ROA On Gold Mines In ZA

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BACKGROUND

Common mining appraisers tend to value gold mining as per number of tonnes of gold extracted from the mines or through estimation of possible gold reserves using TVMs such as discounted cash flows (DCFS) . Although, TVMs have been *"reliable"* in valuing real assets such as gold mines; however, certain variables of gold mines that induce mines' values are mostly not captured by TVMs. Therefore, TVMs tend to lead to incorrect and unreliable values of gold mines. In ZA (South Africa) , most gold mine appraisers have been using TVMs for many decades by now. With the evolution of capital budgeting techniques, some empirical studies, such as ones by Moel and Tufano (2001), Cavender (1992), and Palm, Pearson and Read, Jr (1986) illustrated that novel capital pricing techniques such as real options (ROs) offer insightful values than TVMs. Although, there are a number of reasons why ROs offer more insight than TVMs, one of the most illustrated advantages of using ROs is their ability to capture flexibility (Brennan and Schwartz ,1984). The basic argument here is that when ROs are applied on gold mines, one is able to *"extract"* value that would normally not be *"extracted"* by TVMs. Moreover, other non-financial option variables are costs (maintenance, shutdown, opening and re-opening) and reserves (Brennan and Schwartz ,1985a; Moel and Tufano , 2001). In *"extracting"* the extra value, this empirical study shapes its principles and concepts of option pricing largely around the Moel and Tufano (2001) model. Moreover, this empirical study explores real options parameters, which contribute more towards the option value of South African gold mines during the opening and closing stages of their *"lives"*.

LITERATURE REVIEW

The objective of literature review is to explore whether the following propositions constitute optionality:

❁ **Proposition One:** The opening of gold mines in South Africa constitutes optionality, where the main hypothesis (H_0) states that the opening of gold mines in South Africa constitutes optionality and the null hypothesis (H_1) states that no optionality caused the opening of gold mines in South Africa.

❁ **Proposition Two:** The closing of gold mines in South Africa constitutes optionality. The bulk of the literature review in this research paper supports this notion. However, it remains to be seen whether the same results will be obtained from the present South African gold-mining study, where H_0 is that the closing of gold mines in South Africa constitutes optionality and H_1 is that when gold mines close in South Africa, it does not constitute optionality.

Moel and Tufano (2001) looked at real options from North American gold mining and the right to open and shut a mine in response to output price changes. They examined how often options are exercised and also delved into the situations under which options are exercised.

Mineral economists believe that mines are categorized into exploratory (thus, need further development to reach its full producing capacity) or developed (thus, mine owners have confirmed existing opportunities and resources are being extracted from the ground). Moel and Tufano's sample size of two hundred and eighty five (285) was from the *Metallica* database from North American gold mines, but some data was collected from other sources. From the analysis of the data, it was found that by the end of 1996, some mines were temporarily inactive or permanently closed. Between 1995 and 1997, the gold prices in United States dollars decreased from $387/oz to $287, 05/oz. From their study, it was found that most mines closed down due to economic reasons. In essence, this was an option to abandon due to a decline in gold prices. There were more reasons to mines' closure than a decline in gold prices. Exhaustion of reserves and flooding seem to be other reasons for closure of mines. From the database of 285 mines, 213 (or 75%) closed more than once, and 26 of the closed mines re-opened sometime between 1988 and 1997.

To fully test whether the closure of mines constitutes optionality, Moel and Tufano built a model that has the following independent variables: *Gold Price, Volatility, Interest Rates, and the Mine Cost Structure and Prior State* (open or

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closed). The *Virtual Gold Research* provided the gold prices and volatility of gold returns was calculated based on historical returns (return included daily 3-months gold convenience yield), ten-year Treasury bond rate was used as discount rate and annual average cash costs (obtained from the *Metallica* database). Costs included both fixed costs and marginal costs. Their research supported the fact that fixed costs are a function of mineral reserves and mine technology, and marginal costs are functions of mineral already extracted and mine technology.

Mine technology was represented by dummy variables, thus dummy variable was 1 (if mine was underground) and 0 (if mine was an open pit). The model further took into account remaining reserves on the variable costs and set of dummies (D_R) were created corresponding to reserve quartiles and were interacted with production variable *(q)*.

