Optimal Hedging Decisions for Gold Miners: How Much Future Production Should a Gold Miner Forward Sell?

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Abstract

This paper attempts to answer the question of how much of its current production a gold producer should hedge by forward selling. We develop a model which allows a company manager to determine the optimal (profit-maximising) hedge, and an estimate of the risk of company failure, based on an estimate of the forward price of gold; the mine's operating costs; and the company's tolerance to debt. The model is illustrated with data drawn from historical gold prices and recent Australian company data. By simulating multiple instances of companies operating with different degrees of forward selling under varying levels of volatility in the price of gold, it was shown that the optimal degree of forward selling increased as volatility increased. The model allows managers to gain insights into the effect of volatility on a company's return given its particular cost structure which in turn, supports more informed decision making. The model illustrates why, during the recent period of constant growth and low volatility in gold prices, gold producers are reducing their hedge books.

Keywords: Risk, Hedging, Mining industry, Simulation

1. Introduction

Financial derivatives have a long history of use as a means by which producers of a commodity can insure, or hedge, against unfavourable variations in the sale price of that commodity. Although these hedges have a history in our agrarian past due to the precarious nature of primary production, they have become a feature of the market for a wide variety of production in more recent times (Bernstein, 1996). Because the price of gold varies widely over time depending on market sentiment, a hedging strategy commonly used by gold mining companies is *forward selling,* which consists of an agreement made by a miner with another party (usually a bank) to sell all or part of its future gold production at an agreed price to be delivered at an agreed date in the future. By engaging in this practice, the mining company knows with certainty what the revenue on the forward sold production will be at the time of delivery. This practice is also widespread amongst producers of a wide range of commodities.

The benefit of forward selling for a gold mining company is that it gets a predetermined price for its production and avoids the risk of making a loss should the gold price fall. In this way, the company avoids the expected costs associated with financial distress (Tufano, 1996; Stulz, 2003). The disadvantage of this practice is that in a rising gold market, forward estimates of gold prices tend to underestimate future prices, a condition known as backwardation. Consequently, in this situation, forward selling results in miners failing to realise the maximum profit from their production because by forward selling the miner has actually gambled that gold prices will decrease with the miner having no exposure to higher prices should the market increase (Dunn, 2001).

As Figure 1 shows, the gold price has varied widely over past years, however, in recent years the gold price has been constantly increasing with the effect that forward selling has

lost some of its attractiveness. As a consequence, the degree of hedging has steadily declined throughout this century resulting in the lowest amount of gold forward sold since 1994 (GFMS, 2007; Zonneveldt, 2007). Apart from backwardation, other cited reasons for this decline are a renewed optimism amongst miners that price improvements will continue, leading to investors disapproving of heavily hedged producers (Reeve et al., 2003). Some major Australian miners who have reduced their exposure to hedges recently include Newcrest Mining, Kingsgate Consolidated – who at one point had been almost 100 per cent hedged when completely debt financed (Kingsgate, 2006) but are now on the verge of closing their hedge book, and Lihir Gold (Zonneveldt, 2007).

Figure 1. Gold price $US/oz 1970 - 2006
Source: COMEX, London Bullion Market Association

A further reason for the unpopularity of hedging has been the bad press associated with a number of spectacular failures of hedged companies. These include (a) Pasminco, who in 2001 reportedly incurred a loss $867 million as a result of failed currency hedging (Dunn, 2001) and (b) Sons of Gwalia, who in 2004 were Australia's third largest gold producer and were driven to bankruptcy because they had committed to deliver more gold than they could produce (Bartholomeusz, 2004). However, in both these cases, the reason for company failure is blamed on the company behaving as a speculator on the market, rather than behaving as a miner just hedging anticipated production (Easton, 2006; Zonneveldt, 2007).

In the climate of high gold spot prices there has been a trend towards companies mining ore with lower yields and thus higher production costs than could be considered during times of low gold prices. This is illustrated in Figure 6. Additionally there has been a trend towards companies using greater levels of debt financing in order to proportionally increase returns through increased financial leverage or to fund company growth. As a consequence of these trends, companies have an increased sensitivity to changes in the price of gold, and theory suggests that they are more likely to face financial distress should prices for gold fall (Tufano, 1996). Pegasus Gold Inc. is one example of a company that found itself in exactly that position when falling gold prices in 2001 in the face of expensive extraction costs sent the company bankrupt (McClure, 2001). Thus the recent trend away from hedging is in contrast to the increased risk faced by companies that engage in these practices. Thus, and in spite of the arguably "good times" for miners, the question of how much a company should hedge remains relevant.

In order to balance the risk of financial distress in the face of a falling gold price against undesirable possibility of failing to fully capitalize on the benefits that accrue from an increasing gold price, this paper presents a model to determine the optimal gold hedge ratio, that is, the optimal proportion of gold to be forward sold, for gold mining companies. This minimal hedge will protect the company from the downside risk, should gold prices fall, whilst enabling the company to benefit from the increased profitability due to increases in the gold price. As a result, decision makers will be in a better position to effectively safeguard their shareholders' investments while maximising their return on investment.

