The effect of input commodity price movements on the earnings of South African gold mining companies

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ABSTRACT

Commodity producers in general typically have a commodity driven cost base as well as commodity price driven revenue stream. The research report investigates the correlation between input commodity price and gold price for gold mining companies, and how commodity price behaviour could potentially have been harnessed in managing the earnings of South African gold mining companies.

The research is performed via a regression analysis to gain insight into how much of the underlying gold price is explained by movements in the input commodity costs. Furthermore a representative South African Gold mine is used to understand the earnings effect of simultaneous commodity input price and gold price hedging.

The quantitative analysis confirms a sympathetic movement in gold mining commodity input price and the gold price. Furthermore, the research report has found that for the representative South African gold mining company, simultaneous commodity input and gold price hedging would have increased earnings for the years 2005 to 2008. To this end it is recommended that the co-movement in commodity prices be instrumental in the price risk management of gold mining companies.

DECLARATION

I, _____, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

(Laurence Peter Adams)

Signed at ……

On the …….. day of …… 2009

ACKNOWLEDGEMENTS

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CHAPTER 1: INTRODUCTION

1.1 Purpose of the study

The purpose of the research is to explore key factors affecting the performance of South African gold mining companies and understand the effect of commodity input price and output price on the earnings of South African gold mining companies.

1.2 Context of the study

South Africa is associated for its wealth in minerals, with gold being the foundation and pride of its natural resource portfolio. Furthermore, South African gold mining companies have been world renowned for gold extraction technologies, and with the abundance of reserves, is seen as one of the leaders in the mining and extraction of the yellow metal.

Commodity producers in general typically have a commodity driven cost base as well as commodity driven revenue stream. An understanding of how gold mining companies mitigate commodity price risk is often questioned. One typically finds a hedged or unhedged gold company, but seldom is reference made to cost and revenue risk mitigation strategies.

1.3 Problem statement

1.3.1 *Main problem*

The purpose of the research is to evaluate the correlation between input commodity price and gold price for gold mining companies, and how commodity price behaviour could potentially have been harnessed in managing the earnings of South African gold mining companies.

1.3.2 *Sub-problems*

The first sub-problem is to evaluate the extent of the correlation between input commodity price and output gold price for a representative South African gold mining company.

The second sub-problem is to understand the effect that cost and revenue commodity price risk management would have had on the earnings of South African Gold companies.

1.4 Significance of the study

The study will be of value to the gold industry in South Africa as well as associated partners. These would include suppliers; who typically would benefit from improved financial performance of gold mining companies as well as shareholders understanding how the strength of the underlying commodity can be translated into shareholder wealth. It should furthermore provide direction for South African gold producers as to potential market risk management techniques that can add value to their operations.

Finally, the effort should direct South African gold mining companies to improve economic performance.

1.5 Delimitations of the study

1.5.1 *Delimitations*

The study will only be focused on South African based gold mining companies. It may make reference to global players, but propositions or hypotheses' are only tested on a representative South African gold mining company over a minimum of 4 consecutive years.

The assumptions used in developing simulation aids will be represented as closely as possible to published data of South African gold mining companies.

1.5.2 *Limitations*

The research will be predominantly quantitative in nature. To this end the use of questionnaires will not be required as data will be collected from published financial sources including Bloomberg, Reuters as well as South African gold mining companies. Historical data gathering will be limited to that of official sources.

1.6 Definition of terms

Hedging - Reducing exposure to risk of a monitory loss resulting from fluctuations in exchange rates, commodity prices, interest rates etc. (Crabbe 1999, p. 367)

Bullion - The generic word for gold and silver in bar or ingot form (Crabbe 1999, p. 360)

Market risk – arises from changes in the prices of financial assets and liabilities and is measured by the change in the value of open positions or earnings (Jorion 2003, p. 14)

Contango – The situation when the price of a commodity for forward or future delivery is greater than its cash or sport price (Wolff 1991, p. 203)

Backwardation - The situation when the price of a commodity for forward or future delivery is less than its cash or sport price (Wolff 1991, p. 201)

1.7 Assumptions

The following assumptions have been made regarding the research that will be performed:

a. Assumption of cash costs of gold mining companies to be correct and reflective of marginal cost required to produce gold. This may lead to the composition of a representative South African gold mining company to

test hypothesis and/or propositions.

b. Assumption that cost proxies closely mimic realised input costs.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

The literature review will use the sub-problems as a basis for understanding current thinking on the subject as well as illustrating trends in the industry which can be used to synthesise the hypothesis or propositions. It will further be used to get insight into research techniques that can be explored in attempting to answer the problem statement.

Literature will be mainly from commodity journals and financial journals. Since the research problem is biased towards an analytical argument these sources of current thinking should provide useful insight into the gold mining industry in South Africa.

In trying to investigate commodity price co-movements in the gold mining industry as well as testing how this potential market dynamic could be leveraged by South African gold companies the literature will attempt to investigate literature around commodity prices and their correlation, how companies have managed cost and revenue risk as well as exploring strategic risk management techniques. The relative argument can thus be formulated and tested based on information already published.

The following topics will be reviewed from the literature:

2.1.1 South African resource economy

2.1.2 Commodity price movements

2.1.3 Market risk management and hedging

2.1.4 Cost tracking revenue

2.2. South African gold industry and commodity price behaviour

South Africa boasts extensive mineral resources, diversified industries and efficient services including banks. This portion of the literature review, aims to identify how the gold mining sector has developed in South Africa. It furthermore, looks at commodity price movements and studies around the dynamics of commodity prices.

2.2.1 South African resource economy

Historically gold and mining has been the stronghold of the South African economy. It stabilised revenues and preserved income from fluctuations (Wilson 1999). Furthermore, it focused the world's investment markets on South Africa. Although gold provided the thrust to the South African economy, it was however at the painful expense of the majority of the working force on mines. (Wilson 1999). From as early as 1889 the gold entrepreneur secured labour at the lowest possible cost. This was until 1973 where for the first time the real wages of black gold miners began to rise significantly. Some believe that this was as a result of the gold price increase. However, this same time period also marked the beginning of a decrease in gold miner labour exploitation.

Cost pressure concerns was compounded in 1988 (Wilson 1999) with a drop in gold price in the same year that the colour bar was abolished. The combination of falling revenue and rising cost thus wreaked havoc in the South African gold mining industry.

Clatworthy (1994) summarises the factors that have the greatest impact on gold mining costs as follows:

- Skilled labour 16.7%, unskilled labour 27.7%, stores 33.4%, power 12.5%,

sundries 9.4%.

Labour thus makes up about 40-50% of total expenditure and stores and power make up about 46%. These factors thus account for 90% of expenditure if one excludes capital. (Clatworthy 1994)

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2.2.2 Commodity price movement and correlation

Mean reversion of commodity prices

Various asset pricing methods have been developed for uncertainty in commodity prices. Baker et al (1998) argue the theory of reversion for commodity prices versus the use of the random walk model in predicting future prices based on historical data. As a result of the Random walk model using historical data it fails to recognise external stimuli in a real time environment that can have an impact on prices and may not be suitable for predicting commodity prices. Schwartz (1997) similarly evaluates the stochastic behaviour of commodity prices and concludes that it is important to consider mean reversion of commodity prices when evaluating projects. The argument for reversion of commodity prices is based on the fundamental difference between stock prices and commodities (Baker et al 1998). This lies in the predictability of price changes. To this end if stock markets are efficient, then changes in stock prices above or below the natural rate of price appreciation are not predictable. As a result, the stock price is independent of past changes and there should not be a tendency for stock prices to return to any particular level, and thus follow a random walk (Baker et al 1998). However, for commodity prices, it is potentially fair to argue that a period of repeated price increases will be followed by price declines. The underlying economics of the marketplace constrains the rise or fall of commodity's price. If the price should rise significantly then new sources of supply arise and substitutes enter the market (Baker et al 1998). If the price falls significantly then capacity is reduced until profitability for remaining producers is established. To this end Hsing (2008) attempts to estimate the

critical value of the real oil price per barrel of the US economy. For output maximisation in the US economy, Hsing (2008) calculates a real oil price of $52.92 per barrel.

Irwin et al (1996) examine whether mean reversion is present in corn, soyabean, wheat, live hog and cattle futures prices. Irwin et al (1996) applies a regression test of mean revision to the changes in the futures prices. Monte Carlo simulations are used to generate the small sample distribution of regression parameters and test statistics, with statistics produced under a null hypothesis of no predictability in futures price changes. It is concluded that the Monte Carlo regression analysis provides no support for the existence of mean reversion in commodity future prices and hence their notion that mean reversion in commodity prices should be viewed quite cautiously. (Irwin et al1996)

Co-movement in commodity prices

Pindyck and Rotemberg (1990) led investigations around the phenomenon that the price of raw commodities have a tendency to move together. Pindyck and Rotemberg (1990) find that the co-movement of prices applies to a broad set of commodities that are in some cases unrelated. These would even be so for commodities for which the cross-price elasticity's of demand and supply are close to zero. Kat and Oomen (2006) focused on the dependence measures for individual commodities and conclude that commodities; in general; seem to be statistically independent from other financial markets, but that there is a strong dependence within a commodity group. Contrastingly, Ai, Chatratrath and Song (2006) present evidence against the Pindyck and Rotemberg's excess comovement hypothesis; that commodities move together beyond what can be explained by fundamentals. They show that much of the co-movements come from common tendencies in demand and supply factors. Ai, Chatratrath and Song (2006) fit a partial equilibrium model that controls commodity factor correlation which is stated to be ignored by Pindyck and Rotemberg.