The model was :

$$cq = \alpha_0 + \alpha_1 R + \alpha_2 T + \beta_0 q + \beta_1 qT + \beta_2 D'_R q$$

where α_0, α_1 and α_2 were fixed costs, and β_0, β_1 and β_2 were the marginal costs, T was technology dummy, equal to 1 if the mine was underground (UG) and 0 if it was an open-pit *(OP), D'_R (n)* were dummies which reflected reserve quartile, *c* was average (cash) US dollar cost per ounce of gold and *q* was the annual gold production in ounces.

The impact of dependent variables, as compared with empirical results is outlined by Moel and Tufano (2001:9). The Exhibit 1 below shows predictions about the probability of mine status and data definitions. This Table was adopted from Brennan and Schwartz (1985a) real option model. The positive sign (+) indicates *increases* and the negative sign (-) indicates *decreases*.

Exhibit 1: Optionality Effects of Various Gold Mining Variables

Variables	Probability of being open, conditional on previously being opened	Probability of being open, conditional on previously being closed	Variables, definitions and sources of data
Prior state	+	-	Open (1) or closed (0) in prior year. (Metallica 2000, press reports, filings)
Gold price	+	+	Average of AM & PM London daily US$ fixing gold prices over prior 12 months. (www.virtula-gold.com)
Volatility of gold price	+	-	Standard deviation (%) of daily gold returns from gold prices plus 3-month lease rate over prior 12 months. (www.virtual-gold.com)
Operating costs	-	-	Predicted marginal costs β (in US$) from estimation of cost function, table 3, column E.
Discount rate (nominal)	+	+	Annual average of 10-year T-bond yields. (DataStream)
Discount rate (real)	+	+	10-year T-bond yields (DataStream) minus expected inflation. (Federal Reserve Bank of Philadelphia) Gold lease rate. (www.virtual-gold.com)
Convenience yield	-	-	
Costs of shutting & reopening	+	-	Form of technology dummy variable T interacted with prior state variable. (0=open pit or surface mine;1=underground mine). (Metallica 2000).
	+	-	Capitalized cost of mine investments in constant 1996 US$, interacted with prior state dummy (Metallica 2000).
Costs of maintaining mine	+	+	Predicted fixed costs α (in US$) from estimation of cost function, table 3, column E.
Reserves	+	+	Reserves in oz. (Metallica 2000, press report, filings)
Source: Moel and Tufano (2001), Table 1 (Panel A), Page: 7			

From the model and predictive table, several findings were made. Moel and Tufano's model predicted that re-opening of mines is positively related to the increase in gold price. Between 1988 and 1993, when the gold prices fell from $470/oz to $330/oz, operational and non-productive mines that closed rose from 4% to 16% of all mines. In 1995, the

gold prices went up, but only a few mines re-opened. Moel and Tufano (2001) said that was expected because of hysterical behaviour from different role players. The number of mines that closed when the gold prices dropped between 1996 and 1997 for economic reasons was 20% of all mines from their database. The probability of re-opening a previously closed mined increased when the gold prices were $280/oz and increased to 100% at price of $720/oz (approximation). Probability of opened mine remaining open was positively related to an increase in volatility. Moel and Tufano found that a mine is unlikely to operate with an increase in variable costs. Increasing gold reserves supported the notion that an open mine is likely to remain open and closed mines were likely to reopen. Reserve size had a high predictive power, mostly in previously closed mines being re-opened, with an increase in reserves. For one standard deviation (σ) increase in reserve, probability of being open rose to 99, 9%. The test that nominal interest rates are strongly related to whether or not to open a mine was statistically significant. Thus, there was a positive relationship between reopening of mines with an increase in interest rates. More to their study, the correlation coefficient (ρ) between gold prices and nominal interest rates was 0,60. The impact of dummy variables could not be verified because they lost half of the observations of their experiments. However, from the few observations that were retained, dummy variables confirmed that increase in technological costs will cause more opened mines to remain open and closed mines were to remain closed. Variables *(spot price, in mines it is gold price; volatility; risk free rate, in this study risk free rate is nominal interest rates)* had a similar impact of mines as on financial derivatives. In order to verify their results, they used robustness tests and predictive power, and findings were that explanatory decreased slightly without changing the values of the coefficients. Thus, the original findings still stand.

