanized
HIGH UNIT COST OPERATIONS			
Simphumelele	1,350m	Breast Stopping	Conventional
Thembelani	900m	Scattered breast	Conventional
Dishaba	1,250m	Scattered Breast stopping	Conventional and Mechanized
Khomanani	1,245m	Scattered Breast stopping & Mechanized hybrid mining	Conventional and Mechanized
Bokoni	200m	Scattered Breast stopping & Mechanized hybrid mining	Conventional and Mechanized
Zondereinde	2,200m	Breast mining	Conventional

5.3.1 Low unit cost platinum operations

It can be concluded from Table 5.1 that Mogalakwena, Kroondal, Mototolo and Two Rivers are low unit cost operations in the first quartile of the cost curve because:

- Mogalakwena is an open pit operation and has always been Anglo Platinum's lowest unit cost operation (after its tailings treatment operations). The other reason is its high production; it is third in terms of tonnes milled. Despite its low average head grade of less than 3g/t, its production is high that it gains from economies of scale hence it is a low unit cost operation. Its production has been increasing from 4,187, 000 tonnes milled in 2007 to 10, 835, 000 tonnes in 2011 so it is expected to remain a low unit cost operation because of its high production capacity. Mogalakwena explains the advantages of economies of scale previously discussed in section 2.7.1;
- Kroondal, Mototolo and Two Rivers are relatively shallow underground mines with an average operating depth of less than 400m below surface; and
- Kroondal, Mototolo and Two Rivers are low unit cost mines because they employ the Room and Pillar mining method. In addition the operations are mechanized which offers improved productivity and hence low unit cost of operation as discussed in section 2.6.

5.3.2 High unit cost platinum operations

Simpfumelele, Thembelani, Dishaba, Khomanani, Bokoni and Zondereinde are consistently high unit cost operations as shown in Figure 5.1 to Figure 5.5 because of the findings in Table 5.1 which are:

- the mines are relatively deep averaging 1,190m below surface; and
- the mines employ conventional mining methods that are less productive resulting in high unit cost of operation. Consequently, these mines have low production hence their position on the fourth quartile of the cost curve.

Everest mine was in the first quartile in 2007 and 2008 and moved to the third quartile in 2009 and 2010. This movement to the third quartile was due to subsidence in the main decline that led to the mine being closed temporarily in 2009. Milled production declined from 2,114,000 tonnes in 2008 to 150,000 tonnes in 2010. At the time of this report write-up the company had announced that the mine was being placed under care and maintenance with effect from 21 June 2012 (Aquarius Platinum Limited, 2012). Aquarius Platinum Limited (2012 pp.1) reported that “The ramp-up at Everest has encountered challenges resulting from poor ground conditions and on-going disruptive industrial relations over an extended period and these issues, coupled with the present low PGM price environment, have rendered the mine uneconomic”.

Zondereinde mine is one of the high unit cost operations in the fourth quartile of the cost curve. In 2010 and 2011 the mine was the deepest reported platinum mine, with deepest operations at 2,200m. The mine experienced a series of strikes and safety related stoppages by the DMR; losing 26 production days each in 2008 and 2009, 17 days in 2010 and a total of 65 stoppages due to both safety and strike related stoppages. The mine had a one-week and then a six-week strike related stoppages in 2007 and 2011 respectively. Due to these stoppages the company's production declined from 2,269,206 tonnes milled in 2007 to 1,590 845 tonnes in 2011. Coupled with these stoppages, the mine also encountered operational difficulties associated with mining the Merensky potholes facies that also contributed to lower productions due to less face flexibility.

Royal Bafokeng Rasimone Platinum mine is a relatively high unit cost operation in the third quartile of the cost curve. As an operating cost management initiative, the company implemented a business optimisation strategy in the third quarter of 2010, with positive results already noted in labour efficiencies, drill and blast designs, and practises. The strategy was offset by safety stoppages imposed by the DMR combined with a nine days contractor strike but it is hoped that as the optimisation program rolls out, cost reduction

improvements will continue. This will assist the company move down the cost curve and remain profitable. However, the current stagnant low platinum prices against increasing costs are likely to offset the company's cost management initiative. Figure 5.6 shows the relationship between depth of operation and unit cash cost for FY011.

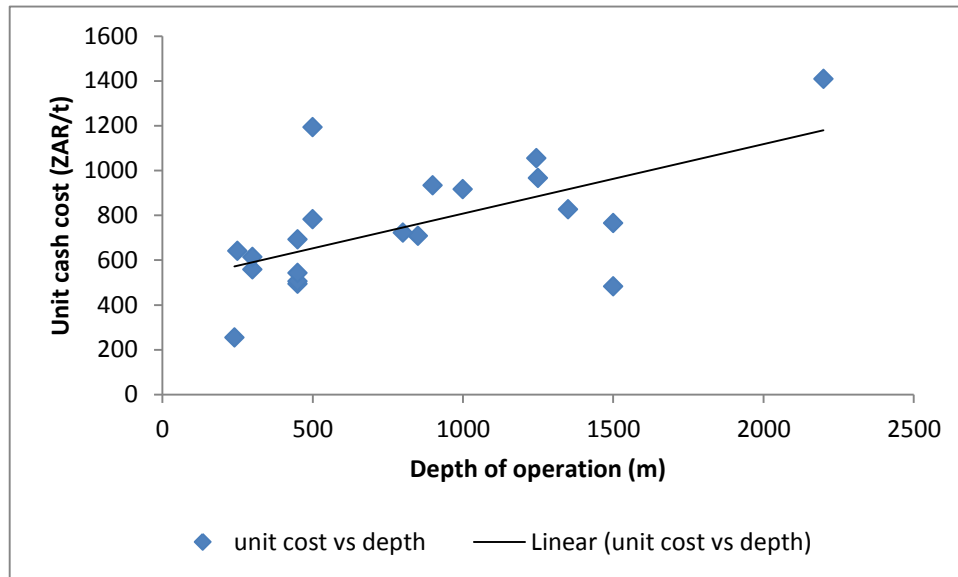


Figure 5.6 Relationship between depth of operation and unit cash cost

From Figure 5.6, shallow operations have a lower unit cost of production compared to deeper operations as already explained in section 2.6. In 2010 and 2011 Zondereinde mine was the highest unit cost mine and deepest reported mine, with deepest operations at 2,200m. Depth of operation is one of the major factors that explain the ranking of operations on the platinum industry cost curve.

5.4 Platinum mining companies cost curves and their analysis

Like gold companies cost curves, platinum companies cost curves were constructed from total production and weighted averages for unit cash cost from the operating mines in the analysis. The production of a particular company was calculated from the total production of the individual mines in the analysis whilst the unit cash cost were weighted averages calculated as:

$$\text{Unit cash cost} = \frac{\sum (\text{mine 1's production} \times \text{mine 1's unit cost, mine 2's production} \times \text{mine 2's unit cost} \dots)}{\sum (\text{mine 1 production} + \text{mine 2's production} \dots)}$$

Figures 5.7 to 5.11 show platinum companies industry cost curves from 2007 to 2011 and were developed from data in Appendix 10.6 to Appendix 10.10 respectively.

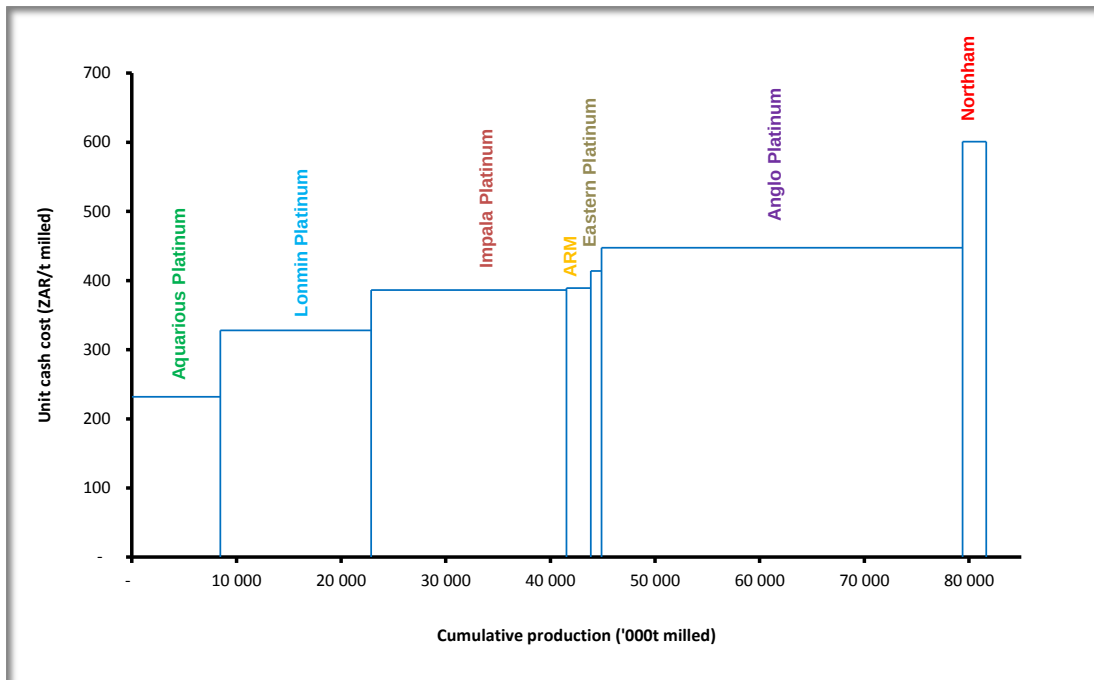


Figure 5.7 Platinum companies cost curve for 2007

(Sources: Anglo American Platinum Limited, 2007; Aquarius Platinum Limited, 2007; Lonmin Plc, 2007; Impala Platinum Holdings Limited, 2007; African Rainbow Minerals, 2007; Northam Platinum Limited, 2007; and Eastern Platinum Limited, 2007)

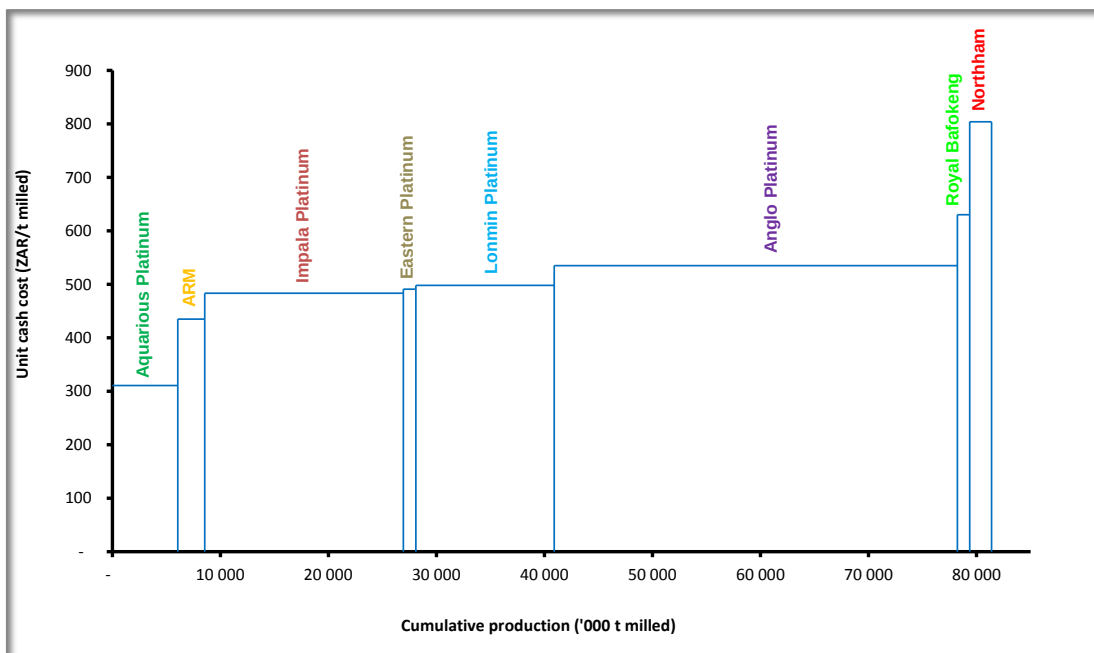


Figure 5.8 Platinum companies cost curve for 2008

(Sources: Anglo American Platinum Limited, 2008; Aquarius Platinum Limited, 2008; Lonmin Plc, 2008; Impala Platinum Holdings Limited, 2008; African Rainbow Minerals, 2008; Northam Platinum Limited, 2008; Eastern Platinum Limited, 2008; and Royal Bafokeng Platinum Limited, 2010)

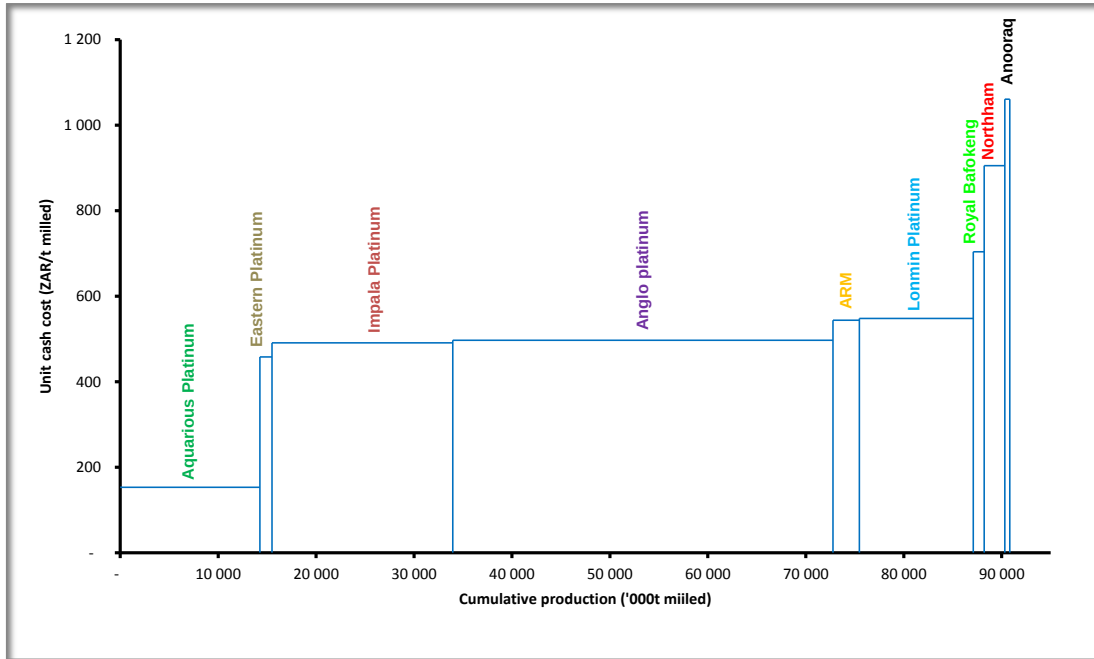


Figure 5.9 Platinum companies cost curve for 2009

(Sources: Anglo American Platinum Limited, 2009; Aquarius Platinum Limited, 2009; Lonmin Plc, 2009; Impala Platinum Holdings Limited, 2009; African Rainbow Minerals, 2009; Northam Platinum Limited, 2009; Anoroaq Resources Corporation, 2009; Eastern Platinum Limited, 2009; and Royal Bafokeng Platinum Limited, 2010)