Proposed explanations for co-movement in commodity pricing is to some extent

seen as the result of 'herd' behaviour in financial markets. (Pindyck and Rotemberg 1990). To this end it is proposed that traders are either generally bullish or bearish on all commodities for no reason. (Pindyck and Rotemberg 1990). This proposition was confirmed amongst brokers and traders and is further endorsed by published papers, articles and magazines that often refer to one commodity price movement attributed to some other commodity price movement. Pindyck and Rotemberg (1990) conclude that commodity prices exhibit excess co-movement and that current and expected future values of macroeconomic variables such as inflation, industrial production and interest rates have a common effect on current and expected future demands and supplies of commodities. In the gold mining industry it would be fair to say that mining companies do not have a influence on macroeconomic changes but if indeed these changes result in the co-movement in commodity prices and their resultant cost and revenue base, it should be used in developing a risk management policy. Pindyck and Rotemberg (1987) have tried to explain this correlation using a simple regression model.

Mansanet-Bataller, Pardo and Valor (2007) specifically investigate the relationship between carbon emission prices in the framework of the Kyoto Protocol in the European Union. Mansanet-Bataller, Pardo and Valor (2007) find, via a correlation analysis, that the most important variables in the determination of the CO2 price changes are Brent Crude and Natural Gas prices. Furthermore, Mansanet-Bataller, Pardo and Valor (2007) find evidence that extremely hot or cold days in Germany have a positive influence on CO2 price levels. However, coal price changes seem to have no statistically significant affect on CO2 price changes.

2.2.3 Hypothesis 1

It is hypothesised that there is a statistically significant relationship between gold mining commodity input price and the underlying gold price.

2.3. Hedging practice and earnings risk management

Risk management, in securing cash flow, has been practiced in the gold industry for many years (Tufano 1998). By fixing the price of an asset, the gold company is able to secure part or whole of its income. This part of the literature review aims to investigate the framework of price risk management with the view of potentially investigating alternative risk management strategies that can affect the performance of South African gold mining companies. Furthermore, it briefly introduces risk management theory and literature around simultaneous input and output price risk management.

2.3.1 Market risk management options and theory

As the world becomes increasingly globalised and competition is prevalent across countries, companies need to be increasingly aware of the financial markets (Jorion 2003). This in turn talks to market risks as well as increased complexity in predicting market movement as well as volatility.

Producer hedging guarantees that miners get a minimum price for their products and essentially involves the producer agreeing to sell some or all of its output at a set price over a period of time (Twite 2002). The goal of hedging as described by Shuldiner and Norkus (1996) is to merely offset pricy gyrations by buying prices of commodities in advance. This notion is however contested based on the volumes of commodity futures contracts that are traded for speculative purposes. To this end Shuldiner and Norkus (1996) find that more contracts for wheat futures trade hands than do physical contracts for the product itself. However, Shuldiner and Norkus (1996) understand that hedgers are less concerned about making a profit on trades than with achieving some sort of price stability and hence the ability to budget for commodity costs. To this end routine hedging can often reduce the variance of returns, at a relatively small costs (Tomek and Peterson 2005).

Petersen and Thiagarajan (1997) measure the risk exposure of a gold mining

company and examine the effect of hedging. It suggests various forms of risk management and that this is not limited to derivatives. These can take the form of operational accounting decisions, extraction techniques and subsequent costs. For example, Homestake Mining adjusts its operations such that both cash inflows (sales) and cash outflows (extraction costs) move with the price of gold. Other forms of hedging include physical storage, as it is another method of counteracting anticipated price rises (Shuldiner and Norkus 1996).

Petersen and Thiagarajan (1997) evaluate hedging based on the hedged and un-hedged cash flows of a firm. It is found that Homestakes Mining had a hedging approach of looking at both revenues and operating costs and using the apparent correlation between these as a means of managing risk (Petersen and Thiagarajan 1997).

The assumption and requirement for hedging on the futures market is possible only with existence that the futures market closely mimics the behaviour of the cash prices of the commodity market selected. Three key considerations raised by Schuldiner and Norkus (1996) in engaging in futures trading as a strategic hedging tool include;

- The companies objectives for hedging

- Understanding which commodities have the greatest impact on cost of goods sold or will be used in the greatest quantity

- The historical and projected price volatility of those commodities.

There are further proponents of risk management that argue that its practice may reduce the probability of bankruptcy and reduces cash flow volatility and corporate tax burden (Smith and Stulz 1985). Tufano (1998) reviews the determinants of the decision to, and extent of hedging in the gold industry. Tufano (1998) assumes that firms hedge their future gold production and finds

that the hedge ratios are higher among firms that keep less liquidity, and lower among firms that reward there executives with more stock options but with less shares of the company. Adam (2002) finds that gold mining firms on average hedge their future capital expenditures, and that the extent of hedging depends positively on measures of financial constraints.

Tufano (1998) studies the gold price exposure of a cross-section of gold mining firms, and finds that hedging has only a marginal effect on a firm's stock price sensitivity to gold prices. Furthermore, differences in operating cost structures can lead some firms to use financial hedges while it leads others to use operational hedges to mitigate gold price exposure (Petersen and Thiagarajan 2000). Brown et al (2002) demonstrate adjusting their hedge ratios due to their expectations about future gold prices.

Value-at-Risk

Multinationals typically have cash inflows and outflows denominated in many currencies and can suffer from adverse currency swings (Jorion 2003). This would naturally be the case for gold mining companies who have exposure to market risks such as currency and commodities. To this end cash flow risk analysis can be used to understand how likely a firm will be to face a critical shortfall of funds.

Mauro (1999) used Value-at- Risk (VaR) to measure price risk exposure in the energy sector, more specifically the refining industry. It looks at specifically brent crude oil and its VaR and gets the reader to understand that the need for a risk management systems stems from the existence of a certain degree of volatility. Similarly, Aloui (2008) uses a Value-at-Risk quantitative tool to manage the price risk for energy commodities. He describes VaR as a quantitative measure, which measures the maximum potential loss in the portfolio of financial or commodity assets over time. This helps financial managers to assess their risks and aids the setting of budgets and margin

requirements.

2.3.2 Cost and revenue risk management

Literature typically focuses on output price hedging and risk management. This is particularly in the case of Gold companies who either actively hedge output or not. Literature dealing with cost uncertainty is not as prevalent. Alghalith (2008) developed a model to understand the merits of simultaneous output and input hedging. The decision is based on the uncertainty of input and output pricing using a profit function and subsequently maximising the expected utility of the profit. Alghalith (2008) concludes that when a firm faces two sources of uncertainty, two hedging tools are needed to stabilize output; which can be applied to a number of input and output uncertainties.

Majucha and Chung (2008) investigate the potential for integrating the revenue cycle and supply chain functions. Majucha and Chung (2008) argue that in the medical industry, purchasing is overseen by the supply chain while finance oversees the revenue cycle. This prevents a critical connection in terms of purchasing cost and associated revenue stream, which ultimately leads to a lack of understanding of the profit and loss. Majucha and Chung (2008) suggests the use of a supply chain profit and loss management model as a strategy to coordinate medical procedures with supplies; subsequently enhancing operating revenues. This can be achieved by conducting a cost per case analysis. Similarly in the mining industry different cost are associated with different mining methods or resources. To this end the focus moves away from just revenue but has an extensive investigation of the supply chain in ensuring operating profits is at the forefront of the business. Risks facing airline industries include interest rate risk, foreign exchange risk as well as fuel price risk. Loudon (2004) investigates the exposures to these risks for the airline industry of Australia and New Zealand. Loudon's (2004) findings reveal that short term returns for Quantas and Air New Zealand a negatively exposed to fuel-price, but not significantly exposed to interest rate and currency. Loudon (2004) suggests that equity is hard to attract because of high earnings volatility as a result of

these risks. Furthermore, the incidence of significant exposures to these risks become more prevalent as the horizon length is extended. Price uncertainty in the energy industry is also investigated by Roques (2006), where high fuel prices have rekindled interest in nuclear power. It is however found that, as a result of the strong correlation between gas and electricity prices, and hence that the correlation between the main cost (gas and carbon) and revenue (electricity price), it reduces the intrinsic riskiness of fossil fuel power stations (Roques, 2006).

2.3.3 Hypothesis 2

From the literature review it is hypothesised that if gold mining companies applied simultaneous input commodity price and gold price hedging, that their earnings would have increased.