Cavender (1992) compared the value of a mine using discounted cash flows (DCFs) method and option pricing methods (OPs). As we know from financial options, when the factors (current stock price, S_0; strike price, K; time to expiration, T; volatility of the stock price, σ ; risk-free interest rate, r and expected dividends, q) cause the value of an option (call or put) to decrease, then it is not worth exercising your option at that moment or time. Cavender assumed the same principles in his study. When using DCFs, at year five, the net cash inflow was $34,863, but when using OPs; there was net outflow of $7,925. During the fifth year, the gold prices decreased and as per financial options' principles, the value of the asset has to decrease. During that year, the project also incurred costs to shut down. OPs tracked the impact of externalities on the value of mine and DCFs did not give a true reflection of the situation. In essence, there was an option to temporarily close operations, and hopefully continue with the project as gold prices picked up. To verify whether the impact of prices from OP was right, he worked on *Stochastic Risk Model* (SRM) as well. The Model assumed that there are possible outcomes of the project with different probabilities. The Monte Carlo technique projected all possible outcomes for the model (variables for the technique can be found in Cavender 1992:1265). Interactions of multiple sets of variables and realistic assessment of the potential financial results were taken into account by this model. The results of this model were more or less in line with OP. The value of OP and SRM (Cavender 1992:1267) were almost the same, and certain circumstances values of two models converged as per daily ore production rate. Thus, the two models (SRM and OPs) resembled each other. In the two models, fixed costs were always the same, no matter what, but variable costs changed as per production levels of the project. The slight difference was due to different assumptions when doing calculations for different models. Cavender (1992) also showed in his study that a closed mine will only start operating when mineral prices exceeded production costs of the period when the mine operated. Production costs were exercise price *(K)* and gold price was stock price *(S_0)*. Re-opening a closed mine was like exercising a call option. We know from derivatives literature that it is worth exercising a call option when $S_0 \rangle K$, thus a call option *is in-the-money*.

Palm, Pearson and Read, Jr. (1986) looked at option pricing as a new technique for valuations of mines. Their study was based on copper mines. Facts and assumptions upfront to their study where mines could recover fixed costs only when incremental costs of production were lower than mine commodity prices, volatility of copper mines was higher than other commodities. When output prices fell below the total cost of production, it was not worth extracting copper, companies benefited by having high variable costs than fixed costs, and mines were like stock options when estimating values. Their paper evaluated deposits containing 100,000 tons of ore. Two technologies were involved in this project; the first strategy had variables costs of $15/ton and fixed costs of $1,000,000. The second strategy involved variable costs of $25/ton and had no fixed costs. The costs of extracting ore were the same, irrespective of the strategy you use. As long as the price of ore was $35/ton or above, you made a net inflow of at least $1,000,000, irrespective of the strategy used. Below $35/ton, it was not worth extracting the ore. Thus, temporarily exit your

project (thus exercising a put option) until the price of copper recovers. The study clearly showed that the price of copper had an influence on whether to extract or not from the mine. The value of the mine seemed to increase with an increase in the price of copper. Variable costs had no effect on the project in the sense that they could be controlled. Thus, when the mineral price went down, you could minimize your variable costs. An increase in volatility has a positive effect on mine value because of unlimited upset and limited downside from shutting down an option. Palm, Pearson and Read, Jr (1986:65) stated that *"much of the value of the mine comes from the option to shut down, and hence, avoid losses when the product price is low, relative to the marginal cost of production."*

Casassus and Cortazar (1998) investigated when it was right to expand a copper mine in Chile and calculated the expansion value using real options. Their model was an extension of the Brennan and Schwartz (1985a) model. The price of copper was assumed to follow mean reverting stochastic process. Production was underway and mine incurred fixed costs, whether it re-opened or closed. The Model took into account an additional cost of waiting. The project was US$6, 48 millions of copper with 12 years of reserves left. Intuition should tell us that if there was no significant convenience yield, speeding production would not bring any economic value. Casassus and Cortazar (1998) showed that expansion values start to be positive from low prices, and the value becomes more valuable with an increase in prices at later stages of the project. Thus, the option to delay the project was more valuable. As we would expect from financial options literature, an increase in the stock prices increase the value of the option . Results confirmed that NPV method gives the lowest value despite being positive and option techniques yield the highest value. Expansion with option timing gives a slightly higher value than expansion without timing. This makes sense as we know that increase of time to expiration increase the value of the option.