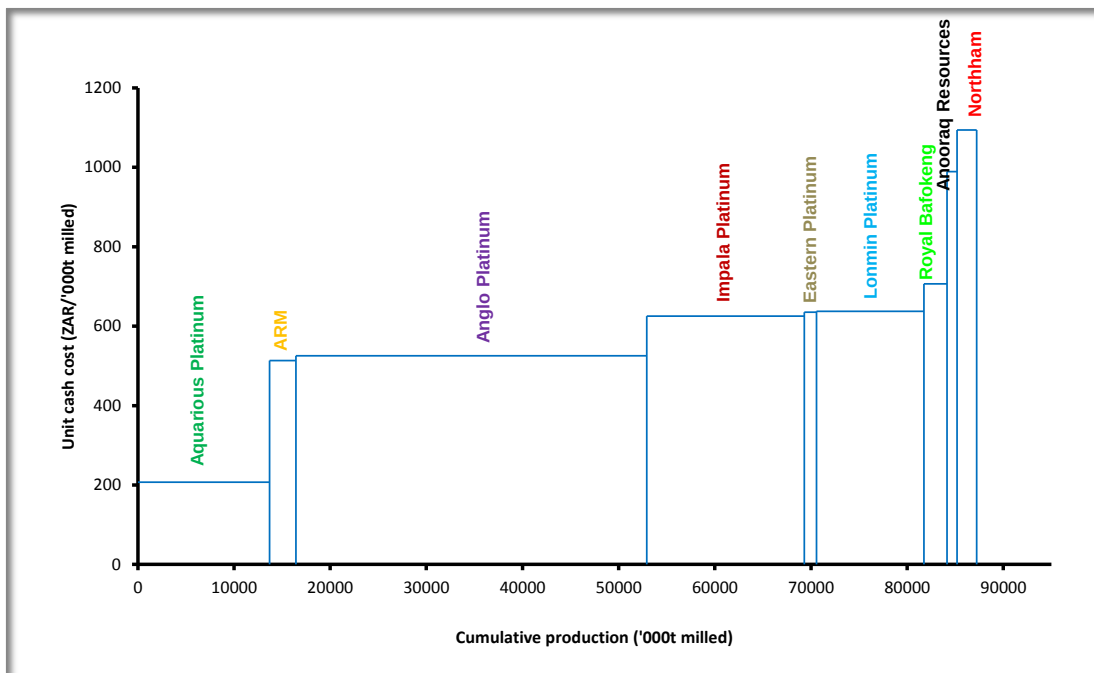


Figure 5.10 Platinum companies cost curve for 2010

(Sources: Anglo American Platinum Limited, 2010; Aquarius Platinum Limited, 2010; Lonmin Plc, 2010; Impala Platinum Holdings Limited, 2010; African Rainbow Minerals, 2010; Northam Platinum Limited, 2010; Anoroaq Resources Corporation, 2010; Eastern Platinum Limited, 2010; and Royal Bafokeng Platinum Limited, 2010)

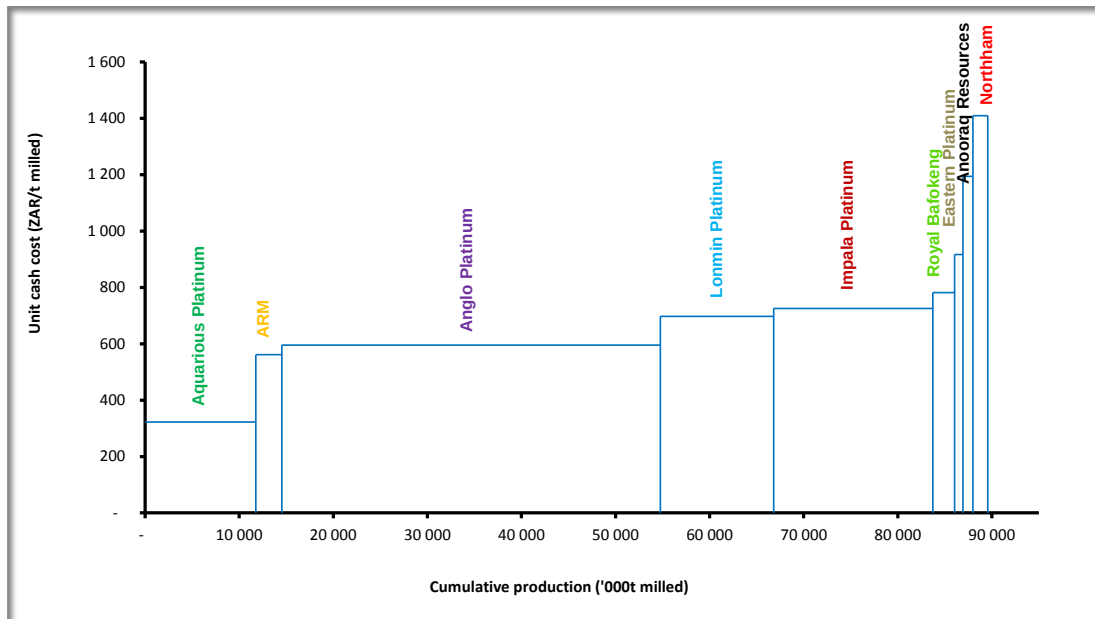


Figure 5.11 Platinum companies cost curve for 2011

(Sources: Anglo American Platinum Limited, 2011; Aquarius Platinum Limited, 2011; Lonmin Plc, 2011; Impala Platinum Holdings Limited, 2011; African Rainbow Minerals, 2011; Northam Platinum Limited, 2011; Anoroaq Resources Corporation, 2011 Eastern Platinum Limited 2011; and Royal Bafokeng Platinum Limited, 2011)

5.4.1 DMR's Section 54 safety stoppages

For the past few years, the DMR has been strict in enforcing Section 54 of the Mine Health and Safety Act 29 of 1996. In case of an accident/fatality at a mine, the department usually does a non-localised stoppage as a punitive measure thereby disrupting the entire mines' production. The platinum sector seems to be severely affected by these stoppages as evident from the statistics below:

- in 2010 alone Anglo American Platinum experienced 36 stoppages at its managed mines and the stoppages more than doubled in 2011 to 81 at its managed operations and 50 from its JV operations. In 2011 a total of 312 days across the group were lost compared to 113 in 2010. This led to a total estimated production loss of 164,000oz in 2011 as a result of these non-localised stoppages;
- in 2008, 2009 and 2010 Northam lost a total of 69 production days; and
- Everest mine lost 36 shifts in 2011.

These DMR interventions to safety are commendable as the total industry fatality rate has been declining, but should be rationally done in affected areas to avoid production disruption to the entire mine operation. These safety related stoppages resulted in year on year reduction in the overall milled tonnage.

5.4.2 Strike related stoppages

The period under review saw an increase in labour unions' wage demands particularly in the platinum mining sector. Several platinum mining companies and mines lost significant production days due to these industrial actions as noted below:

- Northam lost one and six weeks in 2007 and 2011 respectively;
- Two Rivers mine lost 14 production days in 2007;
- Modikwa mine lost 24 production days in 2007;
- Kroondal and Marikana mines lost two weeks in 2010;
- Implats lost two weeks in 2009; and
- Royal Bafokeng's Rasimore mine lost nine days in 2011 due to a contractor strike.

By the time of writing this report, the industry was experiencing severe wage related strikes that started at Lonmin Platinum's Marikana mine in August 2012 claiming the lives of 44 people (Mail and Guardian, 2012). The Marikana incident sparked industrial wage strikes across the mining sector that resulted in workers from several other mines in different companies downing tools and forcing operations to shut down between August to October 2012. Other companies that were affected by the strikes include Anglo American Platinum, AngloGold Ashanti, Atlatsa Resources, Gold Fields, Gold One International, Harmony Gold, Kumba Iron Ore, Petmin Mining, Village Main Reef, Petra Diamonds and Xstrata Coal (Forbes, 2012). These wildcat strikes further reduced the productivity of the already depressed sector. Some of the affected mines, gold and platinum in particular, were already marginal that these strikes put a lot of pressure on their unit costs of production and will affect their competitive positions on the industry cost curve. As noted in Forbes (2012), Deutsche Bank mentioned that the labour strikes saw over 30% of the total workforce in the mining sector, join the wildcat strikes taking place across the country. The bank estimated that 17% of global production has been affected and believed that a loss of 270,000 platinum ounces were lost during these strikes.

5.4.3 Anglo American Platinum Limited

The company moved down the company cost curve from sixth position in 2008 to fourth then third position in 2009 and 2010 respectively because of the following possible reasons:

- from 2007 the company has been increasingly implementing mechanisation programs for its operations including hydro-powered drills for high speed development. Mechanisation of operations offers improved safety and productivity compared to conventional mining as discussed previously in section 2.6. The mechanisation programme also possibly contributed to fatality reduction from a total of 29 (both managed and JV) in 2007, 20 in 2008 then 12 in 2011. This shows the

relationship between safety and productivity as discussed before in section 2.6. The company committed to increase resources to research and develop mechanised mining equipment to enable extraction of narrow width reef of below 0.9m. This will enable the company's safety performance to improve and its operations to be profitable against a background of stagnant platinum prices and increasing input costs;

- the sale of the high cost Bokoni mine to Anoraq Resources now called Atlatsa;
- from 2008 to 2009, the company's Rustenburg and Amandelbult mines underwent a restructuring process that involved unbundling the operations into five and two stand-alone mines respectively and a central services structure. This was to enable easy of control of the entities and resulted in improved efficiency, productivity and reduced unit cost; and
- from 2008 to 2009 the company down-sized its head and regional office staff compliments by 1,150 people. This possibly assisted the company reduce its unit cost and move itself down the industry cost curve. Smaller companies tend to be low unit cost as explained before in section 4.4.

5.4.4 Northam Platinum Limited

The company has always been a highest unit cost company relative to its peers. The company experienced a lot of safety and strike related stoppages that reduced the company's productivity as shown before in section 5.4.1 and 5.4.2. Due to decreasing production from its Zondereinde mine, its operating margin, earnings per share and dividend per share has also been gradually decreasing alongside production which shows the effects of productivity on financial performance.

5.4.5 Other platinum mining companies

No factors were noted that can be attributed to the behaviour of other platinum mining companies on the cost curves. These include Implats, Lonmin, and ARM significant contributors to the platinum sector.

5.4.6 The 2008 Global Financial Crisis

The platinum mining industry was severely affected by the global financial crisis that was full onset in the last quarter of 2008. The crisis was caused by a global credit squeeze resulting in high cost of capital and subsequent declining in consumer demand. At the beginning of 2008, the price of platinum rose to over US\$2,300 per ounce and within six months, it had dropped to below US\$800 per ounce. The effects of the crisis to South African mining

operations were made worse by the strengthening rand against the US dollar from above ZAR10.00/USD in late 2008 to ZAR6.65/USD in January 2011. In response to the crisis most companies implemented cost management initiatives; capex projects were suspended and high cost operations were placed under care and maintenance including Anglo Platinum Ltd.'s Khuseleka, Simhpumele 2 and 3 shafts in 2009, Aquarius Platinum Ltd.'s Blue Ridge mine in 2011, Marikana and Everest mines in 2012.

Production milled

Figure 5.12 shows the trend in production (tonnes milled) of the platinum companies under review from 2007 to 2011. It can be seen from the figure that only Lonmin had marked production decline for the period under review, in terms of tonnes milled.

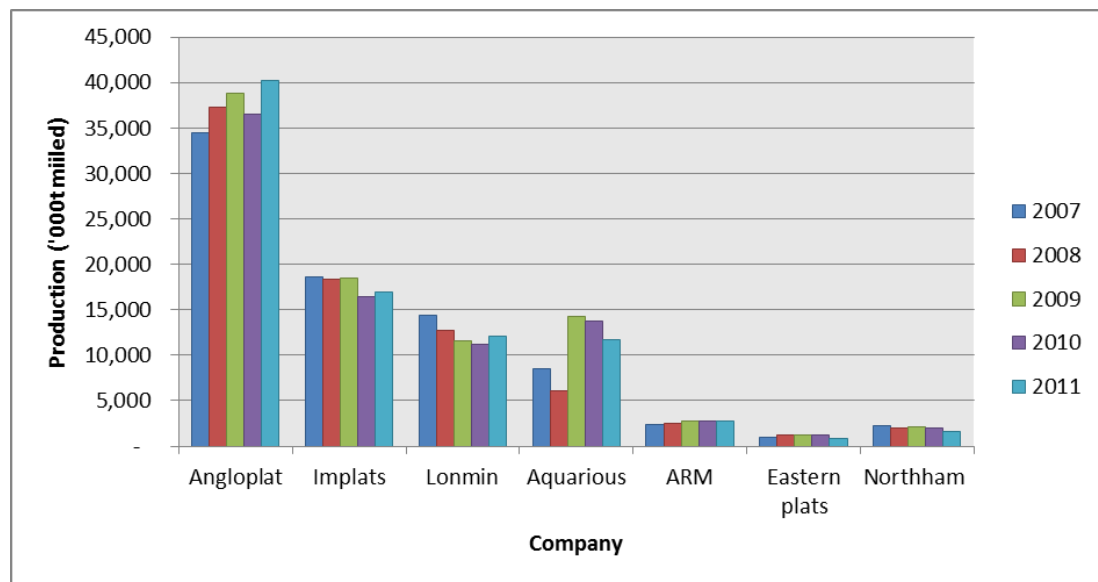


Figure 5.12 Platinum companies' production trend

Dividends per share declared

Figure 5.13 shows declared dividends (in ZAR cents) by companies under review for the period 2007 to 2011.

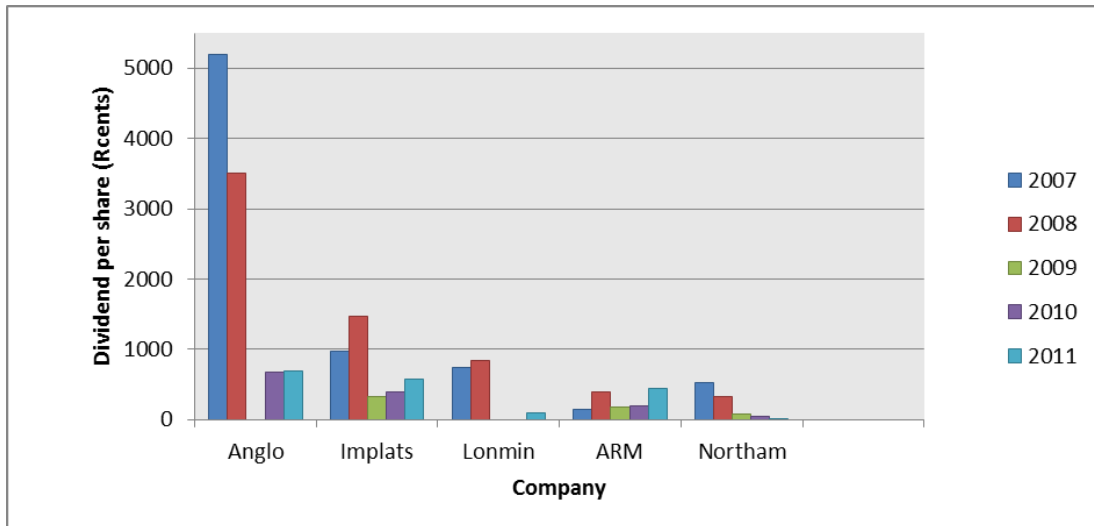


Figure 5.13 Declared dividends per share from 2007 to 2011

It can be seen from Figure 5.13 that most companies' financial performance was affected by the global financial crisis. Dividends from all companies dropped significantly in 2008, with Lonmin declaring zero dividends in 2008 and 2009, Anglo Platinum declaring zero dividends in 2009. All companies' dividends (except Northam) were lowest in 2009, as companies succumbed most to the global financial crisis and started improving in 2010. This same trend is shown in other financial performance measures such as market capitalisation and share price.

Lonmin's declining performance can also be seen from the companies cost curves (Figure 5.7 to Figure 5.11). From Figure 5.7 it can be seen that Lonmin was on second position of the curve, but in 2009 (Figure 5.9) and 2010 (Figure 5.10) it had moved down to sixth position on the cost curve alongside an operating loss of USD142m in 2009. As seen in Figure 5.12, only Lonmin had a marked production decline in terms of milled tonnage. This shows the effects of the global financial crisis to productivity, costs and financial performance of mining operations.