2.4. Conclusion of literature review

In summary, literature suggests that for the foreseeable future, South Africa will remain a strongly resource based economy with commodity input and revenue price pressures. It further investigates stochastic behaviour in commodity prices as well the apparent positive correlation in commodity prices based on supply and demand fundamentals as well as herding behaviour in commodity markets.

Furthermore, literature suggests that hedging does play an important role in managing risk. It is however evident that in times of gold price rises companies wants to increase revenue. It seems sensible that to be properly hedged, one needs to secure input and output price and hence manage the risk in your margin.

2.4.1 Hypothesis 1:

There is a significant correlation between gold mining commodity input price and the underlying gold price.

H0: slope = 0 vs. *H1*: slope > 0

OR

H0: The linear relationship between gold mining commodity input price and the gold price is not significant

H1: The linear relationship between gold mining commodity input price and the gold price is significant

2.4.2 Hypothesis 2:

If gold mining companies applied simultaneous input commodity price and gold price hedging, their earnings would have increased.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Research methodology /paradigm

In this proposed research, the methodology takes a one phased quantitative approach.

Since quantitative research focuses on the characteristics of observations and seeks to correlate factors with one another (Leedy and Ormrod 2001), it is possible to carry out a quantitative research approach based on the historical gold price and cash cost information (commodity input price) that is published by South African gold companies as well as official financial data sources such as Bloomberg and Reuters. To this end the appropriate statistical analysis is performed to understand historical commodity input price and gold price correlation as well as understanding the effect that output and input price risk management would have had on the earnings of the representative South African gold mining company.

From the literature review, statistically testing the aforementioned hypothesis' will be a reasonable way of answering the research questions around gold price and gold input cost correlation; as well as the impact of cost and revenue hedging on South African gold companies.

The gold price - input cost price correlation is best described via simple regression analysis, as one gains insight into how much of the underlying gold price is explained by movements in the input commodity price. The significance of the correlation will give rise to questions around other factors which affect the performance of gold mining companies and potential management techniques in mitigating such risks.

The hypothesis of retrospectively testing the effect of input and output hedging makes use of a representative South African Gold mining company as constructed by the author of this research paper. It uses cost information of a South African gold company, in constructing the representative South African

gold mining company cost and revenue model.

An incremental sensitivity analysis of fixing various cost price proxies and gold price variables is used to determine how historical prices have impacted the outcomes of the representative South African gold companies, and hence the effect of simultaneous input and revenue price risk management. The steps followed in this research paper were as follows:

Step1:

Collating the cost structures of a South African gold company which fairly reflect the cash costs and hence market risk of a typical South African gold mine.

Step 2:

Gathering historical pricing data of the commodities or cost proxies for this representative South African gold mine

Step 3:

Using selected inputs of the representative South African gold company to describe selected market input commodity prices against the revenue commodity (i.e. gold) and hence testing the strength of the “natural” hedge – proposed to exist. This is tested via a regression analysis.

Step 4:

Matching the commodity input price with gold price to understand the aforementioned proposed co-movement

Step 5:

From the historical commodity input price and gold price data, a model of cost and revenue as well as the resulting net income is generated. The second research question is answered by incrementally fixing cost and revenue streams and seeing whether it would have resulted in out-performance for South African gold mining companies.

The flow diagram below depicts the process followed in this quantitative research methodology.

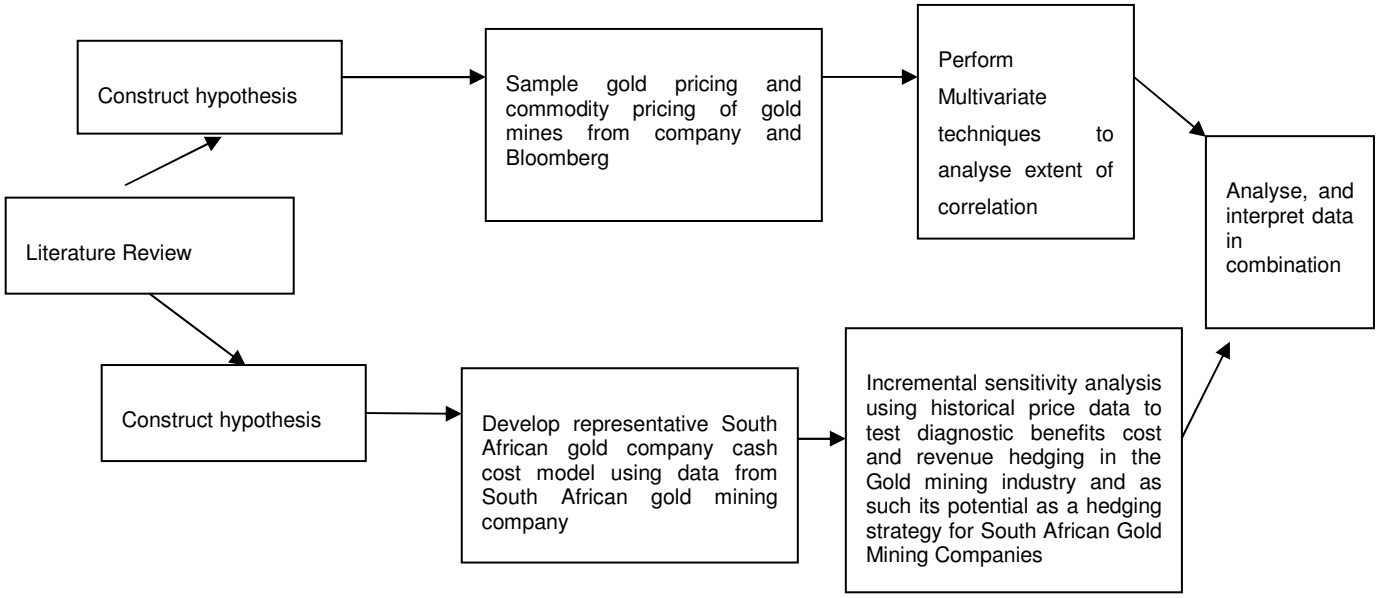

Figure 1: Research process followed

The representative South African gold mining company assumes that historical data can be used to represent a South African gold mining company. The limitation of this is that the retrospective quantitative approach may not be reflective of the future and thus not possible to use as a risk management tool.

3.2 Research design

The method adopted is analytical in nature, drawing on historical data to perform regression analysis and incremental sensitivity analysis.

The historical market data is used to perform the regression as well as aiding the earnings analysis of the representative gold company to understand the impact of simultaneous commodity input price and gold price hedging on the earnings of this representative South African gold mining company.

3.3 Population and sample

3.3.1 Population

The population is limited to South African gold mining companies.

3.3.2 Sample and sampling method

The sample is limited to pricing data obtained from a South African gold mining company as well as Bloomberg for the last 4 to 5 years.

Furthermore, the market data from approved sources such as Bloomberg and Reuters is used to perform a regression analysis to test the first research question.

3.4 The research instrument

The research instruments used is quantitative in nature. For the first research question, a simple *linear regression* using NCSS is used to test whether there is a significant correlation between input commodity price and the gold price for gold mining companies.

For the second research question *historically back tests* the performance of the representative gold mining company to see whether simultaneously fixing of input commodity price as well as gold revenue price would have resulted in greater earnings for the representative South African gold mining company.

Hedging proxies

Below is an example of the correlation analysis that should be performed on an ongoing basis, to determine the suitability of a hedging proxy. (i.e. whether indeed the commodity input prices, like the gold produced, can be hedged)

We consider the price for Gasoil (diesel) in South Africa, whose free on board price comprises of 50% of Arab Gulf Gasoil and 50% Med Gasoil (Mediterranean). A likely candidate for a hedging proxy would be ICE Gasoil

which is an exchange traded commodity. As can be seen by the diagram below, these price series exhibit similar movements.