DATA

This section summarizes the data used in this empirical report and at the same time, it explores a possible trend that can be *"extrapolated"* from the used data set. Moreover, this section *"exploits"* possible reasons for emerging trends from the used data set.

Exhibit 2: Summarized South African Gold Mining Data Between 1980-2002

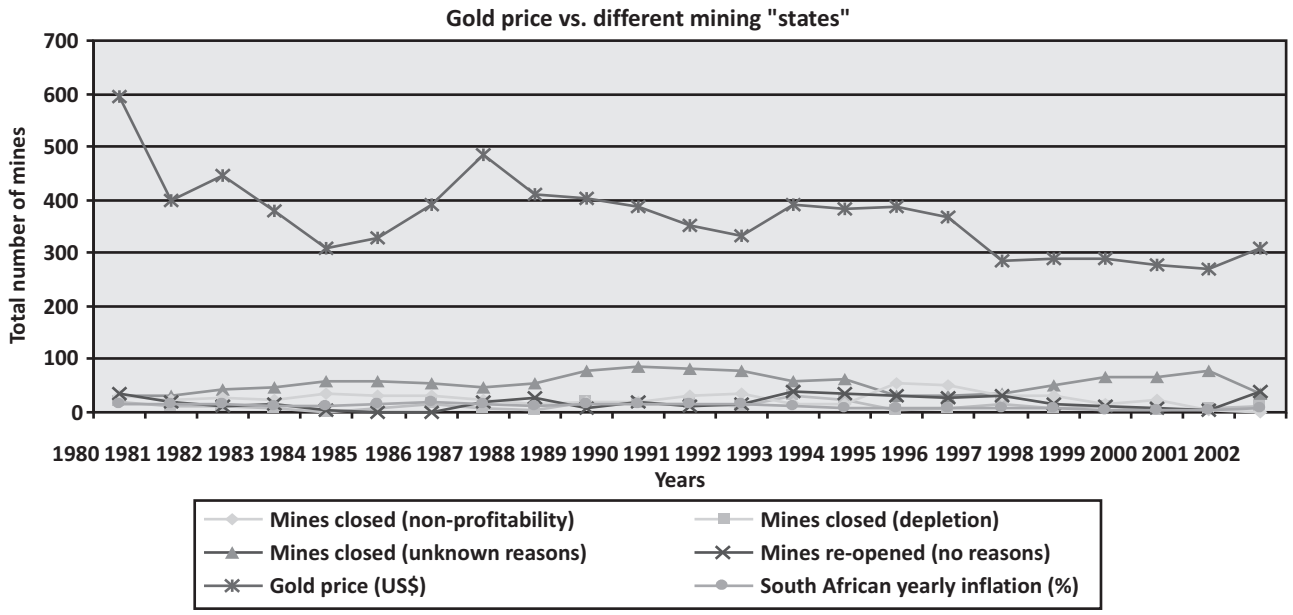
Mining Activities in South Africa, 1980-2002	
Mine Status	**Number of mines**
Total number of mines in database (1)	421 open & 2113 closed
Number of mines with insufficient data (2)	0
Number of mines for which data is available (1+2)	2543
Mines that closed at least once during 1980-2003	
Reasons Companies announced for closure	
a) Economics (lower gold price)	0
b) Depletion of reserves	581
c) Geological reasons (floods, cave-ins)	274
d) Strike or other disputes	0
e) Environmental concerns	0
f) Reasons not given	0
	1258
Reasons company announced re-opening	
a) Economics (higher gold prices)	0
b) None given (i.e. no reasons)	430
Source: Department of Minerals and Energy (South Africa) and Joel Malapane (Marlin Mining Company)	

The data does not exactly add up because it came from different sources. Department of Minerals and Energy (ZA) receives data from different sources (mining companies) hence, it cannot reconcile the authenticity of the data. The responsibility is with the data provider. A reasonable number of mines (both for close and open reasons) did not give reasons for that particular state of the mine. However, the combined data should be able to give indications about what

happened during the period of 1980 to 2002 regarding activities of gold mines in South Africa.