Operating margin

Figure 5.14 shows the operating margin (as a percentage) for the platinum mining companies for the period 2007 to 2011.

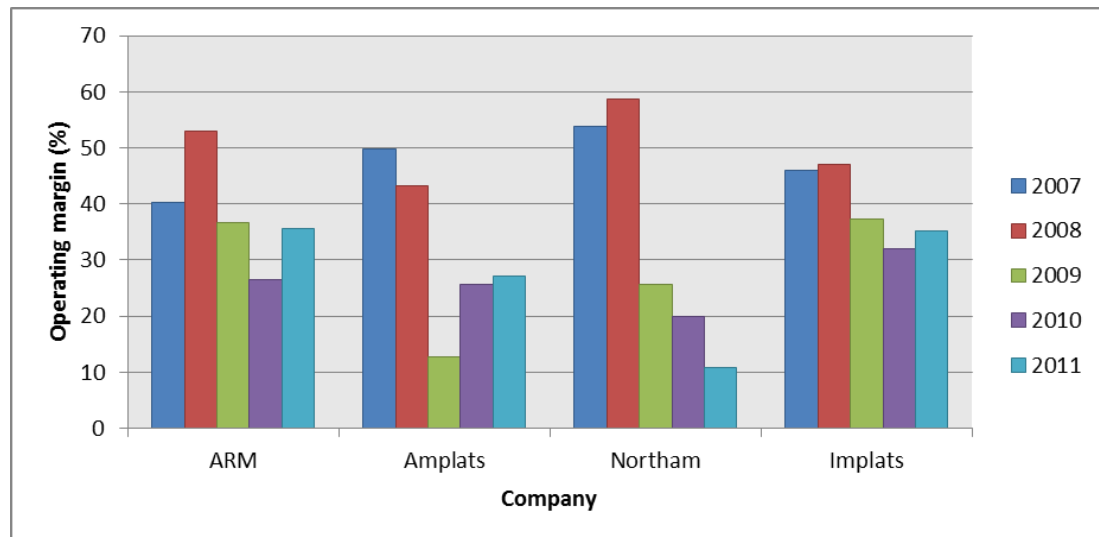


Figure 5.14 Operating margin for the period 2007 to 2011

It can be seen from Figure 5.14 that operating margins for all companies dropped significantly from 2008 to 2009 and peaked up again in 2011 except for Northam.

It can be seen from the above analysis that the global financial crisis was full onset in 2008 progressing to 2009, and severely affected the performance of platinum mining companies in South Africa. As the mining industry slowly recovered from the economic crisis (from 2010) the performance of platinum companies also improved in terms of operating margins, dividends per share and production as shown in Figure 5.12 to Figure 5.14.

5.5 Conclusion

Platinum remains a strategic industrial and premier jewellery metal and hence, the long term fundamentals of the industry are important. Given the declining gold industry performance as discussed in Chapter 4 and the significant platinum resources in the country, it is important that the platinum sector be profitable so that the country's mining industry remains sound. The potential of the sector to remain the mining industry's major contributor is being threatened by various challenges locally and globally. The global economic crisis resulted in some operations being placed under care and maintenance. Locally, safety and labour related stoppages disrupted production undermining the sector's already troubled productivity. These factors together led to a decline in operational and financial performance

of platinum operations. As the global economy generally recovers from the global financial crisis, the platinum sector's profitability is still under threat as platinum prices continue to be stagnant against increasing cost of production. Under current economic conditions, the sector's long term profitability is uncertain as seen by current threats to stall Capital Expenditure (CAPEX) projects and close high cost unprofitable mine operations. The current oversupplied market resulting in stagnant platinum prices requires sound cost management strategies and intervention from various stakeholders to ensure the survival, productivity, profitability and sustainability of the industry.

6 Coal mining industry cost curves

6.1 Introduction

From Table 1.1 it can be seen that the South African coal mining industry competes quite well in the global mining world; it ranked fifth, sixth and seventh in terms of exports, reserves and production respectively. In the local economy, it is a significant sector of the mining industry; ranking second, third and fourth in terms of total sales revenue, remuneration and total export earnings respectively as shown in section 1.4. The global demand for electrical energy continues to grow mainly due to the urbanisation and industrialisation of fast growing emerging economies; Brazil, Russia, India and China (the BRIC countries). In particular, the economic growth in China and India remain the key driver for global coal demand. Locally, Eskom's power stations expansion projects will continue to grow the demand for coal. Given the high coal intensity use in energy and electricity generation, the coal market is expected to grow both locally and globally and it is against this background that coal producers in South Africa must take advantage of the coal market to enhance shareholder value through cost management strategies. However, the coal mining sector in the country is also vulnerable to economic, operational and technical constraints that affect its profitability. The significance of coal as an energy source both locally and globally is the reason it was included in this report analysis and analyse the sector's medium to long term sustainability.

6.2 Coal mining companies in South Africa

6.2.1 Coal mining companies listed on the Johannesburg Securities Exchange

According to the Johannesburg Securities Exchange (2012) and the Chamber of Mines of South Africa (2010) the following coal mining companies are either listed on the JSE or listed on other stock exchanges but have coal mining operations in South Africa:

1. Anglo American Limited;
2. Exxaro Resources Limited;
3. Optimum Coal Holdings Limited;
4. BHP Billiton Limited;
5. Sasol Limited;
6. Xstrata Plc. (Xstrata);
7. Forbes & Manhattan Coal Corp;
8. Hwange Colliery Company Limited;
9. Keaton Energy Holdings Limited;
10. Resource Generation Limited;

11. South African Coal Mining Holdings Limited (SACMH);
12. Wescoal Holdings Limited;
13. Miranda Mineral Holdings Limited;
14. Firestone Energy Limited;
15. Continental Coal Limited;
16. Coal of Africa Limited; and
17. African Rainbow Minerals.

The following companies were excluded from the analysis as explained before in section 3.2 and also because of the following reasons:

1. Resource Generation Limited is a new energy resources company with advanced planning completed to start an open pit mine in the Waterberg coal fields (Resource Generation Limited, 2012);
2. Hwange is listed on the JSE but has no operations in South Africa;
3. SACMH was placed on care and maintenance from April 2009 to October 2010 (South African Coal Mining Holdings Limited (SACMH), 2012). At the time of writing this report, the company was under suspension from the JSE and no data was available on the company's website <http://www.sacmh.co.za/investors> for the period 2007 and 2008;
4. Forbes & Manhattan Coal Corp is a Toronto Stock Exchange (TSX) listed coal producer with operations in South Africa which it both acquired in August 2010 from Slater coal a private company (Forbes & Manhattan Coal Corp, 2012) hence only the 2011 data is available;
5. Miranda Mineral Holdings Limited is currently a mineral exploration investment and holding company and the company expects to commence active coal mining in 2012 (Miranda Mineral Holding Limited, 2012);
6. Firestone Energy Limited is listed on the Australian Stock Exchange Limited (ASX) and the Johannesburg Stock Exchange (JSE) and has completed feasibility studies for its Waterberg project. The company is currently finalising funding of the project (Firestone Energy Limited, 2012);
7. Continental Coal Limited is an ASX listed company with projects and operations in South Africa. It acquired Vlakvarkfontein mine and Ferreira mine in October 2010 (Continental Coal Limited, 2011), so it has full data for the year 2011 only;
8. Wescoal Holdings Limited was involved in the buying, washing and selling of coal until December 2009 when it started mining on the Khanyisa colliery. Full stable production only started in 2011 (Wescoal Holdings Limited, 2010);
9. Keaton Energy Holdings Limited is a relatively new company that was established in 2007. Its first major project delivered its first coal in December 2010 and its first coal delivery to Eskom was in June 2011 (Keaton Energy Holdings Limited, 2011);

10. Coal of Africa Limited, in South Africa is an emerging coal producer with its first operation (Vele colliery) in its early production stages. (Coal of Africa Limited, 2011); and
11. African Rainbow Minerals is in a Joint Venture with Xstrata Coal so its production figures were included in Xstrata Coal's figures which reported on a 100% basis.

6.2.2 Junior coal mining companies

The Black Economic Empowerment (BEE) policy by the South African government saw a transformation of the mining industry including the coal sector. This resulted in the birth of a new junior mining sector. According to the Chamber of Mines of South Africa (2010) the average South African coal production from 2007 to 2010 is 251 million tonnes and from the six companies under analysis, the average production over the same period is 214 million tonnes. This shows that the junior coal producers accounts for only 15% of total coal production. An inclusion of these junior producers would have been useful in the analysis. However, this was not possible mainly because most of them are unlisted hence their Annual Reports are not available in the public domain. The other reason is that most of these operations emerged two to three years ago and are not yet in stable production making their data insufficient for this analysis.

6.3 Coal mines cost curves and their analysis

All coal mining companies except Optimum Coal do not report on individual mine's cash operating costs but consolidated for the whole company. This complicated the construction of coal cost curves at a mine level. Hence the author constructed the cost curves at a company level as will be shown in the proceeding section. Table 6.1 shows the collieries that were included in the analysis together with their production from 2007 to 2011. In the Table, OC and BHP means that the respective mines were reported by Optimum Colliery and BHP Coal companies respectively during those particular years.

Table 6.1 Coal mines and production

Company	Mine		Production ('000t)				
			2007	2008	2009	2010	2011
Anglo Coal	Greenside	underground	3 315	3 401	3 295	3 425	2 853
	Goedehoop	underground	8 508	7 449	6 905	6 026	5 201
	Isibonelo	open cast	5 001	5 152	5 062	4 569	4 338
	Kriel	open pit and underground	11 210	10 344	11 162	9 526	8 152
	Kleinkopje	open pit	3 491	4 546	4 414	4 424	4 401
	Landau	open cast	4 058	4 089	4 232	4 086	4 171
	New Denmark	underground	5 135	5 273	3 729	5 052	4 813
	New Vaal	open cast pillar mining	17 120	17 034	17 554	17 235	17 400
	Nooitgedacht	underground	566	455			
	Mafube	open cast	757	1 673	2 213	2 448	2 313
	Zibulo	open pit and underground	-	-	119	1 662	3 367
	TOTAL		59 160	59 417	58 683	58 452	57 008
Exxaro Coal	Grootegeluk	open pit	18 494	18 201	18 283	18 154	18 231
	Leeuwpans	open pit	2 377	2 989	2 506	3 096	4 030
	Tsikondeni	underground	463	327	268	285	299
	Mafube		-	-	1 499	2 347	2 137
	Inyanda		-	841	1 843	1 779	1 918
	Arnot	underground	3 702	4 865	5 213	4 173	2 291
	Exxaro reduntants		-	-	38	114	142
	Matla	underground	13 030	13 230	11 273	12 288	10 150
	New Clydesdale	open pit and underground	970	1 099	822	850	628
	North Block Complex	open pit and underground	2 283	3 282	3 513	3 371	2 346
	TOTAL		41 319	44 834	45 258	46 457	42 172
Sasol coal	Secunda	underground	41 900	41 100	37 300	40 600	36 700
	Sigma	underground	1 400	1 700	1 800	2 000	1 900
	TOTAL		43 300	42 800	39 100	42 600	38 600
BHP Coal	Khutala	open cut and u/g	13 526	13 327	12 700	10 868	12 928
	Klipspruit	open cut	3 223	3 440	3 964	4 887	7 072
	Middleburg & Wolvekrans(Doug)	open cut	18 731	17 003	15 037	14 704	14 328
	Optimum collieries	open cast and 1 u/g sec	11 304	11 302	OC	OC	OC
	Koornfontein	underground	4 858	-	OC	OC	OC
	TOTAL		51 642	45 072	31 701	30 459	34 328
Xstrata coal	Spitzkop		1 017	1 108	771	593	548
	Tselentis		1 801	1 322	926	519	473
	Impunzi	open cast and underground	6 756	3 366	4 009	4 451	4 601
	Tweefontein	open cast and underground	5 111	6 180	5271	8 874	7 542
	Southstock	open cast and underground	5 069	5 328	4721	4 115	-
	Goedgevonden	open cast	1 689	2 919	2 995	4 394	5 293
	TOTAL		21 443	20 223	18 693	22 946	18 457
Optimum coal	Optimum collieries	open cast and 1 underground section	BHP	BHP	12 600	13 100	14 000
	Koornfontein	underground	BHP	BHP	2 900	2 900	3 100
	TOTAL		-	-	15 500	16 000	17 100

6.3.1 Coal types and process flow

Unlike gold and platinum mines, the final coal product has different qualities which then determine its uses. Three main types of coal are thermal (steam) coal, metallurgical (coking) coal and anthracite (World Coal Association, 2005). Thermal coal is mainly used in power generation and manufacturing cement whilst metallurgical coal is mainly used in steel production and anthracite is used for industrial purposes as a liquid fuel (World Coal Association, 2005). To meet the specifications for different uses and markets, mined coal has to go through various washing stages to allow for an extensive set of quality controls to be instituted (The South African Coal Processing Society, 2002). Run of mine coal from the mines is washed first for the export market and the arising middlings are further washed for

the ESKOM market and other domestic markets. In South Africa, metallurgical and thermal coal is produced for both the export and domestic markets whilst the anthracite coal is mainly for domestic markets but each product has its own qualities. The different coal types and hence markets therefore results in differences in prices and distribution costs. For example, a traded coking coal market producer exporting via the Richards Bay Coal Terminal (RBCT) incurs higher costs associated with the transportation to the terminal as compared to a captive market producer supplying a nearby ESKOM's power station via a conveyor belt. The International Energy Agency Coal Research (1986) mentioned other factors that affect the unit production cost of coal such as:

- geological and geometrical seam characteristics that affect the mining method either longwall vs Bord and Pillar or mechanised vs conventional; and
- seam depth that affect the mining method either underground or surface.

Although some mines only produce thermal coal or low graded coal for the domestic market most companies under analysis produce for both the domestic and export markets. Given the dynamics and variations of the coal mining industry, it would have been most useful to distinguish and analyse the cost performance of specific production for export and domestic markets. However, this was not possible because as highlighted before, coal mining companies did not report cost data per individual mine but on a consolidated basis. Additionally, it was not possible to distinguish the cost performance of underground and surface operations. Hence the analysis was limited and assumed a homogenous final coal product.

6.4 Coal mining companies cost curves and analysis

The cost curves input data was calculated as follows:

- the production for each company is the sum of all the company's operating mines' production as reported in the Annual Report;
- the unit operating cost was calculated from the revenue and EBITDA or profit figures that were reported in the Annual Reports as follows:

$$\begin{aligned} \text{Unit operating cost} &= \frac{\text{Operating cost}}{\text{Production}} \\ &= \frac{\text{Revenue} - \text{Operating profit}}{\text{Production}} \end{aligned}$$

- BHP reported revenue and operating EBIT consolidated for the whole company's coal division, so total revenue and EBIT for the South African operations was calculated by aggregating according to the production percentage contribution; and

- Optimum Coal reported production and on-mine unit cash cost for each mine so the company's production was a sum of the individual mines and the unit cash cost was the weighted average of the two operations. Optimum Coal was established in 2007 and acquired its first operation (Optimum collieries) in 2008 so its full production data were reported from 2009 forward.

EBITDA as discussed in section 2.2.2 excludes non-cash items so the unit operating cost calculated is the unit cash costs. Figure 6.1 to Figure 6.5 show the coal cost curves at a company level and were developed from data in Appendix 10.11 to Appendix 10.15 respectively. The average coal price per tonne could not be shown on the cost curves due to price variations from company to company and also depending on the quality of the coal produced to suit customer specifications.