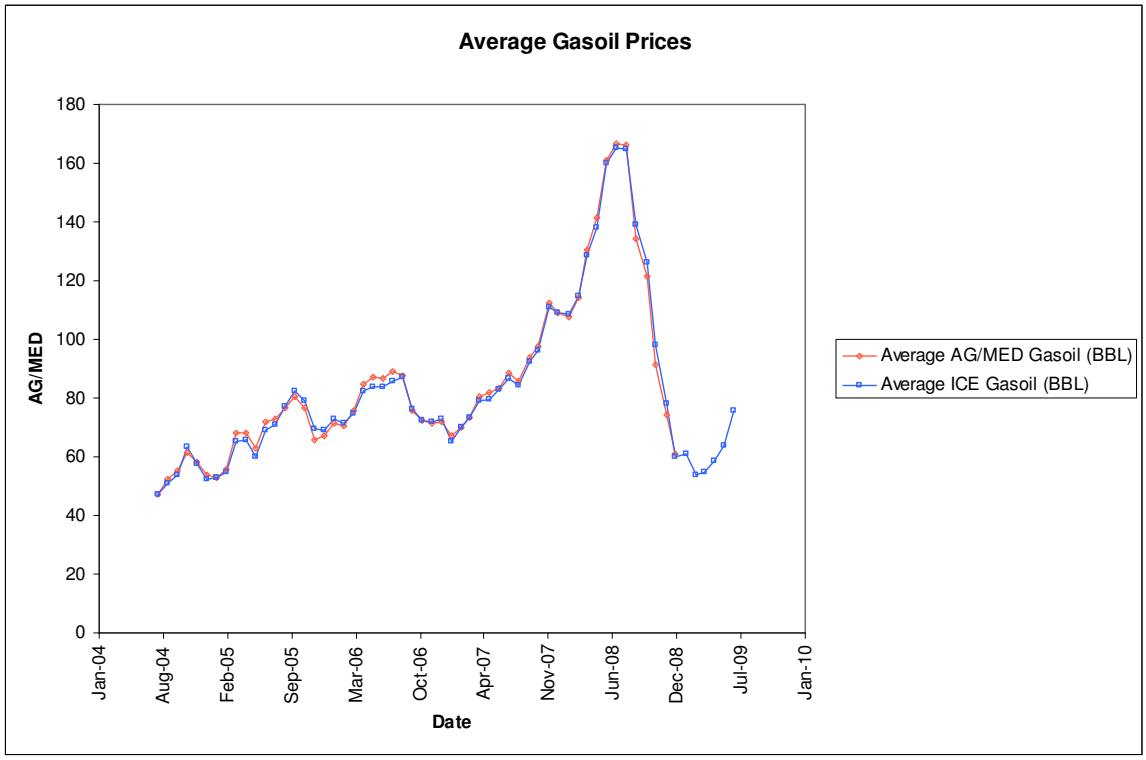

Figure 2: Commodity Hedging Proxy Illustration

To this end the proxy almost exactly mimics the price behaviour of the physical product.

3.5 Procedure for data collection

The financial statements and supporting data as seen in the annual reports of a South African gold mining company, actual price data from a South African Gold mining company as well as Bloomberg and Reuters is used as the source of data. The data dates back at least 4 years.

3.6 Data analysis and interpretation

By building a representative South African gold mining company using data from a South African gold mining company as well as Bloomberg and Reuters commodity prices, the representative South African gold company was used when testing the hypothesis for cost and revenue hedging. Furthermore, market historical price behaviour as referenced from Bloomberg and Reuters was used in performing a linear regression to test for input and output commodity price correlation.

3.7 Limitations of the study

Applicability of this research going forward as financial and commodity markets remain dynamic in nature.

3.8 Validity and reliability

3.8.1 External validity

External validity relates to the "generalisability" of learnings to groups other than the population researched (Neuedorf 2002). Even though the study is quantitative in nature, which potentially reduces the generalisablity of the outputs, it is important to note that past behaviour may not always be an indication of future market behaviour.

3.8.2 Internal validity

Internal validity ensures the data collection process is uniform throughout. This study ensures internal validity by using official historical market data. Internal validity is thus not compromised as data used is weekly market price data for the various commodities for the period in question.

3.8.3 Reliability

Reliability is the extent to which results are consistent and yield the same results on repeated trials (Neuendorf 2002). Reliability and hence the trustworthiness is assured with use of simple regression analysis and back testing which are recognised quantitative research techniques.

CHAPTER 4: PRESENTATION OF RESULTS

4.1 Introduction

The results for the research questions will be presented in a quantitative format. The linear regression analysis outputs will be presented to test the hypothesis for commodity price correlation. The second research question fixes the gold and input commodity prices simultaneously to understand the effect on the dollar income for the representative South African gold mining company from 2005 to 2008.

4.2 Results pertaining to Hypothesis 1

Y = Copper X = Gold

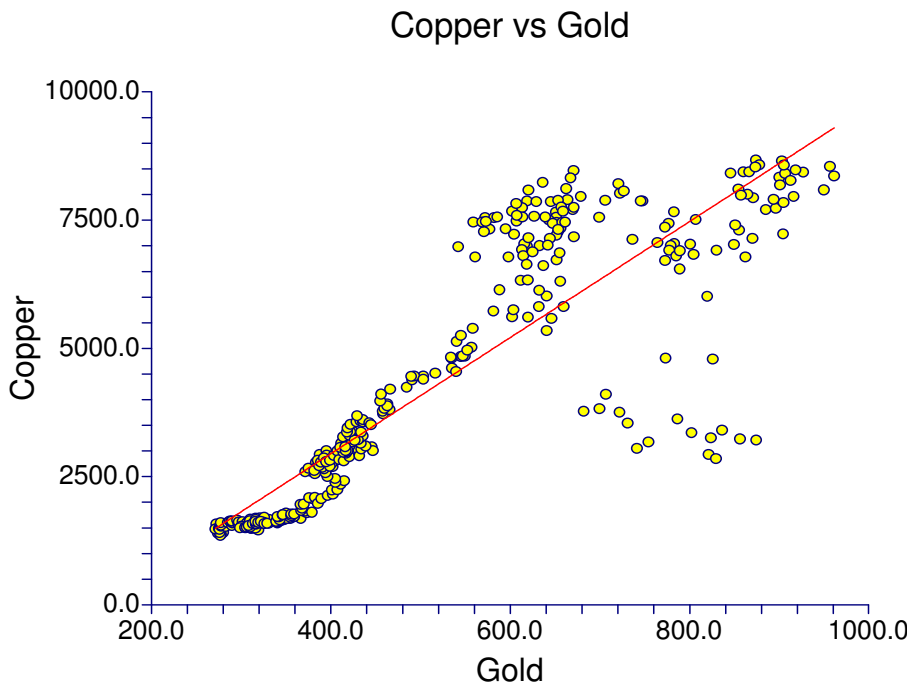

Figure 3: Linear Regression Plot for Copper vs. Gold

Run Summary Section

Parameter	Value	Parameter	Value
Dependent Variable	Copper	Rows Processed	1654
Independent Variable	Gold	Rows Used in Estimation	382
Frequency Variable	None	Rows with X Missing	1272
Weight Variable	None	Rows with Freq Missing	0
Intercept	-1579.6468	Rows Prediction Only	0
Slope	11.3098	Sum of Frequencies	382
R-Squared	0.7574	Sum of Weights	382.0000
Correlation	0.8703	Coefficient of Variation	0.2875
Mean Square Error	1478437	Square Root of MSE	1215.91

Summary Statement

The equation of the straight line relating Copper and Gold is estimated as: Copper = (-1579.6468) + (11.3098) Gold using the 382 observations in this dataset. The y-intercept, the estimated value of Copper when Gold is zero, is -1579.6468 with a standard error of 179.7588. The slope, the estimated change in Copper per unit change in Gold, is 11.3098 with a standard error of 0.3283. The value of R-Squared, the proportion of the variation in Copper that can be accounted for by variation in Gold, is 0.7574. The correlation between Copper and Gold is 0.8703.

A significance test that the slope is zero resulted in a t-value of 34.4450. The significance level of this t-test is 0.0000. Since 0.0000 < 0.0500, the hypothesis that the slope is zero is rejected.

The estimated slope is 11.3098. The lower limit of the 95% confidence interval for the slope is 10.6662 and the upper limit is 11.9533. The estimated intercept is -1579.6468. The lower limit of the 95% confidence interval for the intercept is -1931.9676 and the upper limit is -1227.3261.

Descriptive Statistics Section

Parameter	Dependent	Independent
Variable	Copper	Gold
Count	382	382
Mean	4229.5196	513.6415
Standard Deviation	2465.4628	189.7193
Minimum	1353.0000	271.4500
Maximum	8670.0000	961.7500

Estimated Model

(-1579.64682353604) + (11.3097686730221) * (Gold)