❁ ***"Exploitation"*** **of Possible Emerging Trends:** Figure 1 shows the relationship between gold prices (for different movements) and state of mines per sources.

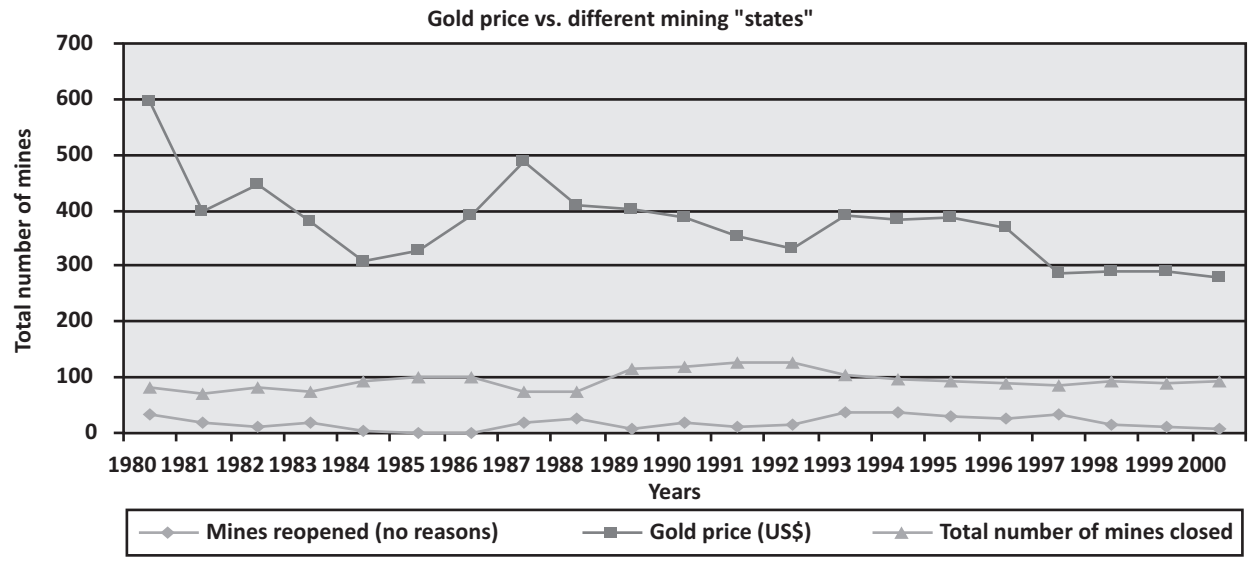
Figure 1: Price Versus States of Different Gold Mines



Source: Department of Minerals and Energy (ZA), South African Reserve Bank and Joel Malapane (Marlin Mining Company)

By looking at the Figure 1, we see that reopening of mines increases with an increase in the gold price and closed (whether for unknown reasons, depletion or non-profitability) mines seem to increase with a decrease in the gold price. The researcher calculated the correlation (ρ) coefficients between gold prices and different mine states between 1980 and 2002. Lets say mines closed (non-profitability) be represented by *b*, (mines closed depletion) by *c*, mines closed (unknown reasons) by *d*, mines reopened (unknown reasons) by *e* and gold price *f*. Correlation coefficients are; ρ_{bf}= 0,136, ρ_{cf} = 0, 350, ρ_{df} = -0,349 and ρ_{ef}= 0,297. There is a reasonable moving together (as shown by correlation coefficients) between the gold price and mines closing due to depletion and gold price mines opening (unknown reasons in this case). Intuitively, it makes sense that as more mines are closing due to depletion in this case, the gold prices decrease, and more mines are reopening as gold prices increase. Whether there is no relationship between mine closings (unknown reasons in this case) and gold prices, the researcher guesses that is due to mining strikes. Labor strikes are very common in South Africa because labor unionism is very strong. In the last ten years, there has been at least one labor strike per year by mine workers. From the Figure 1, it can be seen that during the 1992-1998 period (approximation), the gold prices were decreasing. Normally, mining companies would want to lay off some mine workers during these kinds of periods. Therefore, the argument that mines might be retrenching mine workers and there were labor strikes makes sense from the South African perspective. In most cases in South Africa, rulings were in the mine workers' favor or alternative compromises were found. For example, most common consensus was that mining companies have to train laborers in different areas, so that they could be absorbed by other or related industries at the expense of mining companies. Commonly, it would be related industries such as being security guards, cleaners and builders for the same mining companies. Thus, the mining section of the mining company incurs less cost, but other sections of the same company takes extra costs. From option pricing theory, one way of keeping your expansion or continuation option valuable is to reduce your costs. At the same time, during that period, the number of mines that