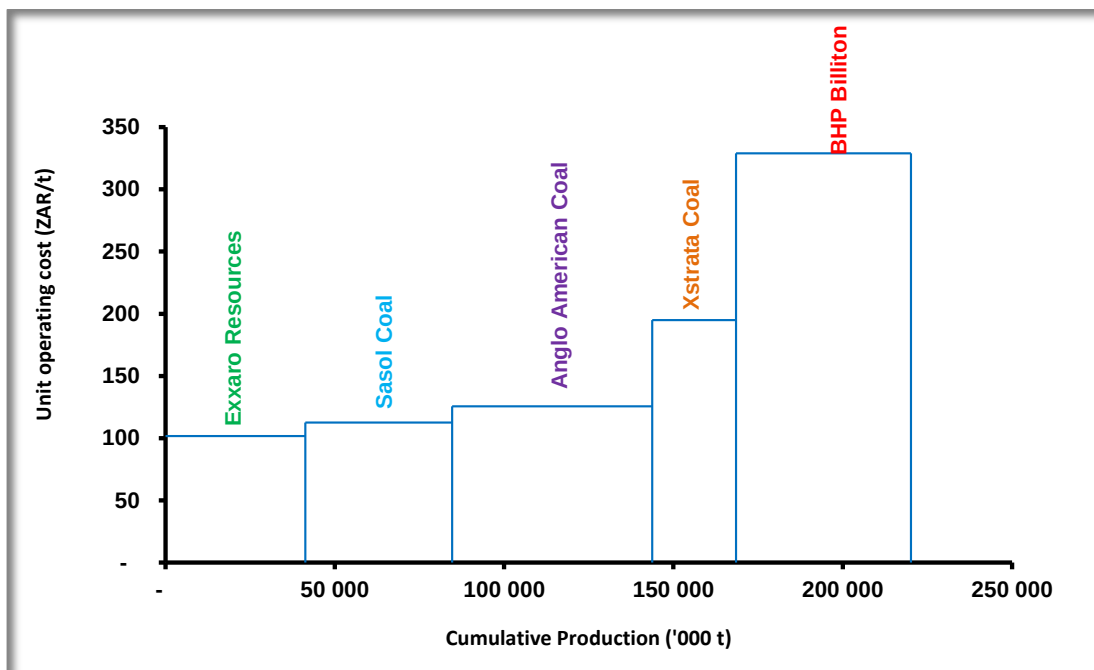


Figure 6.1 Coal companies cost curve for 2007

(Sources: Anglo American Limited, 2007; Exxaro Resources Limited, 2007; BHP Billiton, 2007; Sasol Limited, 2007; and Xstrata Plc., 2007)

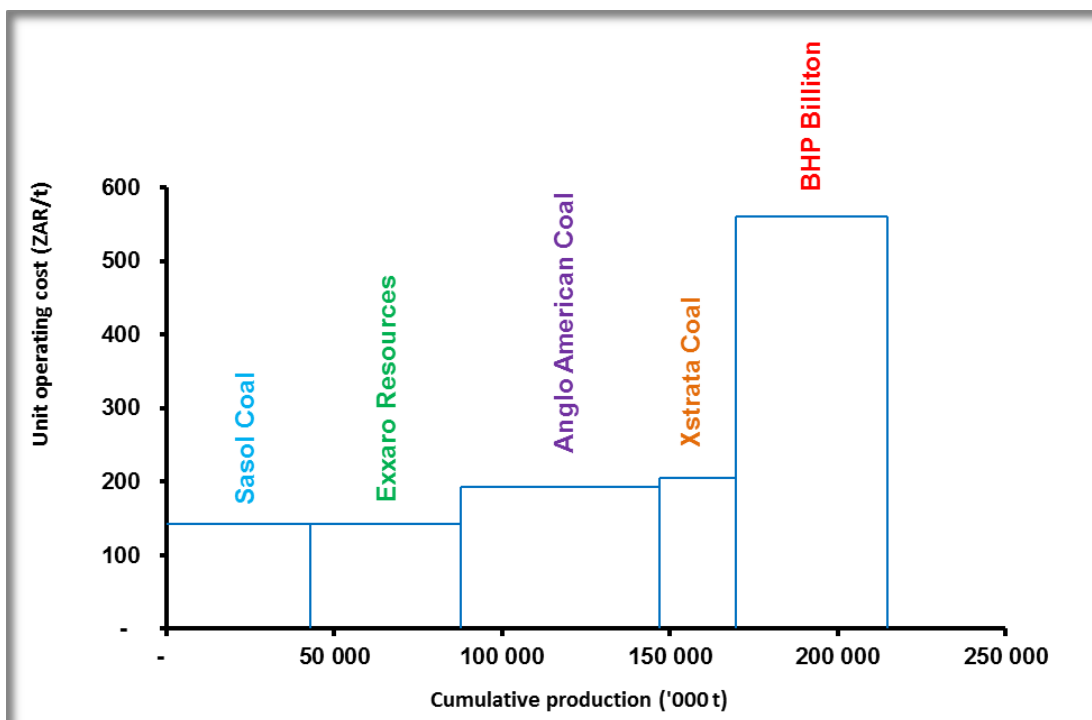


Figure 6.2 Coal companies cost curve for 2008

(Sources: Anglo American Limited, 2008; Exxaro Resources Limited, 2008; BHP Billiton, 2008; Sasol Limited, 2008; and Xstrata Plc., 2008)

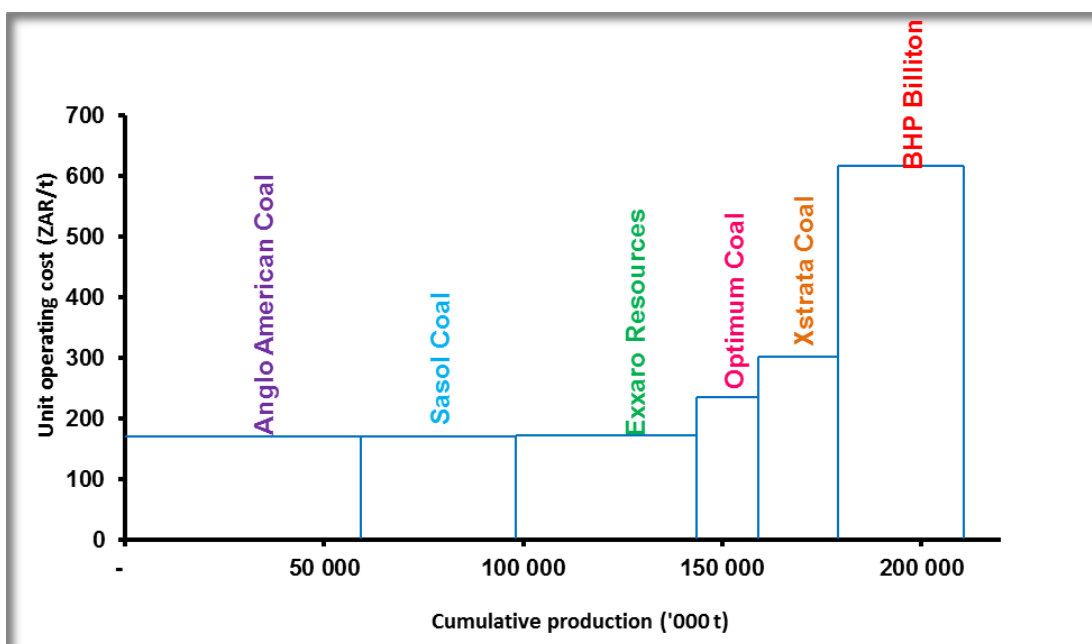


Figure 6.3 Coal companies cost curve for 2009

(Sources: Anglo American Limited, 2009; Exxaro Resources Limited, 2009; BHP Billiton, 2009; Sasol Limited, 2009; Xstrata Plc., 2009; and Optimum Coal Holdings Limited, 2010)

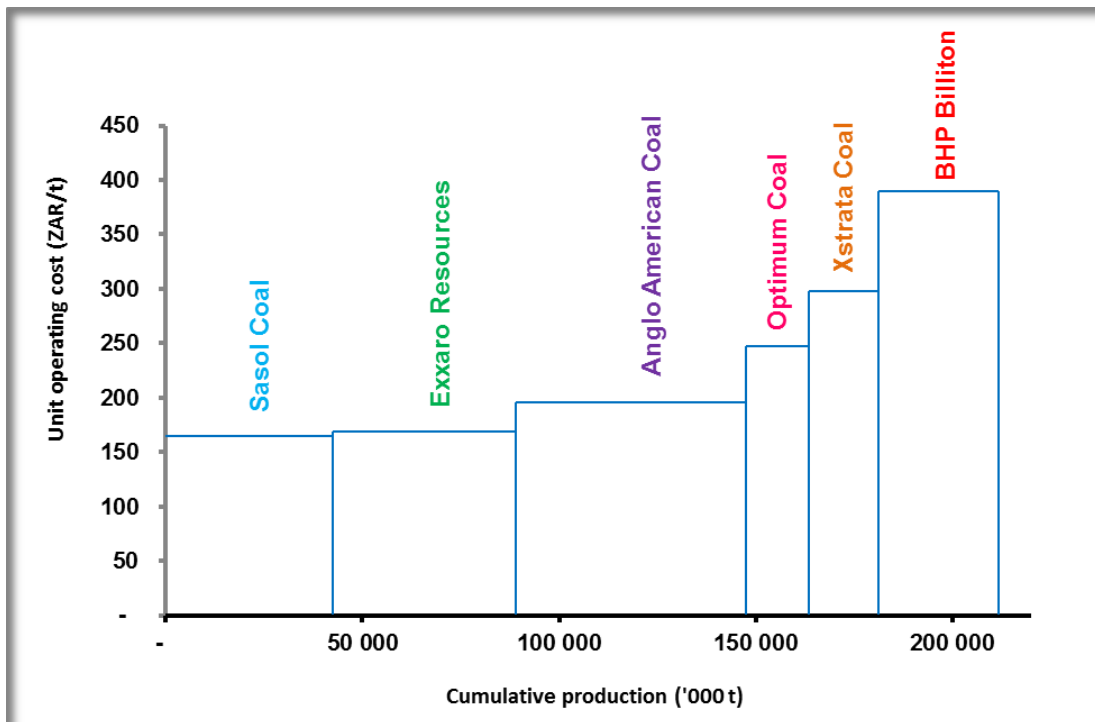


Figure 6.4 Coal companies cost curve for 2010

(Sources: Anglo American Limited, 2010; Exxaro Resources Limited, 2010; BHP Billiton, 2010; Sasol Limited, 2010; Xstrata Plc., 2010; and Optimum Coal Holdings Limited, 2010)

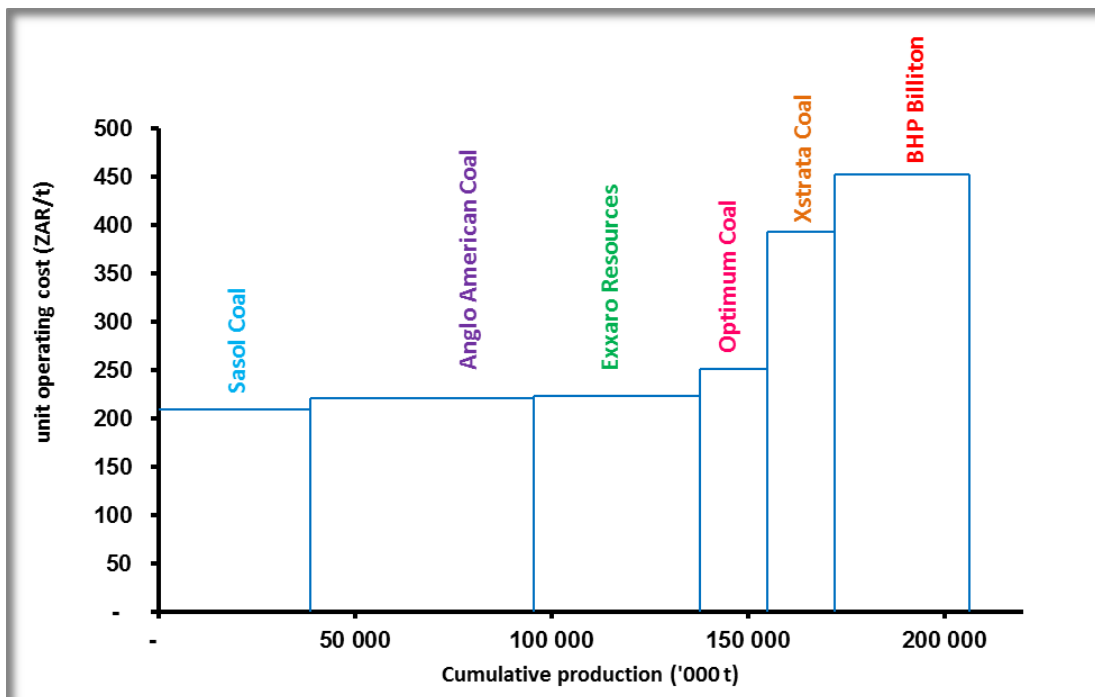


Figure 6.5 Coal companies cost curve for 2011

(Sources: Anglo American Limited, 2011; Exxaro Resources Limited, 2011; BHP Billiton, 2011; Sasol Limited, 2011; Xstrata Plc., 2011; and Optimum Coal Holdings Limited, 2011)

The following highlights can be seen from all the cost curves:

- all coal companies generally maintained their respective positions on the cost curve;
- the three (3) highest production companies are always in the first half of the cost curve whilst the three (3) lowest production companies are in the second half. This is explained by the principle of economies of scale previously discussed in section 2.7.1 which is also evident in gold and platinum cost curves in Chapters 4 and 5.

Less information reported for each coal operation made the detailed analysis of the cost curves limited.

6.4.1 Production

All the companies have a general equal mix of underground and open cast/pit operations. Figure 6.6 shows the production trend for each company from 2007 to 2011.

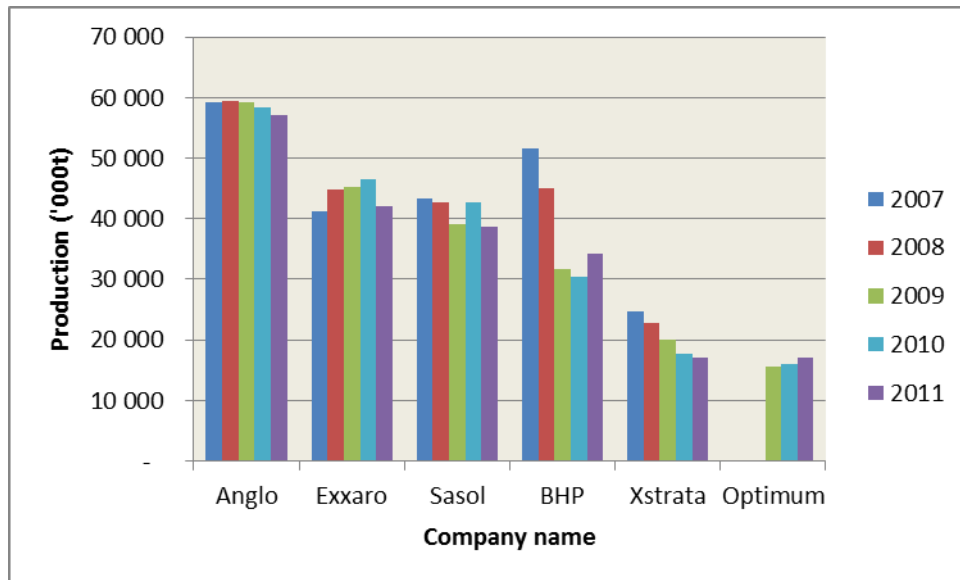


Figure 6.6 Production of each coal company

All companies except Xstrata have generally maintained their production with insignificant changes to production levels. Xstrata's production has been gradually declining for the period under review mainly because of:

- declining production from the Mpumalanga division (Spitzkop and Tselentis) which were finally sold in 2011; and
- the planned closure of the Southstock operation in 2009.