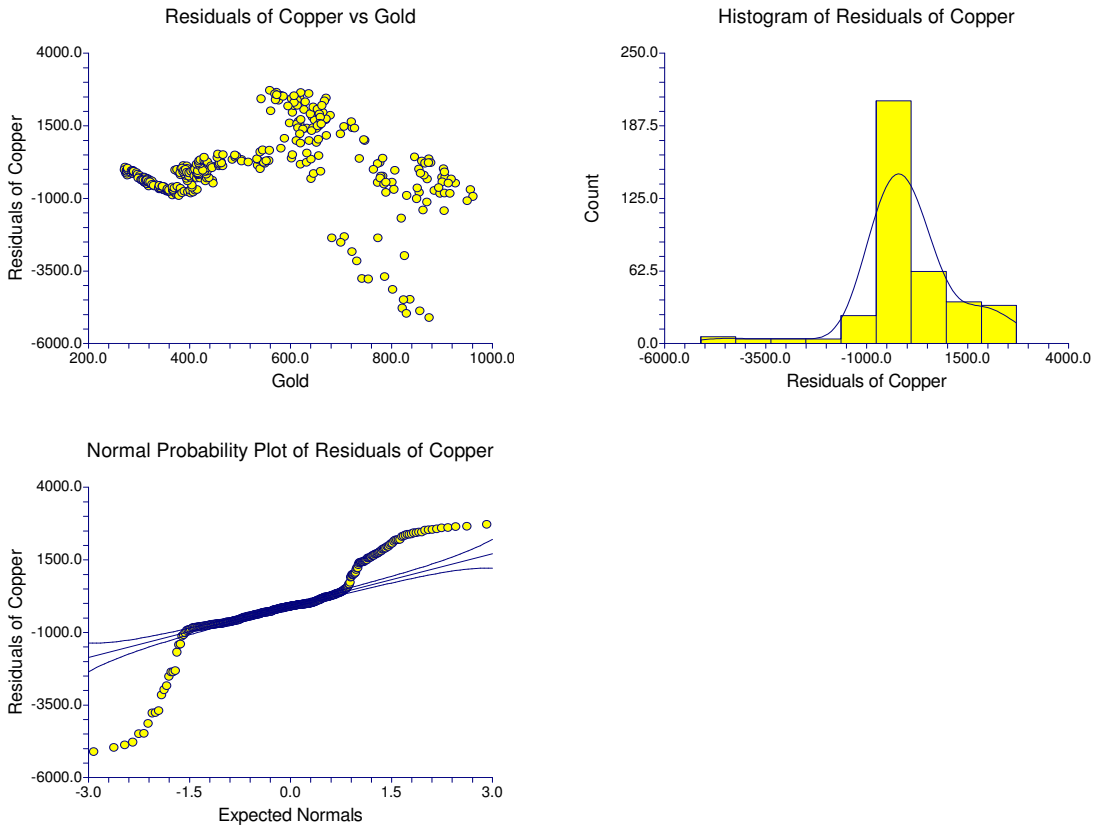

Figure 4: Residual Plots for Copper

Y = Steel X = Goldx

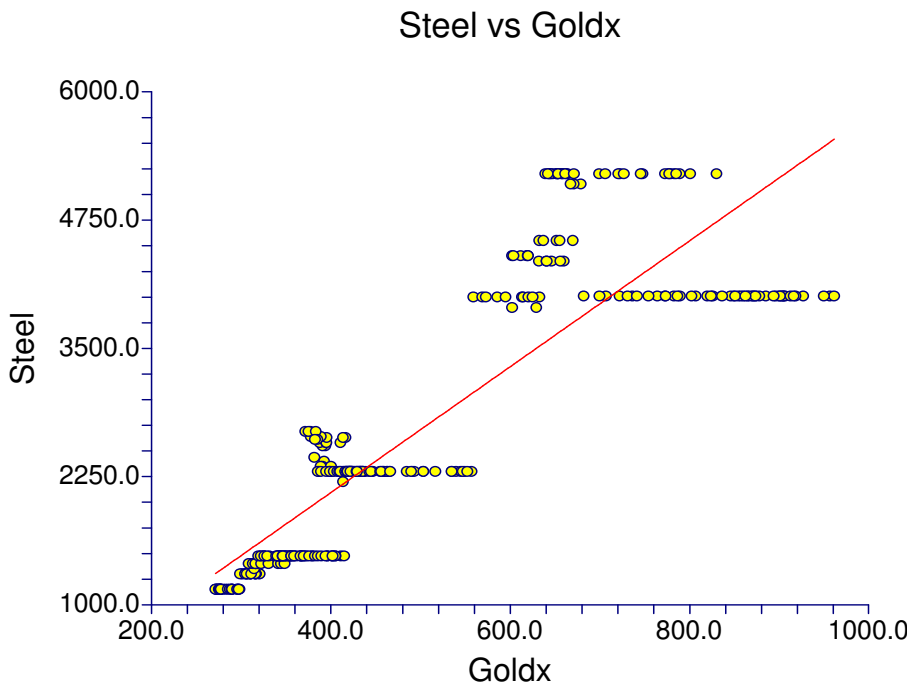

Figure 5: Linear Regression Plot for Steel vs. Gold

Run Summary Section

Parameter	Value	Parameter	Value
Dependent Variable	Steel	Rows Processed	1654
Independent Variable	Goldx	Rows Used in Estimation	343
Frequency Variable	None	Rows with X Missing	1311
Weight Variable	None	Rows with Freq Missing	0
Intercept	-359.7338	Rows Prediction Only	0
Slope	6.1316	Sum of Frequencies	343
R-Squared	0.7613	Sum of Weights	343.0000
Correlation	0.8725	Coefficient of Variation	0.2430
Mean Square Error	433890.2	Square Root of MSE	658.7034

Summary Statement

The equation of the straight line relating Steel and Goldx is estimated as: Steel = (-359.7338) + (6.1316) Goldx using the 343 observations in this dataset. The y-intercept, the estimated value of Steel when Goldx is zero, is -359.7338 with a standard error of 99.6579. The slope, the estimated change in Steel per unit change in Goldx, is 6.1316 with a standard error of 0.1859. The value of R-Squared, the proportion of the variation in Steel that can be accounted for by variation in Goldx, is 0.7613. The correlation between Steel and Goldx is 0.8725.

A significance test that the slope is zero resulted in a t-value of 32.9786. The significance level of this t-test is 0.0000. Since 0.0000 < 0.0500, the hypothesis that the slope is zero is rejected.

The estimated slope is 6.1316. The lower limit of the 95% confidence interval for the slope is 5.7672 and the upper limit is 6.4960. The estimated intercept is -359.7338. The lower limit of the 95% confidence interval for the intercept is -555.0596 and the upper limit is -164.4079.

Descriptive Statistics Section

Parameter	**Dependent**	**Independent**
Variable	Steel	Goldx
Count	343	343
Mean	2710.4111	500.7098
Standard Deviation	1346.2635	191.5737
Minimum	1150.0000	271.4500
Maximum	5200.0000	961.7500

Estimated Model

(-359.733771832453) + (6.13158535258653) * (Goldx)