Figure 2: Gold Price Versus All Closed Gold Mines (Irrespective of Reasons For Closure)



Source: Department of Minerals and Energy (ZA), South African Reserve Bank and Joel Malapane (Marlin Mining Company)

reopened decreased, but at a decreasing rate.

Figure 2 combines all the closed mines irrespective of the reasons, and compares them to changes in gold prices. At the same time, it looks at the relationship of closed mines, gold prices and reopened mines. From the Figure 2, we can see that as the gold price moves downwards, the total number of closed mines increases and when it (gold price) moves upwards, more mines reopened. The results of Figure 2 are more or less the same as that of Figure 1. Thus, the total closed mines (irrespective of reasons) respond in a similar manner to gold prices, as closed mines for different reasons. Let total number of closed mines (irrespective of reasons) be represented by *a*, mines reopened (no reasons) by *b* and gold prices by *c*. Correlation coefficients are; $\rho_{a,c} = -0{,}111$ and $\rho_{b,c} = 0{,}297$. Correlation coefficients tell us that there is no moving together between total number of mines closed (irrespective of reasons) and gold prices, but mines reopened (no reasons) and gold prices move together 30% (approximation) of the time. Reasons for moving together and not moving together should be the same as per the Figure 1.

EMPIRICAL ANALYSIS

Table 1 is adopted from Moel and Tufano (2001) for their tests of likelihood of mines remaining opened, given changing market conditions. Within each cell, the first term represents a regression intercept, the second term represents the slope and the third term represents p-values for the significance of the coefficient. The total number of all available mines is two thousands, five hundred and sixty four (2564). Column A models the probability of mines being opened per gold price change, given a prior mine state. Column B adds volatility (σ) to the initial stage, Column C adds both fixed and marginal costs, Column D looks at increasing reserves' effect, Column E takes into account the impact of interest rates and Column F looks at deflated gold prices and likelihood of mines remaining opened. Dummy variable one (1) shows that the mines were opened the last year. Signs predict the possible likelihood and its statical significance. As expected, increasing gold prices increase the chance of mines remaining opened, given the prior state of being opened, a phenomenon observed by. Moel and Tufano (2001). Figure 1 and Figure 2 do show that the number of opened mines increased with an increase in gold prices. At the time, for South African mines, gold prices were statically significant for opened mines remaining opened. The correlation coefficient between all closed mines and changing gold price (see figure 2), is negative, as indicated by ρ of -0,111. Yes, for South African gold mining, it makes sense as there are other factors such as highly unionized mining labor as from early 1980s. Labor unionization in South Africa has a great influence on mining.

The impact of volatility on gold mines confirms the prediction of the model. More importantly, the changing volatility