Once the company's new operations (Impunzi open cast and Goedgevonden) reach full production, Xstrata Coal's production is expected to increase and maintain its normal production capacity.

BHP's production declined significantly from 45 million tonnes in 2008 to 32 million tonnes in 2009 because it sold the Optimum Collieries and the Koonfontein mine to Optimum Coal Limited in 2008. Figure 6.7 shows the total production trend for all the companies in the analysis from 2007 to 2011.

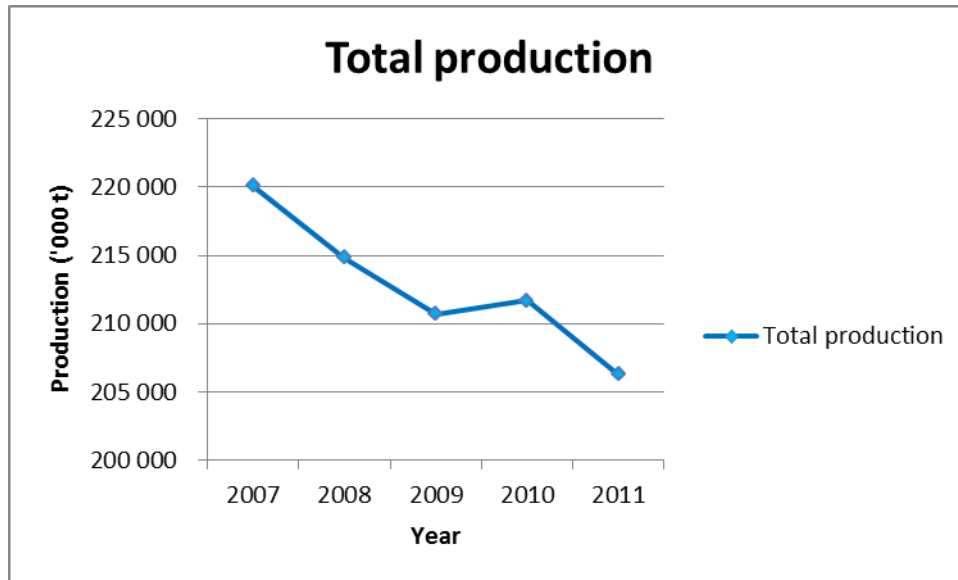


Figure 6.7 Total coal production from 2007 to 2011

It can be seen from Figure 6.7 that South Africa's coal output has generally been declining. This general declining trend can be attributed to:

- the 2008 global financial crisis which was experienced by the whole mining industry constraining the sector's capacity to produce. As the global economy slowly recovers, it is expected that the sector's production will also improve; and
- the depletion of coal resources in the prominent Mpumalanga province's coal fields; the significant current source of South Africa's mined coal. However, the Waterberg coal field in Limpopo is expected to be the country's future coal resource. As new projects begin producing from the Waterberg coalfield the country's coal production is expected to increase.

6.5 Conclusion

Despite the increasing attention to green and renewable energy, coal remains the most abundant and economic source of fuel for electricity generation for the country's increasing energy demand with reserves of over 100 years left. The South African coal sector is dominated by six major companies; Anglo Coal, Exxaro Coal, Sasol Coal, BHP Billiton Energy South Africa, Xstrata Coal and Optimum Coal. In addition to these big companies there are several other junior companies that are emerging from the Black Economic

Empowerment initiative of the Mineral and Petroleum Resources Development Act but were not considered as part of this analysis.

Like any other mineral sector, the South African coal mining sectors was not immune to global and local economic activities during the period under review which was evident in declining production. However, the impacts of the global and local economic activities were less in the coal mining sector than the gold and platinum sectors as previously shown in Chapter 4 and 5. The conservative nature of coal company's Annual Reports made the construction of cost curves at a mine level impossible and the detailed analysis of the coal mining sector difficult. This resulted in the author only managing to construct cost curves at a company level with some limited analysis, unlike the analysis that was done for gold and platinum at mine level.

7 Diamond mining industry cost curves

7.1 Introduction

According to the United States Geological Survey (2012) South Africa ranked fifth in terms of mined diamonds, producing 7.8% of the world's mined diamonds in 2010 and 2011 and holds 6.6% of the world's diamond reserves. The Chamber of Mines of South Africa (2010) showed that in 2010 South Africa accounted for 15% of the value of world diamonds production, ranking fourth after Botswana, Russia and Canada. In the national economy, in 2010 diamonds accounted for 2.2% of remuneration earnings and employment as shown in Figure 1.1 and Table 1.3 respectively. Diamonds are not fungible, hence in economic crises they are not a good store of value. Hence the diamond mining sector was hard hit by the 2008 global economic crisis. The importance of diamonds to the South African mining sector together with diamonds' uniqueness and high unit value makes it necessary to analyse this sector using cost curves.

7.2 Diamond mining companies listed on the Johannesburg Securities Exchange

According to the Johannesburg Securities Exchange (2012) the following are diamond mining companies that are listed on the JSE:

1. Rockwell Diamond Limited.;
2. Delrand Resources Limited;
3. Trans Hex Limited;
4. Thabex Limited;
5. Tawana Resources NL; and
6. De Beers Consolidated Mines (DBCM).

The following two companies are not listed on the JSE, but have operations or assets in the country:

1. Petra Diamond Limited (Petra Diamond); and
2. DiamondCorp Plc.

The following four companies were excluded from the analysis for reasons explained in section 3.2 and also because of the following reasons:

1. Delrand Resources Limited is listed on the JSE but has no operations in South Africa (Delrand Resources Limited, 2012);
2. Tawana Resources' key focus is on gold and iron ore in Liberia, West Africa with some non-producing alluvial diamond and primary kimberlite projects in South Africa (Tawana Resources NL, 2011);

3. Thabex Limited is currently involved in the processing of some kimberlite dumps at the Monastery Mine which was acquired in 2010 (Thabex Limited, 2011); and
4. DiamondCorp Plc. is an emerging diamond producing company listed on the London Stock Exchange (LSE). Its main asset in South Africa is the Lace diamond mine which was acquired in 2006 and is yet to start full production (DiamondCorp Plc., 2012).

7.3 Diamond mines cost curves and their analysis

Like coal companies, diamond companies are also conservative in reporting cost data for individual mines. This led to the construction of diamond mines cost curves impossible except for Petra Diamond Limited as indicated in the next sub-sections.

7.3.1 Petra Diamond Limited

Petra Diamond Limited is the only diamond company that reported both production and unit operating cost per individual mine. Figure 7.1 to Figure 7.3 show the Petra Diamond Ltd mines' cost curves from 2009 to 2011 which were developed using data in Appendix 10.16 to Appendix 10.18 respectively. Cost curves for 2007 and 2008 were not constructed because in 2008 the company had one mine in operation for the full year and in 2009 there were only two operating mines making the analysis and comparison irrelevant.

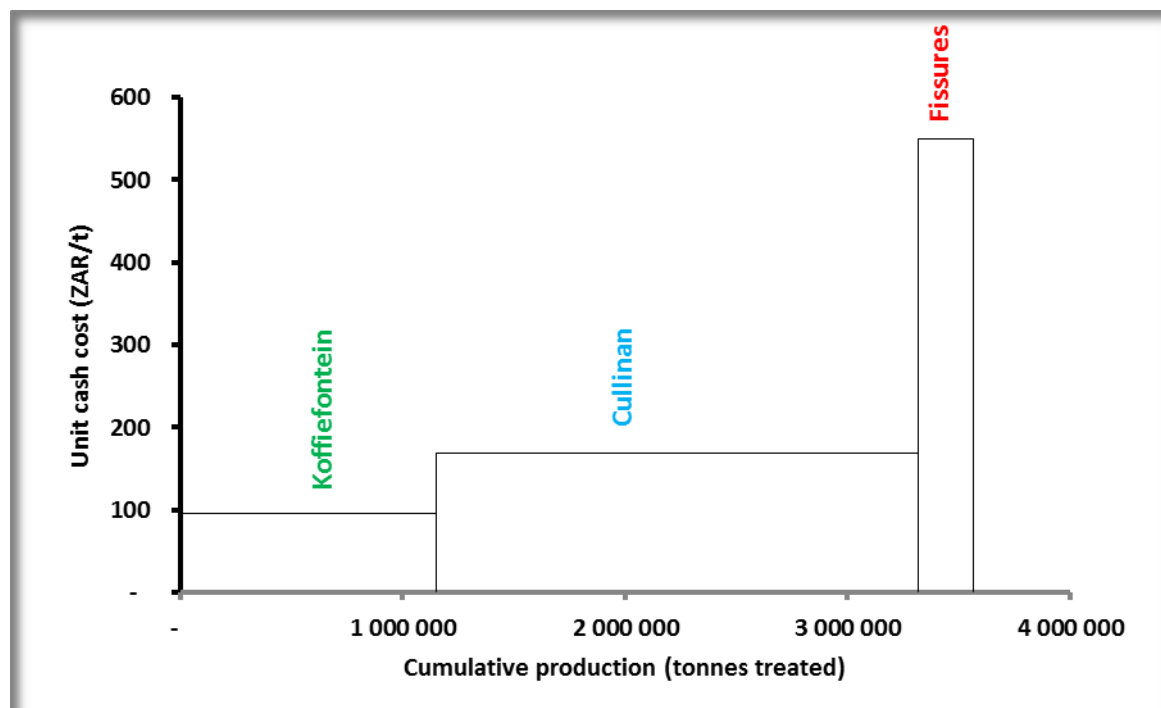


Figure 7.1 Petra Diamond mines cost curve for 2009

(Source: Petra Diamond Limited, 2009)

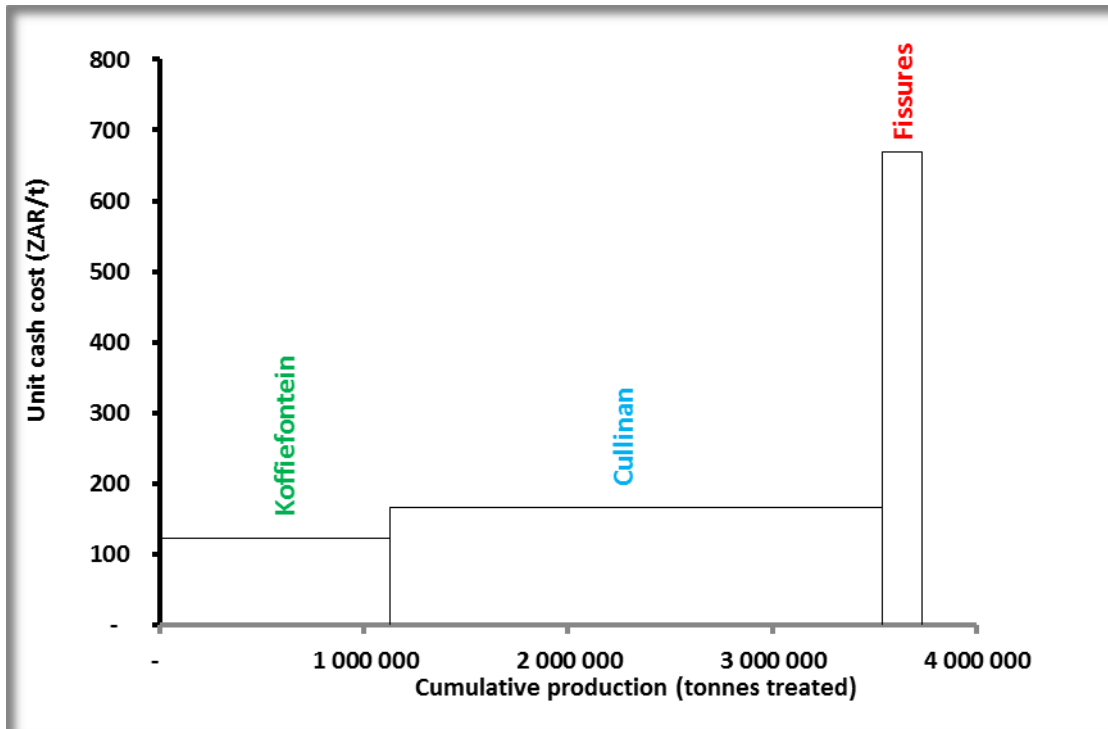


Figure 7.2 Petra Diamond mines cost curve for 2010

(Source: Petra Diamond Limited, 2010)

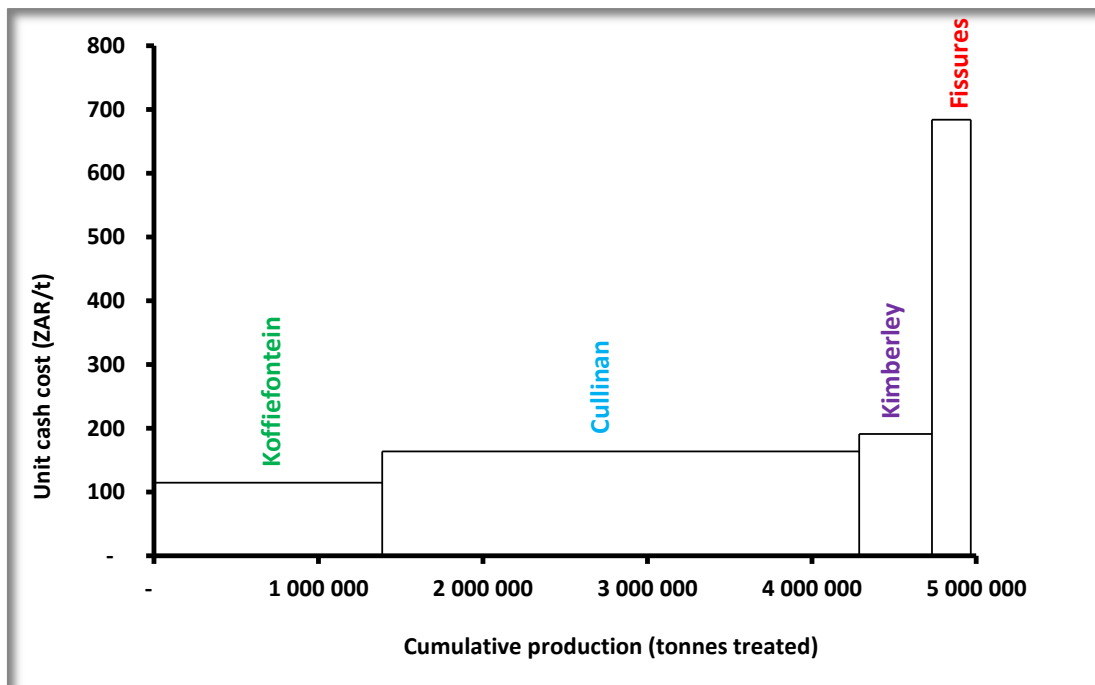


Figure 7.3 Petra Diamond mines cost curve for 2011

(Source: Petra Diamond Limited, 2011)

Low unit cost operation

As shown on all the cost curves, Koffiefontein is the lowest unit cost Petra Diamond's operation most probably because:

- it is the shallowest underground operation for the company with operations at an average depth of 490m below surface compared to Cullinan's 747m, Kimberely's average of 903m and Fissures' average of 706m below surface in 2011. This shows the effects of depth to operating cost as discussed before in section 2.6;and
- all Petra Diamond mines rely mainly on underground production except Koffiefontein that has significant production contribution from the shallow (35m) Ebenhaezer open pit which reports under Koffiefontein. This shows that underground operations tend to be high unit cost operations as explained before in section 2.6.