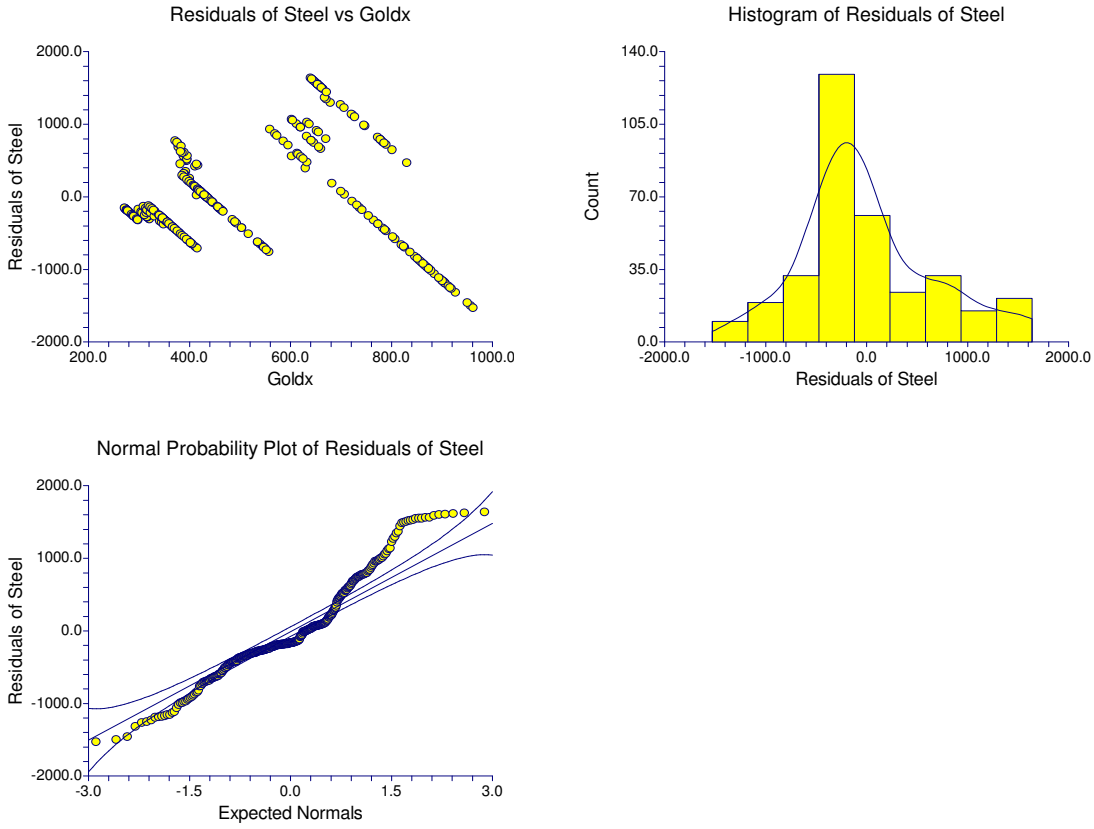

Figure 6: Residual Plots for Steel

Y = Brent_Crude X = Goldxxx

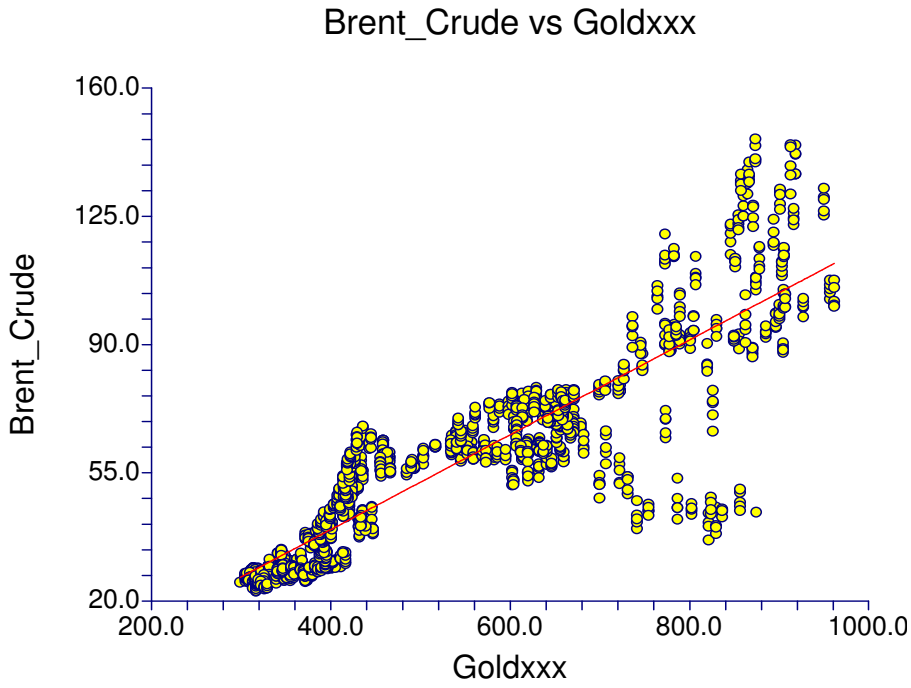

Figure 7: Linear Regression Plot for Brent Crude vs. Gold

Run Summary Section

Parameter	Value	Parameter	Value
Dependent Variable	Brent_Crude	Rows Processed	1654
Independent Variable	Goldxxx	Rows Used in Estimation	1653
Frequency Variable	None	Rows with X Missing	1
Weight Variable	None	Rows with Freq Missing	0
Intercept	-12.2208	Rows Prediction Only	0
Slope	0.1293	Sum of Frequencies	1653
R-Squared	0.7712	Sum of Weights	1653.0000
Correlation	0.8782	Coefficient of Variation	0.2224
Mean Square Error	165.3766	Square Root of MSE	12.85989

Summary Statement

The equation of the straight line relating Brent_Crude and Goldxxx is estimated as: Brent_Crude = (-12.2208) + (0.1293) Goldxxx using the 1653 observations in this dataset. The y-intercept, the estimated value of Brent_Crude when Goldxxx is zero, is -12.2208 with a standard error of 0.9909. The slope, the estimated change in Brent_Crude per unit change in Goldxxx, is 0.1293 with a standard error of 0.0017. The value of R-Squared, the proportion of the variation in Brent_Crude that can be accounted for by variation in Goldxxx, is 0.7712. The correlation between Brent_Crude and Goldxxx is 0.8782.

A significance test that the slope is zero resulted in a t-value of 74.5987. The significance level of this t-test is 0.0000. Since 0.0000 < 0.0500, the hypothesis that the slope is zero is rejected.

The estimated slope is 0.1293. The lower limit of the 95% confidence interval for the slope is 0.1259 and the upper limit is 0.1327. The estimated intercept is -12.2208. The lower limit of the 95% confidence interval for the intercept is -14.1630 and the upper limit is -10.2787.

Descriptive Statistics Section

Parameter	**Dependent**	**Independent**
Variable	Brent_Crude	Goldxxx
Count	1653	1653
Mean	57.8315	541.8372
Standard Deviation	26.8769	182.5616
Minimum	22.7000	298.9500
Maximum	146.0800	961.7500

Estimated Model

(-12.2208326565778) + (.129286625965954) * (Goldxxx)

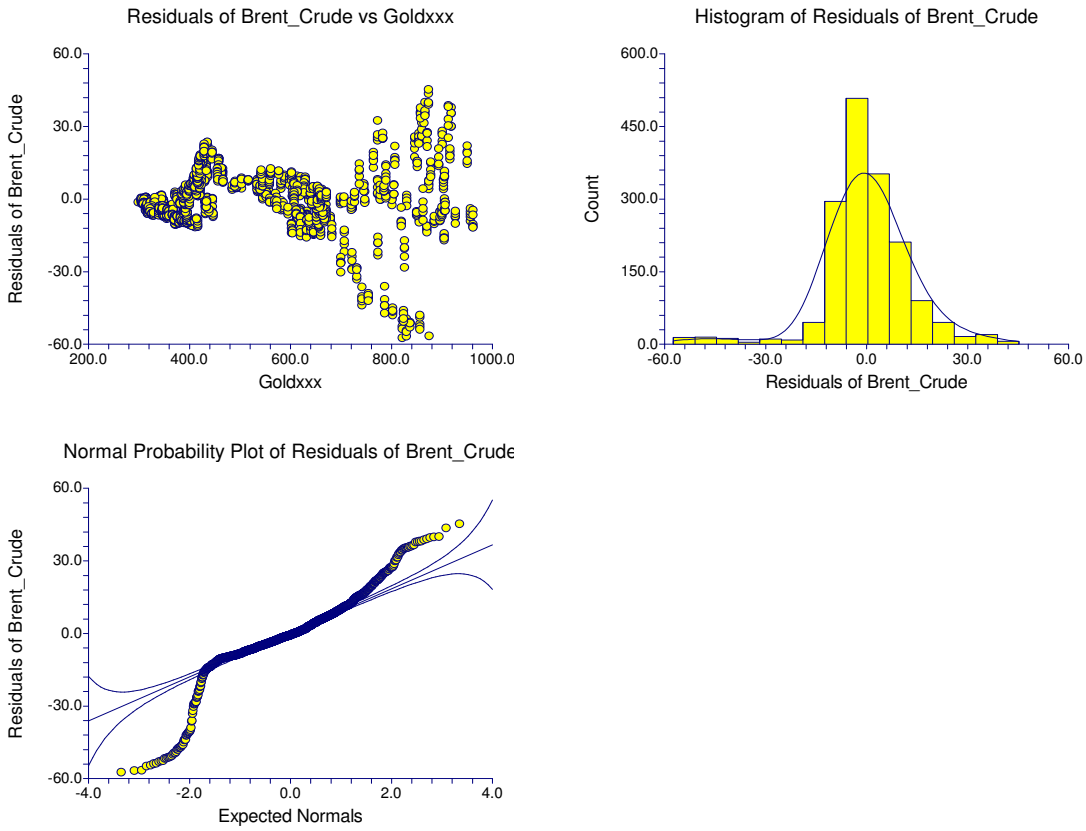

Figure 8: Residual Plots for Brent Crude

Y = Gasoil X = Goldxxxx

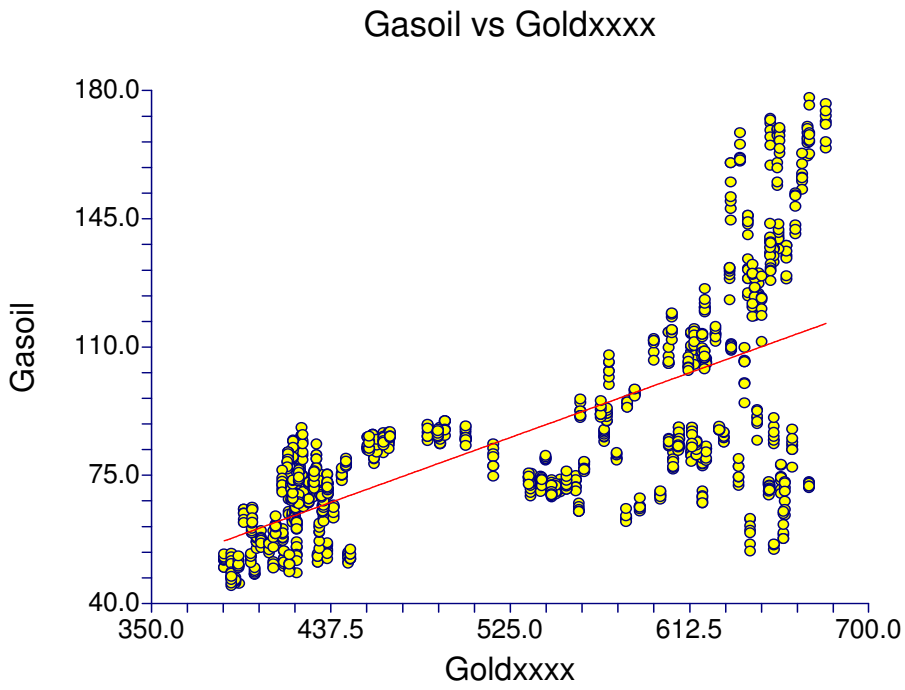

Figure 9: Linear Regression Plot for Gasoil vs. Gold

Run Summary Section

Parameter	Value	Parameter	Value
Dependent Variable	Gasoil	Rows Processed	1654
Independent Variable	Goldxxxx	Rows Used in Estimation	1152
Frequency Variable	None	Rows with X Missing	502
Weight Variable	None	Rows with Freq Missing	0
Intercept	-20.8031	Rows Prediction Only	0
Slope	0.2020	Sum of Frequencies	1152
R-Squared	0.4740	Sum of Weights	1152.0000
Correlation	0.6885	Coefficient of Variation	0.2452
Mean Square Error	436.5157	Square Root of MSE	20.89296