Table 1 : Optionality in Gold Mines Due To Different Mine States								
	Mean Value	**Sign**	**A**	**B**	**C**	**D**	**E**	**F**
Intercept			-2,614	-2,928	-0,1006	-0,3858	-0,684	-2,371
			(0,5826)	(0,2140)	(0,0000)	(0,2058)	(0,0000)	(0,3775)
Gold price(US$)		+	0,0170	0,0032	0,0021	0,0011	00,0012	0,3257
Nominal:	367,16		0,0507	0,0453	0,0578	0,0039	0,0434	0,0568
Deflated:	337,09		(0,2974)	(0,9334)	(0,0001)	(0,0006)	(0,2889)	(0,3775)
Gold volatility interacted with open last year dummy	0,12	+		0,0034	0,0010	4,2898	0,9059	4,1046
				0,1624	0,0360	0,0002	0,0004	0,0502
				(0,2140)	(0,1211)	(0,2058)	(0,3095)	(0,3918)
Gold volatility interacted with closed last year dummy	0,12	-			-1,006	-0,4471	-2,4716	-4,1094
					-0,0283	-0,0034	-0,3765	-0,5676
					(0,7765)	(0,1923)	(0,3281)	(0,3775)
Marginal cost, β (US$/oz)		-			-0,000103		0,00062	-0,0017
Nominal:					-0,00008		0,00018	-0,00048
Deflated:	203				(0,00014)		(0,0000)	(0,0000)
	171							
Reserves (oz)	1020000	+				0,13E-5		
						0,02E-6		
						(0,0000)		
10 year T-Bond rate	7,29%	+					0,3108	0,3008
Nominal:	3,64%						0,1595	0,1651
Real:							(0,0000)	(0,0000)
Open last year dummy y_{-1}	0,46	+	0,5964	0,5960	0,0985	0,1132	0,2392	4,1094
			0,3958	0,5476	0,0031	0,1025	0,2941	0,1723
			(0,2974)	(0,2777)	(0,000)	(0,0001)	(0,2921)	(0,3775)
Open mines when sanctions were imposed ($dummy_{-1}$)		+	0,2950	0,0891	2,5240	0,5294	0,3485	0,5246
			0,1113	0,0833	0,0032	0,0036	0,0065	0,0018
			(0,3845)	(0,0001)	(0,0017)	(0,8047)	(0,0000)	(0,5678)
N			2564	2564	2564	2564	2564	2564
Pseudo R^2			0,4347	0,4208	0,4311	0,3551	0,1987	0,9096
Source: Moel and Tufano (2001), Ofentse Maduma (Anglo Platinum), Joel Malapane (Marlin Mining Company), Department of Minerals and Energy (ZA), Department of Statistics (ZA)								

is highly significant for South African gold mines, than it was for North American mines as per Moel and Tufano's (2001) study for previously opened mines. Thus, it is 93, 34% for South Africa. Moel and Tufano (2001) confirmed the same concept. However, increasing volatility is negatively related to a previously closed mine, but is statistically significant. Moel and Tufano (2001) confirmed that there is a negative relation, but it is statistically insignificant. One reason might be that gold mining contributes a significant portion to South African's Gross Domestic Product (GDP) in relation to North American's GDP.

Column C confirms that a mine increasing variable costs is less likely to remain open. Increasing fixed costs increases the likelihood of a mine to remain open. This is consistent with Moel and Tufano's (2001) findings and the prediction of the model. Variable costs are generally easy to maintain as trade unions and mining managers negotiate labour's packages. In South Africa, most of the (labour force) packages are in line with the South African inflation rate.

Coefficients for marginal costs are negative, but positive for fixed costs. Thus, clearly confirming that variable costs can be controlled, but fixed costs cannot be controlled. Proper negotiations are one way of maintaining fixed costs.

An increase in gold reserves increases the likelihood of a previously opened mine to remain open. This is consistent with Moel and Tufano (2001) and the prediction of the model. The paper was not able to confirm the joint effect of reserves and costs because as stated earlier, costs and reserves are taken for Moel and Tufano's (2001) study. Reserves in their study do not reflect reserves within South African mining industry. Given that South Africa contributes a significant portion of gold to the world, it makes sense to assume that there should be more reserves within the South African mining sector. However, it is hard to determine the quantity of the reserves from the South African mining sector. In Moel and Tufano's (2001) study, joint effect of reserves and costs lead to multicollinearity. Multicollinearity is solved through step-up wise regression, taking into account all independent variables that are correlated to the dependent variable. As stated earlier, the answer might be an open-ended one because the independent variables used are for the North American mining industry as per Moel and Tufano (2001). However, this should give some idea as to which of the independent variables has more bearing than others.