Highest unit cost operation

As shown on all Petra Diamond's cost curves, Fissures mine has been Petra Diamond's highest unit cost operation mainly because of its mining method. All other mines employ the mechanised trackless block caving mining method which offers opportunities and advantages of mechanisation as discussed before in section 2.6. Fissures mine is the only Petra Diamond mine that employs labour intensive mining methods; the shrinkage overhand stoping for its two mines (Helam and Sedibeng mines) and underhand open stoping for the third mine (Star mine). Fissures mine also has the lowest treated tonnes because of its mining method. Labour intensive mining methods are less productive and hence are high unit cost operations as they fail to benefit from economies of scale as discussed in section 2.7.1. Fissures' Helam, Star and Sedibeng shafts have been undergoing mechanisation programs that are expected to reduce Fissures mine's unit operating costs and improve its overall productivity and in future.

7.4 Diamond mining companies cost curves and their analysis

The input data (Appendix 10.19 to Appendix 10.23) to construct diamond companies cost curves was calculated as follows:

- Trans Hex and Rockwell Diamond reported carats produced per individual mine and the consolidated mine-site operating cost for the companies' South African divisions. The company's production is the sum of the individual mines' production whilst the unit cost is the quotient of the operating cost and carats produced;
- De Beers Consolidated Mines (DBCM) reported carats produced per individual mine and consolidated revenue and EBITDA for the company's South African division. The company's production is the sum of the individual mines' production whilst the

unit cost is the quotient of operating cost (revenue - EBITDA) and carats produced; and

- Petra Diamond reported both the individual mines' production and unit cash cost so the company's production is the sum of the mines' production whilst the unit cost is the weighted average of all the mines' unit costs.

Commonality in all the companies is the carats produced and operating cost per carat produced which was used to construct the companies cost curves in Figure 7.4 to Figure 7.8. Figure 7.4 to Figure 7.8 were developed using data in Appendix 10.19 to Appendix 10.23 respectively. The average diamond price per carat could not be shown on the cost curves due to price variations from company to company depending on the 4c's (colour, carat, clarity and cut) as quality measures for diamonds.

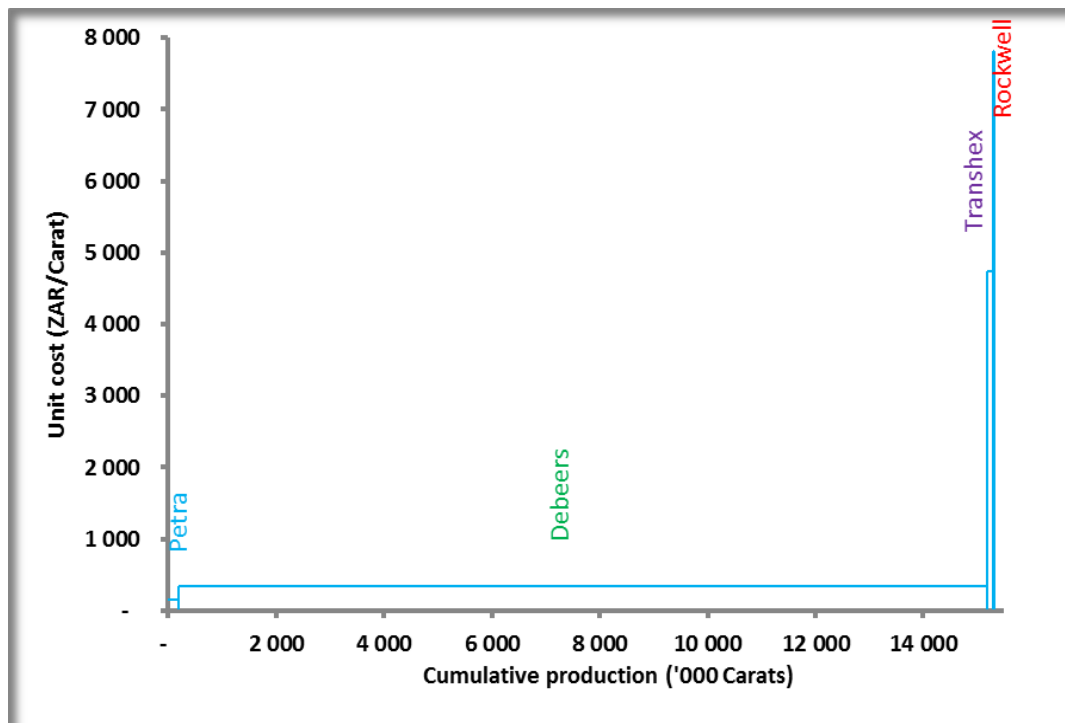


Figure 7.4 Diamond companies cost curve for 2007

(Sources: De Beers, 2007; Petra Diamond Limited, 2007; Rockwell Diamond Inc., 2007; and Trans Hex Limited, 2008)

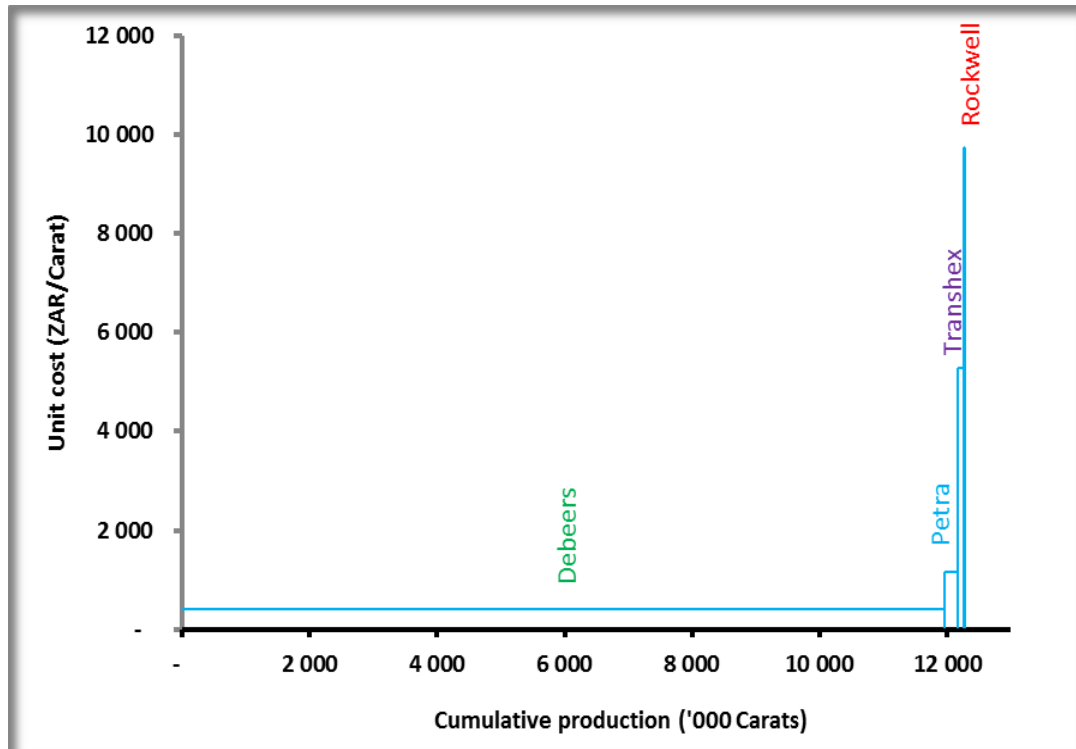


Figure 7.5 Diamond cost curve for 2008

(Sources: De Beers, 2008; Petra Diamond Limited, 2008; Rockwell Diamond Inc., 2008; and Trans Hex Limited, 2008)

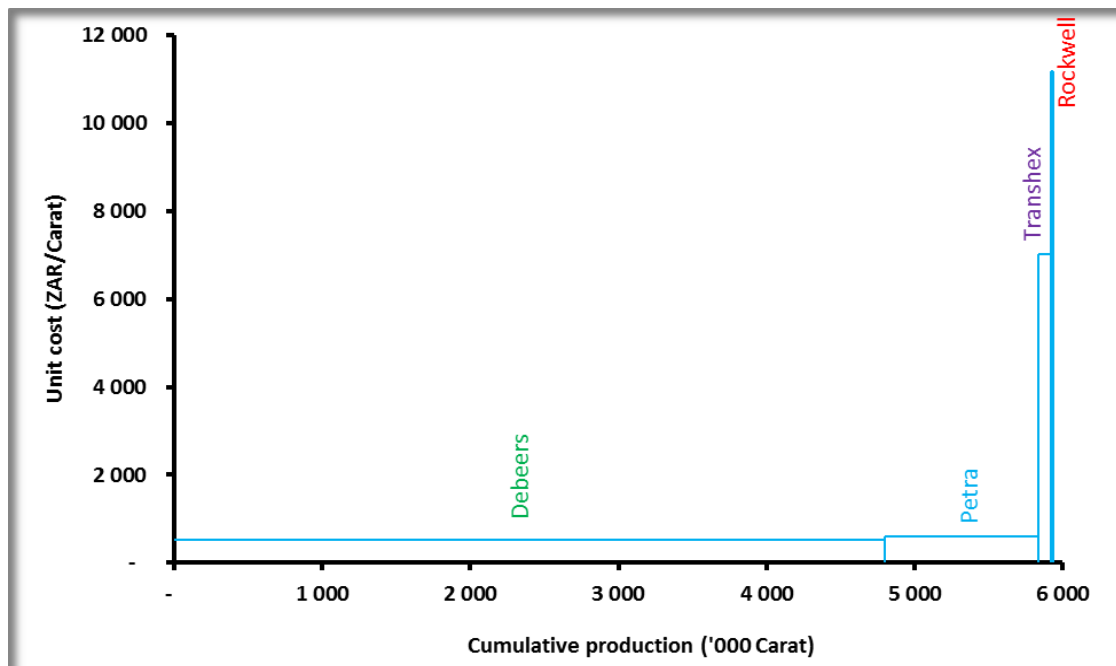


Figure 7.6 Diamond companies cost curve for 2009

(Sources: De Beers, 2009; Petra Diamond Limited, 2009; Rockwell Diamond Inc., 2009; and Trans Hex Limited, 2009)

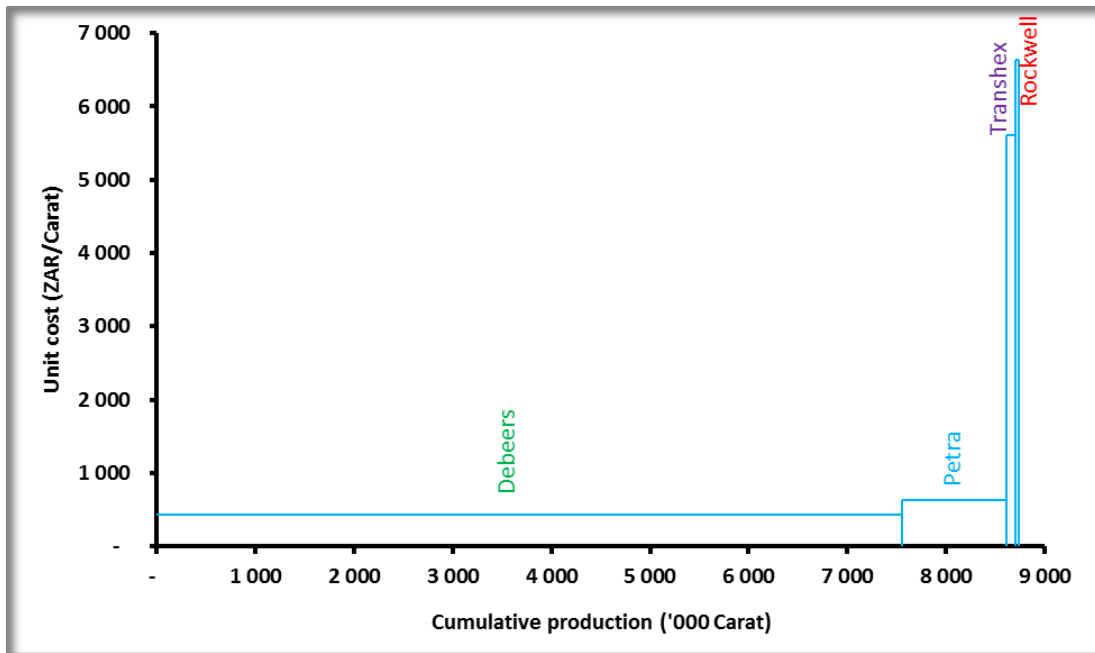


Figure 7.7 Diamond companies cost curve for 2010

(Sources: De Beers, 2010; Petra Diamond Limited, 2010; Rockwell Diamond Inc., 2010; and Trans Hex Limited 2010)

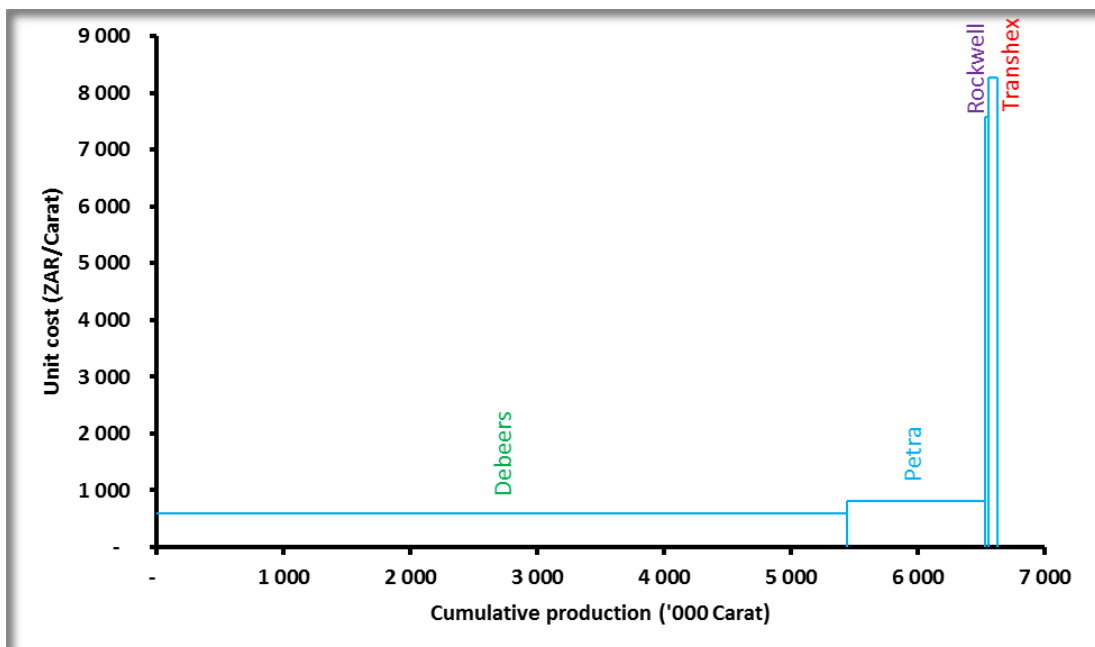


Figure 7.8 Diamond companies cost curve for 2011

(Sources: De Beers, 2011; Petra Diamond Limited, 2011; Rockwell Diamond Inc., 2011; and Trans Hex Limited, 2011)

It can be seen from all the diamond companies industry cost curves that there is a marked variation in unit costs, with Rockwell and Trans Hex placed high above Petra and De Beers. This is because unlike other precious metals, diamonds are not fungible which means that no two diamond carats are the same (because of the 4c's) hence companies received different prices per carat of diamond. Since unit operating costs for most companies (except Petra) were calculated by subtracting operating profit from revenue it means price influenced the calculated cost hence this marked variation in unit cost. This made the construction of diamond cost curves based on carats produced and unit cost per carat the nearest reliable basis for comparison. Fair cost curve analysis and comparison could have been possible if tonnes treated were considered which was not possible because most companies never reported on such or if the cash cost used was not calculated from revenue but reported in the Annual Reports. Table 7.1 shows the varying average diamond prices in USD per carat received by different companies over the same period as reported in the Annual Reports, except for DBCM which was calculated as a quotient of revenue and carats sold.