Summary Statement

The equation of the straight line relating Gasoil and Goldxxxx is estimated as: Gasoil = (-20.8031) + (0.2020) Goldxxxx using the 1152 observations in this dataset. The y-intercept, the estimated value of Gasoil when Goldxxxx is zero, is -20.8031 with a standard error of 3.3501. The slope, the estimated change in Gasoil per unit change in Goldxxxx, is 0.2020 with a standard error of 0.0063. The value of R-Squared, the proportion of the variation in Gasoil that can be accounted for by variation in Goldxxxx, is 0.4740. The correlation between Gasoil and Goldxxxx is 0.6885.

A significance test that the slope is zero resulted in a t-value of 32.1920. The significance level of this t-test is 0.0000. Since 0.0000 < 0.0500, the hypothesis that the slope is zero is rejected.

The estimated slope is 0.2020. The lower limit of the 95% confidence interval for the slope is 0.1897 and the upper limit is 0.2143. The estimated intercept is -20.8031. The lower limit of the 95% confidence interval for the intercept is -27.3692 and the upper limit is -14.2370.

Descriptive Statistics Section

Parameter	**Dependent**	**Independent**
Variable	Gasoil	Goldxxxx
Count	1152	1152
Mean	85.2079	524.7705
Standard Deviation	28.7952	98.1362
Minimum	44.8000	385.5500
Maximum	178.0400	679.1500

Estimated Model

(-20.8030655124649) + (.202014041110105) * (Goldxxxx)

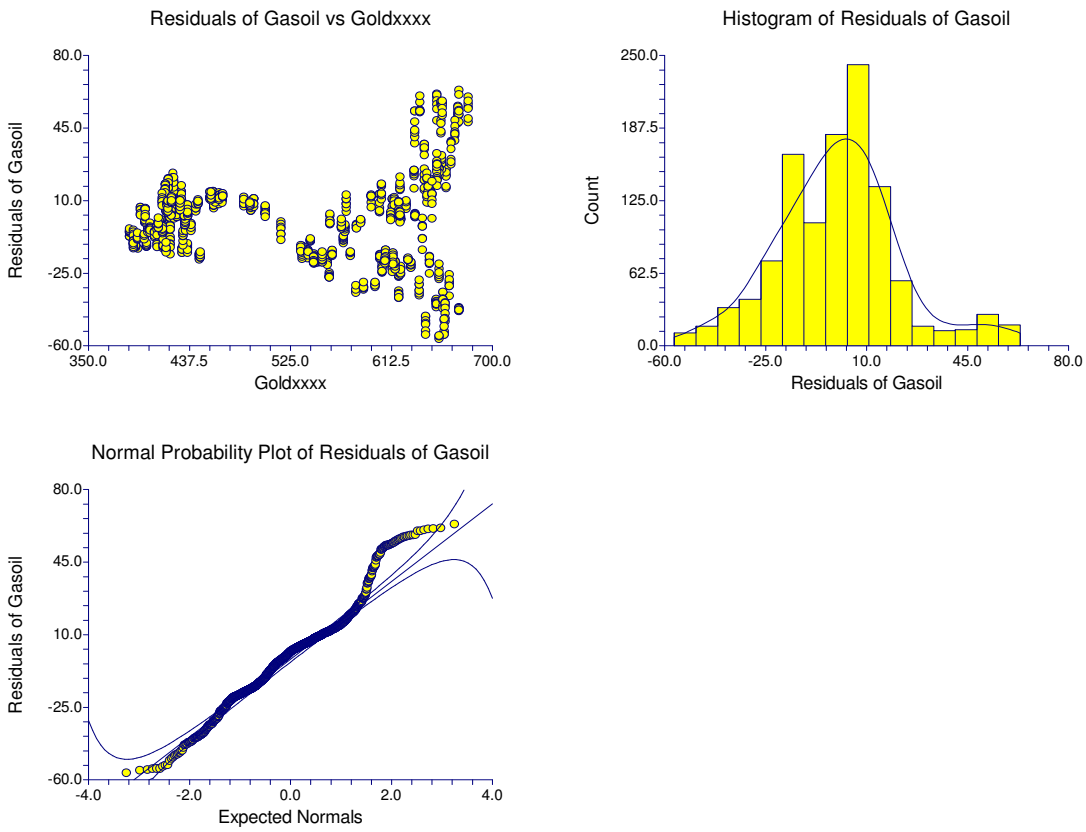

Figure 10: Residual Plots for Gasoil

4.3 Results pertaining to Hypothesis 2

The table below is a representation of the contracted costs of the South African mining operations of a global gold mining company. The percentage of total contracted spend is indicated in the right hand columns. To this end the spend

model can be used for a representative gold mining company in South Africa.

Table 1: South African Gold Mining Company Spend (Representative Gold mining company)

Commodity	Contracted Spend Value Impacted 2007	2008 Impact	spend Value 2008	% of Spend 2007	% of Spend 2007
Steel Products (Weighted)	R 593,127,544.00	R 280,502,444.00	R 873,629,988.00	29.69%	33.66%
support, drilling, Labour Hire, etc.)	R 308,343,490.00	R 44,613,208.00	R 352,956,698.00	15.43%	13.60%
Copper & Electrical	R 101,361,877.00	R 23,613,045.00	R 124,974,921.00	5.07%	4.82%
Explosives	R 141,089,034.00	R 30,922,613.00	R 172,011,646.00	7.06%	6.63%
Food (e.g. Meat)	R 95,341,866.00	R 17,849,366.00	R 113,191,232.00	4.77%	4.36%
Fuels and Lubricants	R 238,409,699.00	R 77,779,694.00	R 316,189,393.00	11.93%	12.18%
Cementatious Products	R 38,686,394.00	R 7,844,383.00	R 46,530,777.00	1.94%	1.79%
Chemicals	R 81,068,663.00	R 15,031,398.00	R 96,100,060.00	4.06%	3.70%
Timber & Support Products	R 276,117,215.00	R 73,710,545.00	R 349,827,760.00	13.82%	13.48%
Cyanide	R 39,282,040.00	R 11,784,612.00	R 51,066,652.00	1.97%	1.97%
Commodities other , Conveyor Belts. etc.	R 84,948,497.00	R 13,767,992.00	R 98,716,489.00	4.25%	3.80%
Basket Spend Subtotal	R 1,997,776,318.00	R 597,419,299.00			
TOTAL (Total Spend Basket est. Index)	**R 1,997,776,318.00**	**R 597,419,299.00**	**R 2,595,195,617.00**	**100.00%**	**100.00%**

As seen from the table above. Gold mining input costs are generally driven by various commodity prices. These include fuel, copper, steel, explosives and timber. However, in order for a commodity like gold to be hedged the product needs to have a suitable hedging proxy. To this end the product purchased needs to derive its pricing from actively traded commodities. In addition, the monthly average prices of the proxy have to exhibit a high correlation with underlying commodity.

Input costs such as timber, cyanide and consumables are harder to match to a proxy and prices could potentially be linked to fixed priced contracts or inflation. To this end the hypothesis will only be tested where clear commodity proxies for input costs are available, i.e. copper and brent crude oil, which represent the copper and fuel input commodity costs.

Since not all the commodity input costs will be hedged the results will make use of typical volume of South African mining operations, and on an equally weighted cost basis hedge and equivalent volume of gold on the revenue side.

Table 2 below gives an indication of typical gold volumes sold from 2005 to 2008. These will be the years where historical back testing will be applied to see whether simultaneous commodity input and gold revenue hedging would have realised increased profits.

Table 2: South African Selected Gold Mining Operation Production

Mine	2005	2006	2007	2008
South African gold mine 1	36162	35755	31618	28865
South African gold mine 2	32258	28429	28705	25533
South African gold mine 3	19418	18541	16903	13625
South African gold mine 4	0	0	5166	7220
total (ounces)	**87838**	**82725**	**82392**	**75243**

Table 3 below indicates the average commodity prices for the years in question as the base unhedged scenario. It also indicates the price effect of simultaneous commodity input as well as gold output hedging. The hedged prices are a function of the commodity term structure (forward price) as of the 1st week of the years presented. To this end the additional revenue or loss is noted given the price and volumes affected.