Increasing interest rates increases the likelihood of a previously opened mine to remain open. For this study, the correlation between annual gold prices and nominal interest rates is not strongly positively ($\rho = 0, 18$) and p-value for statistically significance is 0, 2889 versus 0, 8888 from Moel and Tufano (2001). But the results confirm the findings of Moel and Tufano (2001). The same as in Moel and Tufano (2001) do not necessarily confirm increasing likelihood of opened mines remaining opened. To see the impact of deflated prices, the researcher used the South African consumer price index (CPI) to deflate the gold prices. The variables confirm the prediction of the model and Moel and Tufano (2001). Thus, an increase in deflated gold prices increase the chances of a previously opened mine to remain open, and it is statistically significant. The correlation coefficient between deflated gold price and opened mines is forty percent. The pseudo R^2 for deflated gold price and mines being opened is high.

The dummy representing mine technology and capitalized costs for measuring reopening and closing costs confirm that as costs increases, open mines are likely to remain open, and closed mines are likely to open. Results are supported by Moel and Tufano's (2001) study and the prediction of the model. Bear in mind that in Moel and Tufano's (2001) study, most observations were lost, hence the validity of this result is an open ended one, as assumed their costs to be correct. However, it does give us some picture on the technology variable.

In order to do a step-up wise regression, let us say opened mines are represented by *o*, costs (fixed and variable costs together) by *c*, interest rates by *i*, reserves by *r*, fixed costs individually by *f* and marginal costs by *m*. After step-up wise regression, the results are as follows in a descending order as per correlation co-efficient (ρ) are as follows; $\rho_{(o;r)} = 0{,}21$, $\rho_{(o;i)} = 0{,}18$, $\rho_{(o;m)} = 0{,}05$, $\rho_{(o;c)} = 0{,}012$ and $\rho_{(o;f)} \approx 0$.

For the South African mining industry, it makes sense that gold reserves have probably the highest impact on whether or not to continue with mining operations. As stated earlier, mining contributes a significant portion to South Africa's GDP. The second variable that has been high with opening of mines is interest rates. In Moel and Tufano's study (2001), interest rate had the highest impact on whether or not to continue with mining operations. The US dollar has been the widely used currency in the world for a long time. The movement in the American dollar should have a significant impact on the margins of the North American mines. As interest rates movements have a direct impact on currencies' values, it makes sense with what Moel and Tufano (2001) found in relation to their study. The impact of interest rates in South Africa is different from North America, because of different mining environments.

For South Africa, it is sensible that fixed costs have less impact than variable costs in terms of opening and closings of mines. The South African mining industry is highly protected by different stakeholders. We know that governments use workforces as in gaining votes for public office. Given that most South Africans are semi-skilled or unskilled and mining industry contributes handsomely to the country's GDP, there is no reason why the mining sector should be immune to tighter labour laws. For example, retrenching mining workers takes a lengthy legal procedure in South Africa and under certain situations, mining strikes are considered legal by the South African labor laws.

CONCLUSION

Results of this study showed that opening and closings of gold mines in South Africa between 1980 and 2002 constituted optionality. Using variables (for example, costs, reserves, other related figures) from Moel and Tufano (2001) supported the notion of mining managers acting accordingly as per variables' changes in order to maximize

margins from mining operations. The two hypotheses in this paper are supported by the data empirical tests. However, the overall answer might be open ended because of non-homogeneity of mines in South Africa and North America. For this paper, it is assumed that all related variables from Moel and Tufano (2001) are *"representatives"* of the South African mining industry.

Another interesting factor is that interest rate tends to have a high impact to option values of gold mines in ZA, while in other empirical studies, interest rates influenced the opening and closing of mines, but interest rates were not major drivers. One of the reasons why interest rates have such a *"huge"* impact in ZA is that the South African currency (Rand) is one of the highest traded currencies in the world, and as the value of each country's currency is closely related to its interest rates; therefore, what happens to the country's currency should have a replicator effect on the country's interest rates. The gold prices had the second biggest impact of the emergence of optionality, as it would be expected, this is largely due to the fact that gold is largely regarded as a currency than a precious metal because of its tradability. In principle, opening and closing of South African gold mines during the 1980-2002 period were largely currency changes driven than anything else. Lastly, gold-mining investors would have been exposed to extra *"values"* by applying ROs as opposed to using TVMs.

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