Table 7.1 Average received diamond prices from 2009 to 2011

Company	2009 US\$/carat	2010 US\$/carat	2011 US\$/carat
De Beers	70	80	106
Petra	88	159	184
Rockwell	2159	1010	1365
Transhex	805	957	1162

From Table 7.1 it can be seen that diamond prices vary very much from company to company depending on the diamond quality. De beers and Petra are comparable as well as Rockwell and Trans Hex. Figures 7.4 to 7.8 show the relationship of price and unit cost. This price variation shows that diamonds' value often lies in the eyes of the beholder hence there is no universal world price per unit weight of diamonds. Various operational and economic issues affected the cost performance and productivity of diamond operations in South Africa over the period under review. Table 7.2 shows production of diamond companies in thousand carats from 2007 to 2011.

Table 7.2 Diamond companies' production from 2007 to 2011 in thousand carats

Company	2007 ('000 carats)	2008 ('000 carats)	2009 ('000 carats)	2010 ('000 carats)	2011 ('000 carats)
Petra	180	200	1 035	1 062	1 088
Debeers	14 998	11 960	4 797	7 555	5 443
Transhex	125	107	89	93	70
Rockwell	7	18	18	25	26
TOTAL	15 310	12 285	5 939	8 735	6 601

It can be seen from Table 7.2 that the general trend in South African diamond production has been declining from 15.3 million carats in 2007 to 6.6 million carats in 2011. This production trend is explained in the next sub-sections.

7.4.1 *Petra Diamond Limited*

Petra Diamond's production has been gradually increasing from 180,000 carats in 2007 to 1.088 million carats in 2011. This is mainly because of its acquisition strategy which transformed and established the company from being a junior mining company to a significant global diamond producer. Koffiefontein was acquired in 2007, Cullinan in 2008, Kimberely in 2010 and Finsch in 2011. With its acquisition strategy, the company's production is expected to increase and continue to be the second diamond producer in the country after DBCM. The acquisition strategy has built the company's solid resource base ensuring improved long term productivity, earnings and cash flows for the company. However, efficiency in all Petra Diamond's operations is required for sustainable profitability as some of the acquired mines were marginal under care and maintenance before their acquisition, in particular, the Koffiefontein and Kimberely underground mines.

Before 2007, the company had been operating Fissures mine only. It acquired Koffiefontein mine which was on care and maintenance and Kimberely underground mine which had ceased operations in 2005 but managed to turn them into profitable operations. This is because it is a relatively smaller company with less overhead costs compared to DBCM. Small companies have several advantages as discussed before in section 4.4.

Petra Diamond's production increased markedly by 418% from 200,000 carats in 2008 to 1.035 million carats in 2009. Despite this increasing production, EBITDA decreased from USD25.5m profit in 2008 to USD8.6m (loss) in 2009 mainly because of weakening diamond prices due to the global financial crisis which negatively affected revenue. As the diamond price rose steadily from late 2010 to mid-2011, EBITDA also improved to USD70.9m in 2010 and USD67.1m in 2011.

7.4.2 *De Beers Consolidated Mines (DBCM)*

DBCM's production has been gradually declining from 14.998 million carats in 2007 to 5.443 million carats in 2011. This is mainly because:

- it has been divesting from old marginal operations; all operations acquired by Petra Diamond as discussed above were once owned by DBCM. Since 2007 the company has been selling its old operations in South Africa and in 2011 the sale of Namaqualand to Trans Hex was almost complete. Additionally, Oaks mine in

Limpopo ceased production in 2008 impacting DBCM's production profile. The overall effects to the De Beers group were offset by the opening of two new mines in Canada (Victor and Snap Lake) and one in South Africa (Voorspoed) in 2008 and through efficiencies and expansion projects at more established mines outside South Africa;

- in 2008 after the onset of the global financial crisis, the company planned to drastically reduce production starting in 2009. This was to reduce operating costs, conserve cash and align production with reduced demand as a result of the global financial crisis. As the price of rough diamonds slightly increased in 2010, production also increased in line with demand but declined in 2011 after the sale of Finsch mine to Petra Diamond; and
- in 2011 DBCM experienced a 14 days industrial strike which together with other operational challenges (including persistent heavy rainfall) impacted negatively on the company's productivity.

Due to the global financial crisis, De Beers group had an operating loss in 2009 but recovered in 2010 with an operating profit of USD487m.

7.4.3 Trans Hex Limited

Trans Hex's production has been declining from 125,000 carats in 2007 to 70,000 carats in 2011. Production increased slightly in 2010 because of improved grades at the Baken operation from 1.46 carats per 100m³ in 2009 to 1.90 carats per 100m³ in 2010. In 2011 production declined by 25% to 69,508 carats mainly because of low grades at the Baken mines. The company's operations in South Africa are all alluvial operations; Braken mine and Richtersveld operations are both located on the banks of Orange River whilst the Shallow waters operations are done in the sea. Due to the operations' locations production is often disrupted by heavy rainfall, flooding and rough sea conditions during summer periods. In response to the global financial crisis on the diamond market, a number of cost reduction and rationalisation measures were implemented by the company including:

- suspending all South African operations in December 2008 to January 2009;
- placing Shallow Water operations under care and maintenance in 2009 but re-commissioned them in 2010';
- selling the Middle Orange River operation in 2008; and
- Baken's satellite operation which was cash flow negative in 2009 was closed.

These measures contributed to the declining production from the South African operations. In 2011 the company acquired the Namaqualands operations from DBCM which is expected to provide a strong production profile for the company.

7.4.4 Rockwell Diamond Limited

Rockwell's production has been generally increasing from 7,000 carats in 2007 to 26,000 carats in 2011. The 2007 production is only for the four months that Rockwell has managed the three operations since their acquisition. It acquired Holpan, Klipdam and Wouterspan alluvial operations in 2006 from Durnpike Investments (Proprietary) Limited. In 2008 Rockwell acquired Trans Hex's Saxendrift which comprises of two open pit alluvial diamond mines which were on care and maintenance. Hence as these alluvial operations get into stable production, Rockwell's production is gradually increasing. However, the company experienced some operational challenges since 2007 that it has been reporting net losses from 2007 to 2010. Some of the challenges are:

- the global financial crisis that forced the company to extend its normal end of year shut down by two months from November 2008 to February 2009 for all its operations to conserve cash;
- in 2008, the Wouterspan operation was placed under care and maintenance due to an industrial action from 25 July to 3 September. This also caused production disruptions at all other operations which ultimately reduced the company year-end production;
- operations at Wouterspan were also suspended in February 2009 and continue suspended in 2012 but there is an expansion project of the processing plant to bring it back into operation soon; and
- in 2011 all the operations were affected by persistent heavy rainfall and flooding in summer that caused saturation of material thereby reducing plant throughput. The flooding damaged infrastructure and stopped production for five days at Holpan and Klipdam and three days at the Saxendrift mine. This put pressure on unit costs and rendered the Holpan operation unprofitable in the fourth quarter of 2010 and a decision was made to place it under care and maintenance since May 2011.

Rockwell Diamond had a challenging period for the period under review coupled with operations closure and production disruptions that put pressure on productivity and unit costs. The closure of Holpan and the suspension of production activities at Wouterspan undermined the company's efforts to be a significant diamond producer in South Africa. However, as the diamond market improves due to strong demand growth in China and India and Saxendrift's production stabilises, Wouterspan operation come back into production and as its projects come on stream, the company' production profile is expected to ramp up to ensure sustainable profitability of mining operations.

7.5 Conclusion

The conservative nature of diamond mining companies' reporting in terms of operating costs for individual mines made the construction of diamond mines industry cost curves impossible. As a result only diamond companies industry cost curves were constructed. However, the fact that most diamond companies never reported unit cost per individual mine and that diamonds' price varies according to the 4c's made the comparison of the diamond industry cost curves to be limited to company level unlike the analysis that was done for gold and platinum at mine level.

The South African diamond sector was severely affected by the global financial crisis. This is mainly because a significant diamond market is the United States of America where the global financial crisis started. This global financial crisis negatively impacted the performance of South African diamond producers as seen by a gradual decline in diamond production since 2007. As most economies recover from the global financial crisis the demand for diamonds is expected to recover. This will increase diamond prices and motivate increasing production from diamond operations improving the growth and profitability of South African diamond operations.

8 Conclusions and recommendations

8.1 Introduction

South Africa remains a major mining force hosting significant mineral resources including chrome ore, gold, PGMs, coal and diamonds. It is a significant gold and diamonds producer, the world's largest producer of PGMs, manganese, chrome and vanadium and the second largest exporter of coal. PGMs, gold and coal are the major economic contributors hence their selection in this analysis with the addition of diamond as a high unit value mineral commodity. The period of the analysis (2007 to 2011) clearly showed the effects of the global financial crisis to the South African mining industry. However, the industry is confronted by several challenges some old and some new that puts pressure on operating costs threatening its profitability and sustainability. The industry's significance to the global and national economy and its challenges motivated analysing its cost performance.

This analysis of the gold, platinum, coal and diamonds mining sectors was done using industry cost curves. To plot the cost curves a Microsoft Excel algorithm was used as explained fully in Chapter 3. The algorithm is based on the concept of error bars. On the cost curve, unit cost is plotted against cumulative production such that mines are placed on the curve according to their production cost; with the lowest cost production mine or company placed at the start of the horizontal axis whilst the highest cost production one is placed at the extreme right of the horizontal axis. From the cost curve, low and high unit cost operations are clearly distinguished and compared and cost management decisions made to move down operations on the industry cost curve. The profitability of operations can also be clearly seen from the cost curves by comparing the price and position of the operation on the curve. For accurate comparison, it is important to identify and treat various production and cost items of each company consistently. The cost curves have proved to be a useful tool in analysing the cost performance of mining operations. This was evident in some correlation between the competitive positions of different mines or companies on the cost curve and the performance of the particular mine or company during that period. New projects can easily be benchmarked against operating mines using the cost curves. The cost curves are useful to mining stakeholders including management, analysts and investors in the cost performance analysis of mining operations from which strategic decisions can be made. However, they are most useful where costs are reported on the same basis and to compare fungible mineral products where there is a uniform pricing benchmark for the commodity.

8.2 Findings

From the analysis, several findings were observed for the gold, platinum, coal and diamonds mining sectors. These affected the cost performance of these sectors and will be discussed in the following sub-sections.

8.2.1 *Gold mining sector*

South Africa has rich gold reserves, but they are fairly deep underground, making extraction complicated and expensive with much of the remaining reserves between 1,500 to 3,000m below the surface. Gold production peaked in 1971 when the country produced 79% of the world's production but the depletion of accessible resources and challenges facing the gold mining sector dropped the country's contribution to 8% in 2010. From the operations under review South African gold production declined by 30% from 7,340,000 ounces in 2007 to 5,147,00 ounces in 2011 despite the general increasing gold price over the same period. The operating challenges faced by South African gold producers are forcing some of the large producers, for example Gold Fields and Harmony, to focus and increase their production from outside the country. These challenges resulted in South Africa losing its position as a global leader in gold production around the 1970s to being fifth in 2010. This is also leading to the emergence of marginal miners taking over old and marginal operations disposed by big companies. The cost performance and competitive position of a gold mine on the cost curve is influenced by:

- head grade- Kopanong, Mponeng and Moab Khotsong mines have always been in the first quartile of the cost curve because of their high head grades of above 9g/t for the whole period under review;
- production- from all the cost curves, low production mines dominated the second half of the cost curve while large production mines dominated the first half. This is explained by the principle of economies of scale discussed before. Mines in the first quartile of the cost curve accounted for an average of 33% whilst those in the fourth quartile accounted for an average of 13% (Table 4.1); and
- Production profile- mines in their early production stages tended to be located in the lower quartile of the cost curve including Modder East and Moab Khotsong, some of the newest gold mines in the country. Most of AGA's operations are in the first half of the cost curve because they are in stable state of production except Great Noligwa which is towards the end of its production life. On the other hand Great Noligwa has been consistently moving up the cost curve, from the second quartile in 2008 to the fourth quartile in 2011 because it is a mature mine nearing its end of economic life;

- Type of operation- tailings treatment operations tend to be concentrated in the first half of the cost curve because of no mining costs associated with them hence they tend to be low unit cost operations;
- Seismicity related disruptions- gold mines in South Africa are deep and prone to seismic events that disrupt production. For example, Savuka was in the first quartile in 2008 but moved to the fourth quartile in 2009 and 2010 after a seismic event in 2008 and in 2011 Buffelsfontein was the highest unit cost operation because it was affected by a seismic accident in May 2010 that disrupted production activities;
- About 67% of the mines in the second half of the cost curve are Harmony Gold's operations. This is possibly because the company's portfolio consists marginal and aging deep-level mines acquired from other companies; and
- Cost management strategies- several cost cutting measures were implemented by companies to contain production costs and move mines down the industry cost curve. Among the strategies are:
 1. merging infrastructure to reduce overheads and maintain production, for example, merging of Kloof and Driefontein mines to form KDC by Gold Fields;
 2. a cost restructuring and people transformation programme at Harmony Gold's Masimong and Tsephong mines that resulted in these mine being the company's lowest unit cost mines in South Africa since 2009;
 3. revitalising mines by mining reefs below infrastructure to maintain production and extend the life of mine, for example, Harmony Gold's Kusasalethu, Doornkop and Phakisa mines' expansion projects; and,
 4. full mechanization of operations to improve safety and productivity. The mechanisation of flat-end development by Gold Fields is a case in point.

8.2.2 Platinum mining sector

The platinum mining sector has overtaken gold as a major contributor to the national economy. In 2010, it ranked first in total export earnings, remuneration earnings, employment figures and total sales revenue. The competitive position of a platinum operation is much determined by production, the depth of operation and mining method; either mechanised or conventional. Other factors that severely affected the cost performance of platinum mining operations and their subsequent positions on the cost curves are:

- the global financial crisis as seen by several mines that were placed under care and maintenance since end-2008. These include Anglo Platinum's Khuseleka, Simphumele 2 and 3 shafts in 2009 and Aquarius Mines' Blue Ridge mine in 2011. By the time of writing this report, several other operations have been placed under care and maintenance including Aquarius' Marikana and Everest mine in 2012 and cutting of capital project expenditure by Royal Bafokeng and Eastern Platinum;

- the DMR's Section 54 safety stoppages which severely affected the platinum mining sector compared to other mining sectors; in 2010 and 2011 Anglo Platinum alone lost a total 425 days across the group as a result of these stoppages; from 2008 to 2010 Northam lost a total of 69 production days and in 2011 Everest mine lost a total 36 production shifts; and
- strike related stoppages which are severe in the platinum mining sector. Northam lost a total of 7 weeks in 2007 and 2011, Royal Bafokeng's Rasimore mine lost nine days in 2011, Impala mine lost two weeks in 2009, Aquarius Platinum lost 2 weeks in 2010, Modikwa mine lost 24 days in 2007 and Two Rivers mine lost 14 production days due to strike related stoppages. By the time of writing this report, the mining industry was experiencing severe wage related strikes that started at Lonmin's Marikana claiming the lives of 44 people. This strike spread to the rest of the South African mining industry as wildcat strikes into the last quarter of 2012.

8.2.3 Coal mining sector

Coal mining in South Africa remains a key sector of the economy as a source of fuel for electricity generation for the country's increasing energy demand. From the companies under review coal production has been slightly declining from 217 million tonnes in 2007 to 208 million tonnes in 2011. This is possibly because of the 2008 global financial crisis which resulted in some operations down-scaling production and the declining coal resources in the prominent Mpumalanga province's coal field. Coal companies are conservative in annual reporting of costs for individual mines. This limited the construction of coal cost curves at company level as it was not possible to do so at mine level.