Table 3: Hedged vs. Unhedged Earnings Impact Assessment

2005	Base scenario (unhedged)	Hedged Scenario	price difference	volume impacted (ounces)	average spend impact	profit impact
average fuel price (Brent) $/bbl	$ 66	$ 40	$ 26	10592	$ 278,396	
average copper price $/tonne	$ 3,500	$ 2,867	$ 633	4343	$ 2,750,791	
average gold price $/oz	$ 446	$ 439	$ -8		$ -117,691	$ 2,911,496
2006	Base scenario (unhedged)	Hedged Scenario	price difference	volume impacted (ounces)	average spend impact	profit impact
average fuel price (Brent) $/bbl	$ 66	$ 63	$ 3	9976	$ 33,476	
average copper price $/tonne	$ 6,680	$ 4,349	$ 2,331	4090	$ 9,536,184	
average gold price $/oz	$ 606	$ 550	$ -56		$ -788,664	$ 8,780,996
2007	Base scenario (unhedged)	Hedged Scenario	price difference	volume impacted (ounces)	average spend impact	profit impact
average fuel price (Brent) $/bbl	$ 73	$ 60	$ 13	9935	$ 127,388	
average copper price $/tonne	$ 7,118	$ 5,593	$ 1,525	4074	$ 6,211,433	
average gold price $/oz	$ 699	$ 620	$ -79		$ -1,100,260	$ 5,238,562
2008	Base scenario (unhedged)	Hedged Scenario	price difference	volume impacted (ounces)	average spend impact	profit impact
average fuel price (Brent) $/bbl	$ 99	$ 95	$ 3	9935	$ 33,317	
average copper price $/tonne	$ 6,886	$ 6,916	$ -30	3721	$ -111,360	
average gold price $/oz	$ 871	$ 880	$ 9		$ 121,519	$ 43,476
Total 4 year earnings impact						***$ 16,974,529***

4.4 Summary of the results

Based on the quantitative outputs of the linear regression it is noted that for the commodities tested there is a significant correlation between the input commodity price and the gold price.

The results also reflect that additional earnings would have been realised if simultaneous commodity input and output hedging was implemented at the beginning of years 2005 to 2008 for the representative South African gold mining company.

CHAPTER 5: DISCUSSION OF THE RESULTS

5.1 Introduction

From the literature review and subsequent results presented, this chapter will discuss the findings with the objective of bridging the gap between literature, the research questions and subsequent results obtained. It will discuss potential applications of the results especially as it pertains to the gold mining industry in South Africa.

5.2 Discussion pertaining to Hypothesis 1

From the results, it is suggested that there is a significant correlation between gold and commodities typically associated with the input costs of gold mining. To this end the hypothesis that the slope is zero is rejected for all the commodities tested. This finding is similar to the view of Pindyck and Rotemberg (1990) who suggest excess co-movement between commodities and that potentially commodities are influenced by global macro economic supply and demand fundamentals as well as trader 'herding' behaviour.

The fundamentals around global demand and supply and subsequent mean reversion of commodities suggested by Baker et al (1998), seems to bear fruit as commodities are typically globalised and as such the global demand of commodities which is typically associated with wealth and infrastructure growth should drive its pricing behaviour. Hence the finding that gold is significantly correlated with commodities such as copper, brent crude and steel.

How this sympathetic price behaviour can be harnessed to derive maximum value for a gold mining company should be considered. To this end there should be an opportunity to harness breakdowns in the correlation to the benefit of the South African gold mining company. An example of this would be the occasion where the input commodity does not increase on the back of a gold price increases. This realises an opportunity to lock in a favourable operating

margin.

The results presented conclude that there is a significant correlation between gold mining commodity input price and the underlying gold price.

5.3 Discussion pertaining to Hypothesis 2

From the results presented for the simultaneous gold price and commodity input price hedging performed retrospectively for the representative South African gold mining company, for years 2005-2008; South African gold mining companies would have realised additional earnings on the back of a simultaneous gold price and commodity input price hedging policy.

It is important to note the commodity forward curves for both input commodities as well as gold was used to fairly reflect the hedged prices for copper, brent crude as well as gold.

Furthermore, it is noted that the results do not present the gold mining companies entire cost base, but is a reflection of commodity input prices that have hedging proxies, as is the case for the gold revenue stream.

It is however noted that for the period tested, the annual prices of the commodities have increased. However, this should be negated by the found correlation between input commodities and gold. As such, one could potentially have proven that an overall commodity price decrease would have yielded similar results.

Commodity forward curve

From the results it has also become apparent that the term structure or commodity forward curve needs to be considered in establishing the hedged price when simultaneous hedging takes place. The benefit here is that gold typically has a forward curve that is in contango and as such a hedged price for any given year would trade at a premium to the spot price on the day of hedging. The input commodities on the other hand typically neither favour a contango nor a backwardated curve, as it is typically a function of supply

tightness as well as the markets view of future pricing. To this end it is important when implementing simultaneous hedging that the gold mining company takes cognisance of the term structure of the commodities being hedged.

Proxy hedging

Not all input commodities can be commoditised, i.e. hedged via derivative instruments. It is however important that like the gold mining company has an understanding of its gold revenue, costs need to be understood, as it will not diminish risk by simply fixing its revenue, especially given the significant correlation that exists between gold mining commodity input price and the gold price. While some gold mining companies choose to hedge their gold exposure, many of them are quick to point out that rising cost have resulted in their underperformance, in spite of the fact that the price risk management activity was primarily revenue stream focused.

The research concludes that for the time period under consideration, that if gold mining companies used commodity price correlation as a margin management tool, - i.e. simultaneous commodity input and output hedging - that their earnings would have increased.

5.4 Conclusion

The discussion reaffirms literature that there is a significant correlation between commodities. Moreover, and pertinent to this research, that there is a significant correlation between gold mining input commodities and gold itself. The use of this sympathetic movement can be harnessed by looking at potential breakdowns in correlation to enhance operating margin or simply looking to simultaneously hedge input and output commodity prices for a South African Gold mining company.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

From the literature, research questions, results and discussion, a conclusion around commodity correlation and simultaneous cost and revenue hedging for South African gold mining companies is presented.

6.2 Conclusions of the study

It has been quantitatively found that there is a significant correlation between commodities. More specifically that there is a significant correlation between gold mining commodity input prices (e.g. Copper, fuel and steel) the gold price. To this end, the notion that commodity prices move together has been proven.

The understanding that there tends to be this sympathetic movement between commodities. may negate the effectiveness of applying gold revenue hedging in isolation, as this could leave commodity input costs and prices exposed. To this end the research report has found that for the representative South African gold mining company, simultaneous commodity input as well as gold output price hedging would have increased earnings for the years 2005 to 2008. Although research on simultaneous hedging is not that prevalent, it talks to the theory of margin management as the focal point of price risk management for corporations. As such the principle of reducing volatility in margin could be applied to a variety of industries.

6.3 Recommendations

Based on the outcomes of the research the following recommendations are prescribed.

- South African gold mining companies not only hedge the gold commodity price in isolation but take into account the input costs associated with the extraction and refinement of the metal.
- Simultaneous commodity input and gold output hedging be considered as part of a South African gold mining company's price risk management strategy.
- Commodity correlation breakdowns are viewed as an opportunity to either lock in additional margin via simultaneous hedging or dissuade simultaneous hedging.

6.4 Suggestions for further research

Based on the outcomes of the research it is suggested that further research around margin management and risk management be undertaken, with the specific aim of testing cost and revenue risk management for extended periods as well as across different industries.

It is further recommend that an investigation into the commodity forward curve for gold and its input commodities such as fuel and copper be studied with the purpose of seeing whether there is an arbitrage opportunity to be leveraged on the back of the fact that gold typically has a contango term structure and that input commodities could be impartial to being in contango or backwardation.

Finally an investigation into potential commodity hedging proxies for timber, explosives and cyanide could provide further ability to effectively hedge more of the gold companies cost base.

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APPENDIX A

Consistency matrix

The effect of input commodity price movements on the earnings of South African gold mining companies					
Sub-problem	**Literature Review**	**Hypotheses or Propositions or Research questions**	**Source of data**	**Type of data**	**Analysis**
Evaluate the extent of the correlation between input commodity price and output gold price for a representative South African gold mining company.	It is hypothesised that there is a statistically significant correlation between gold mining commodity input cost and the underlying gold price	Various: Academic journals, Financial publications.	Goldfields confidential cost data, Bloomberg and Reuters	Published data, Official financial data resources	Quantitative hypothesis test
Identify the applicability of VAR as a cost management tool for non financial organisations such South African gold mining companies.	It is hypothesised that if gold mining companies applied simultaneous input commodity price and gold price hedging, their earnings would have increased.	Various: Academic journals, Financial publications.	Goldfields confidential cost data, Bloomberg and Reuters	Published data, Official financial data resources	Quantitative hypothesis test