8.2.4 Diamond mining sector

Like coal companies, diamond companies are also conservative in reporting cost data and there are variations in production reporting between companies. Only Petra Diamond reported tonnes treated and unit cash cost for individual mines. Other companies reported their carats produced for individual mines and consolidated revenue and EBITDA or operating profit from which unit operating cost was calculated as a quotient of operating cost (revenue-EBITDA or operating profit) and carats produced. This limited the construction of diamond cost curves at company level as it was not possible to do so at mine level. However, because diamond price per carat varies from company to company it means that either diamond mines or companies industry cost curves are not easily comparable when considering carats produced and the unit cost per carat produced unless the unit cost is reported in the Annual Report.

8.3 Research limitations

Inconsistencies in companies' annual reporting across different companies and inadequacy of data from some Annual Reports made the author to derive unit costs. Since corporate governance drives for materiality and integration of financial reporting, companies should improve on materiality of their financial reports. Operating cost is an important measure of performance, so companies must be mandated to fully and transparently report them so that stakeholders can make informed decisions.

8.4 Recommendations for future research work

After discussing the research work with some industry peers the following issues form areas of possible future research:

- due to the globalisation nature of the mining industry it may be necessary to construct industry cost curves for all commodities at a global level and compare how the South African mining industry is performing against other national mining sectors. This is important for international benchmarking of projects and operations;
- because cut-off grades vary from country and region to another it may also be necessary to analyse the relationship between unit cost and cut-off grade/pay limit of different operations globally and explain the variation;
- because of differences in grade and prill splits between the Merensky and UG2 platinum reefs, it may also be useful to compare the cost performance of platinum operations mining these reefs; and
- from the industry cost curves it may also be necessary to do an analysis of how revenue and value (US\$ per oz or t) varies from country or region to another.

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10 Appendices

10.1 Input data for 2007 gold mines/companies cost curve

Company name	Operation	Production ('000 oz)	Unit Cost (USD/t)
Anglo Gold Ashanti	Great Noligw a	483	403
	Kopanang	418	307
	Moab Khotsong	67	668
	Mponeng	587	264
	Savuka	73	403
	Tailings	125	305
	Tau Lekoa	165	474
	Tau Tona	409	317
DRD Gold	Blyvoor tailings	41	287
	Blyvoor underground	110	642
	Crow n	103	450
	ERPM tailings	22	606
	ERPM underground	58	654
Gold Fields	Beatrix	543	377
	Driefontein	1 017	348
	Kloof	923	366
	South Deep	163	595
Harmony Gold	Bambanani	197	586
	Cooke	224	499
	Doornkop	57	439
	Elandsrand	195	527
	Evander	235	481
	Joel	80	418
	Kalgold	56	485
	Masimong	148	552
	Tailings	21	293
	Target	142	370
	Tshepong	319	351
	Virginia	267	546
Pan African Resources	Baberton Mines	90	465

10.2 Input data for 2008 gold mines/companies cost curve

Company name	Operation	Production ('000 oz)	Unit Cost (USD/t)
Anglo Gold Ashanti	Great Noligw a	330	458
	Kopanang	362	348
	Moab Khotsong	192	379
	Mponeng	600	249
	Savuka	66	411
	Tailings	92	440
	Tau Lekoa	143	533
	Tau Tona	314	374
DRD Gold	Blyvoor tailings	37	387
	Blyvoor underground	104	772
	Crow n	87	553
	ERPM tailings	12	588
	ERPM underground	57	812
Gold Fields	Beatrix	438	515
	Driefontein	928	412
	Kloof	821	430
	South Deep	232	727
Harmony Gold	Bambanani	159	641
	Doornkop	44	703
	Elandsrand	159	652
	Evander	240	525
	Joel	61	639
	Kalgold	93	411
	Masimong	118	745
	Phakisa	4	558
	Tailings	32	381
	Target	85	605
	Tshepong	273	457
	Virginia	250	719
Pan African Resources	Baberton	82	476

10.3 Input data for 2009 gold mines/companies cost curve

Company name	Operation	Production ('000 oz)	Unit Cost (USD/t)
Anglo Gold Ashanti	Great Noligwa	158	794
	Kopanang	336	406
	Moab Khotsong	247	424
	Mponeng	520	329
	Savuka	30	1 115
	Tailings	164	341
	Tau Lekoa	124	718
	Tau Tona	218	559
DRD Gold	Blyvoor tailings	41	307
	Blyvoor underground	89	801
	Crown	80	572
	ERPM tailings	15	697
	ERPM underground	19	1 132
Gold Fields	Beatrix	391	552
	Driefontein	830	448
	Kloof	643	507
	South Deep	175	717
Harmony Gold	Bambanani	122	611
	Doornkop	42	804
	Elandsrand	174	660
	Evander	190	572
	Joel	66	636
	Kalgold	65	506
	Masimong	154	476
	Phakisa	22	555
	Tailings	22	534
	Target	87	645
	Tshepong	231	483
	Virginia	258	638
Pan African Resources	Baberton	95	469

10.4 Input data for 2010 gold mines/companies cost curve

Company name	Operation	Production ('000 oz)	Unit Cost (USD/t)
Anglo Gold Ashanti	Great Noligw a	132	884
	Kopanang	305	613
	Moab Khotsong	292	588
	Mponeng	532	453
	Savuka	22	1 100
	Tailings	179	485
	Tau Lekoa	63	921
	Tau Tona	259	700
DRD Gold	Blyvoor Tailings	29	405
	Blyvoor underground	77	1 209
	Crow n	99	742
	Ergo	35	878
Gold One	ModderEast	66	484
Gold Fields	Beatrix	392	740
	Driefontein	710	692
	Kloof	567	768
	South Deep	265	811
Harmony Gold	Bambanani	133	723
	Doornkop	63	822
	Evander	112	1 018
	Joel	64	792
	Kalgold	49	748
	Kusasaletu	175	857
	Masimong	156	602
	Phakisa	44	953
	Tailings	21	762
	Target	114	783
	Tshepong	217	677
	Virginia	170	1 036
Pan African Resources	Baberton	97	650

10.5 Input data for 2011 gold mines/companies cost curve

Company name	Operation	Production ('000 oz)	Unit Cost (USD/t)
Anglo Gold Ashanti	Great Noligwa	94	1 194
	Kopanang	307	681
	Moab Khotsong	266	689
	Mponeng	500	546
	Savuka	49	864
	Tailings	164	660
	Tau Tona	244	818
DRD Gold	Blyvoor tailings	27	522
	Blyvoor underground	91	1 388
	Crown	96	916
	Ergo	48	834
Gold One	Modderkast	123	686
Gold Fields	Beatrix	347	957
	KDC	1 100	946
	South Deep	273	1 073
Harmony Gold	Bambanani	98	1 247
	Doornkop	81	1 054
	Evander	74	1 186
	Joel	47	1 297
	Kalgold	40	1 135
	Kusasaletu	180	1 008
	Masimong	138	788
	Phakisa	57	1 200
	Tailings	19	1 141
	Target	128	1 011
	Tshepong	208	810
	Virginia	71	1 114
Pan African Resources	Baberton Mines	92	781
Village Main Reef	Buffelsfontein	69	1 602
	Tailings	18	910
	Tau Lekoa	98	1 053

10.6 Input data for 2007 platinum mines/companies cost curve

company	Operation	Production ('000t milled)	Unit Cost (R/t)
Anglo Platinum	Bafokeng Rasimore	1 284	492
	Bathopele	2 587	300
	Bokoni	1 333	644
	Dishaba	1 755	579
	Khomanani	1 195	700
	Khuseleka	3 225	518
	Mogalakw ena	4 187	282
	Mototolo	901	280
	Simpfumelele	2 385	659
	Thembelani	1 254	649
	Tumela	5 226	411
	Union	5 610	396
Aquarius Platinum	Everest	2 387	232
	Kroondal	6 319	213
	Marikana	2 026	341
African Rainbow Minerals	Modikw a	2 320	467
	Tw o Rivers	2 040	306
Eastern Platinum	Crocodile River	1 025	414
Impala Platinum	Impala	16 302	397
	Marula	1 450	395
Lonmin Platinum	Limpopo	781	562
	Marikana Lonmin	12 685	319
	Pandora	950	253
Northam Platinum	Zondereinde	2 269	601

10.7 Input data for 2008 platinum mines/companies cost curve

company	Operation	Production ('000t milled)	Unit Cost (R/t)
Anglo Platinum	Bathopele	2 776	413
	Bokoni	1 098	942
	Dishaba	1 716	729
	Khomanani	1 144	911
	Khuseleka	2 723	737
	Mogalakw ena	7 180	288
	Mototolo	911	368
	Simpfumelele	2 115	845
	Thembelani	1 245	787
	Tumela	4 053	599
	Union	5 570	462
Aquarius Platinum	Everest	2 114	308
	Kroondal	6 068	271
	Marikana	2 131	446
African Rainbow Minerals	Modikw a	2 460	538
	Tw o Rivers	2 370	340
Eastern Crocodile	Crocodile River	1 176	491
Impala Platinum	Impala	15 855	493
	Marula	1 455	476
Lonmin Platinum	Limpopo	534	708
	Marikana lonmin	11 369	502
	Pandora	888	319
Northam Platinum	Zondereinde	2 023	804
Royal Bafokeng	Rasimore	2 248	630

10.8 Input data for 2009 platinum mines/companies cost curve

company	Operation	Production ('000t milled)	Unit Cost (R/t)
Anglo Platinum	Bathopele	2 962	428
	Dishaba	1 866	752
	Khomanani	1 274	939
	Khuseleka	2 343	791
	Mogalakw ena	9 722	196
	Mototolo	1 120	384
	Simphumelele	1 509	879
	Thembelani	1 174	856
	Tumela	4 202	586
	Union	5 517	479
Aquarius Platinum	everest	839	511
	Kroondal	6 482	337
	Marikana	2 584	408
African Rainbow Minerals	Modikw a	2 460	708
	Tw o Rivers	2 620	399
Anooraq Resources	Bokoni	943	1 061
Eastern Crocodile	Crocodile River	1 226	458
Impala Platinum	Impala	15 702	494
	Marula	1 574	529
Lonmin Platinum	Limpopo	92	870
	Marikana lonmin	10 770	566
	Pandora	765	256
Northam Platinum	Zondereinde	2 105	905
Royal Bafokeng	Rasmore	2 154	704

10.9 Input data for 2010 platinum mines/companies cost curve

company	Operation	Production ('000t milled)	Unit Cost (R/t)
Anglo Platinum	Bathopele	3 107	436
	Dishaba	1 908	851
	Khomanani	1 317	963
	Khuseleka	1 967	812
	Mogalakw ena	10 380	231
	Mototolo	1 131	438
	Simphumelele	1 032	1 053
	Thembelani	1 447	797
	Tumela	4 488	582
	Union	5 543	516
Aquarius Platinum	everest	150	652
	Kroondal	6 180	496
	Marikana	2 230	524
African Rainbow Minerals	Modikw a	2 270	639
	Tw o Rivers	2 920	425
Anooraq Resources	Bokoni	1 044	989
Eastern Platinum	Crocodile River	1 266	635
Impala Platinum	Impala	13 531	644
	Marula	1 545	645
Lonmin Platinum	Marikana lonmin	10 784	639
	Pandora	391	597
Northam Platinum	Zondereinde	2 038	1 094
Royal Bafokeng	Rasmore	666 996	707

10.10 Input data for 2011 platinum mines/companies cost curve

company	Operation	Production ('000t milled)	Unit Cost (R/t)
Anglo Platinum	Bathopele	2 440	558
	Dishaba	1 865	966
	Khomanani	1 334	1 055
	Khuseleka	2 038	916
	Mogalakwena	10 835	254
	Mototolo	1 151	494
	Simpfumelele	1 422	827
	Thembelani	1 476	933
	Tumela	4 192	708
	Union North	2 338	483
	Union South	2 448	765
Aquarius Platinum	Everest	1 380	641
	Kroondal	6 240	505
	Marikana	1 950	542
African Rainbow Minerals	Modikwa	2 300	692
	Two Rivers	2 950	468
Anoorag Resources	Bokoni	1 047	1 194
Eastern Platinum	Crocodile River	903	917
Impala Platinum	Impala	14 054	723
	Marula	1 542	773
Lonmin Platinum	Marikana lonmin	11 644	700
	Pandora	394	614
Northam Platinum	Zondereinde	1 591	1 409
Royal Bafokeng	Rasimone	2 305	782

10.11 Input data for 2007 coal companies cost curve

Company	Production ('000t)	Unit cost (ZAR/t)
Exxaro Resources	41 319	102
Sasol Coal	43 300	112
Anglo American Coal	59 160	126
Xstrata Coal	24 700	195
BHP Billiton	51 642	329

10.12 Input data for 2008 coal companies cost curve

company	Production ('000t)	Unit cost (ZAR/t)
Sasol Coal	42 800	142
Exxaro Resources	44 834	142
Anglo American Coal	59 417	193
Xstrata Coal	22 700	205
BHP Billiton	45 072	560

10.13 Input data for 2009 coal companies cost curve

company	Production ('000t)	Unit cost (ZAR/t)
Anglo American Coal	59 158	170
Sasol Coal	39 100	171
Exxaro Resources	45 258	173
Optimum Coal	15 500	236
Xstrata Coal	20 000	302
BHP Billiton	31 701	617

10.14 Input data for 2010 coal companies cost curve

company	Production ('000t)	Unit cost (ZAR/t)
Sasol Coal	42 600	165
Exxaro Resources	46 457	168
Anglo American Coal	58 452	196
Optimum Coal	16 000	247
Xstrata Coal	17 700	298
BHP Billiton	30 459	390

10.15 Input data for 2011 coal companies cost curve

company	Production ('000t)	Unit cost (ZAR/t)
Sasol Coal	38 600	209
Anglo American Coal	57 008	221
Exxaro Resources	42 172	223
Optimum Coal	17 100	251
Xstrata Coal	17 100	393
BHP Billiton	34 328	452

10.16 Input data for 2009 Petra Diamond mines cost curve

Mine	Tonnes treated (tons)	unit cash cost (ZAR/t)
Koffiefontein	1 149 590	96
Cullinan	2 166 356	169
Fissures	249 116	550

10.17 Input data for 2010 Petra Diamond mines cost curve

Mine	Tonnes treated (tons)	unit cash cost (ZAR/t)
Koffiefontein	1 127 772	123
Cullinan	2 409 287	167
Fissures	199 480	669

10.18 Input data for 2011 Petra Diamond mines cost curve

Mine	Tonnes treated (tons)	unit cash cost (ZAR/t)
Koffiefontein	1 388 135	115
Cullinan	2 899 008	164
Kimberley	443 655	191
Fissures	235 895	684

10.19 Input data for 2007 diamond companies cost curve

company	carats ('000)	Unit cost (ZAR/carat)
Petra	180	142
Debeers	14 998	343
Transhex	125	4 745
Rockwell	7	7 813

10.20 Input data for 2008 diamond companies cost curve

comapany	Carats ('000)	unit cash cost (ZAR/carat)
Debeers	11 960	418
Transhex	107	5 272
Petra	200	1 157
Rockw ell	18	9 734

10.21 Input data for 2009 diamond companies cost curve

comapany	carats ('000)	Unit cost (ZAR/carat)
Debeers	4 797	516
Petra	1 035	593
Transhex	89	7 013
Rockw ell	18	11 191

10.22 Input data for 2010 diamond companies cost curve

comapany	carats ('000)	Unit cost (ZAR/carat)
Debeers	7 555	438
Petra	1 062	635
Transhex	93	5 603
Rockw ell	25	6 631

10.23 Input data for 2011 diamond companies cost curve

comapany	carats ('000)	Unit cost (ZAR/carat)
Debeers	5 443	585
Petra	1 088	810
Rockw ell	26	7 587
Transhex	70	8 267