The following section presents an analysis of the reasons why companies hedge and current approaches to determining the financial benefit of hedging through a review of relevant literature. In this section we show that although the reasons for hedging are well understood for companies in general, these analyses do not present a framework for

determining the degree to which a particular company should forward sell its production in a given situation. We address this gap in the literature in Section 3 by presenting a discrete-event simulation model from which the expected value of the company's earnings can be determined, as well as the risk of financial distress based the proportion of production a manager chooses to forward sell. In section 4 we illustrate the model using parameter values that reflect historical gold prices and recent operating ratios for Australian mining companies. Section 5 summarises and concludes the paper. Historical variation in the gold price and company operating ratios are summarised in Appendix 1.

2. Hedging decisions

Empirical studies have examined the characteristics of mining and other companies, through regression analysis of their financial statements, in order to determine the relative significance of factors affecting a company's decision to hedge (e.g. Tufano, 1996; Nguyen and Faff, 2002; Dionne and Garand, 2003). This research supports the idea that an important reason that companies hedge is to minimise the risk of financial distress, which in turn increases company value by eliminating a variety of bankruptcy-related costs. Other reasons for hedging include managerial aversion to risk due to management having a significant investment in the company by direct share ownership or through options and to obtain taxation benefits. However, these benefits are more or less congruent with the fortunes of the company with respect to profitability and company survival – which are the focus of this paper – and are not further developed.

The prevention of financial distress as a reason for hedging holds that the expected value of the firm can be increased by reducing the likelihood of financial distress. This is due to the resultant reduction in deadweight costs and increase in debt capacity (Smith and Stulz, 1985; Judge, 2003). Regression based studies have tended to test this hypothesis by using

particular financial ratios as a proxy for the probability that a company will face financial distress. See, for examples of this approach applied to gold producers (Tufano, 1996; Dionne and Garand, 2003; Judge, 2006) and more generally (Francis and Stephen, 1993; Berkman and Bradbury, 1996; Haushalter, 2000; Nguyen and Faff, 2002). These ratios include: leverage, or the degree of debt financing, the proportional cost of production relative to sales, and the proportion of net income required to service borrowings amongst others. These studies have shown that the higher the firm's leverage and the lower its interest cover ratio, the more likely a company is to hedge. This, in turn, implies that the greater the expected financial distress costs (because of riskier operations), the more the firms hedge (Judge, 2006). However, a difficulty in modelling the relationship between financial distress costs and hedging in these empirical studies is that there is not a clear consensus between researchers as to how to measure financial distress costs (Judge, 2003). Production costs have also been used as an indicator of the likelihood of financial distress, from the premise that a firm with higher per-unit production costs is more susceptible to commodity price fluctuations and hence has a higher probability of financial distress (Dionne and Garand, 2003; Tufano, 1996; Haushalter, 2000).

Analytical studies that look specifically at forward selling, as opposed to hedging more generally tend to take the approach of estimating the expected cost of the risk of financial distress over a finite period taking into account the anticipated variations in the value of the commodity. A typical approach is described in (Stulz, 2003), where the cost of this risk is valued as the expected cost of financial distress should the future price of gold fall below a threshold and comprises the repayment of debt in addition to the additional costs of restructuring finances and managing legal affairs caused by bankruptcy etc. As an indication of the magnitude of these additional costs (Weiss, 1990), in a study of 31 companies

determined the direct costs of managing bankruptcy as ranging from 2.8 to 7 percent of a company's total assets.

Existing approaches to determining hedging policies have several limitations. Whilst analyses of the factors affecting a company's decision to hedge in empirical studies do yield insights into reasons why a company would hedge, they give little guidance for the hedging decision of a particular company at a particular point in time. That is, taken on their own, these models cannot be used as models for decision making given a company's particular circumstances. In addition, the proxies for financial distress used in these studies are not always intuitively apparent, consistent, or easily determined. Quantitative models tend to base profit and loss calculations on a single period of operation which fails to account for losses or retained profits being carried from year-to-year. Estimates of the cost of financial distress are limited to the operational costs of restructuring financial arrangements and fail to account for the loss of future revenue in the catastrophic event that the company does fail. Because of this, current models tend to underestimate the cost of financial distress. Finally, these models tend to treat hedging as an all-or-nothing decision, in spite of empirical evidence that companies do partially hedge, and thus do not offer a means of determining an optimal proportion of production to hedge.

In order to overcome the limitations of previous approaches to determining a hedging policy, we propose to determine the proportion of its current production a given company should forward sell in order to maximise its revenue adjusted for the risk of company failure based on parameters that may be known or estimated by a manager. In this way, the optimal policy could be determined under a variety of scenarios based on the preference of a manager. A manager could choose to maximise expected earnings, or minimise risk of company failure to an acceptable level. The model takes as its inputs parameters shown by earlier studies to be significant in a company's hedging decision. Because there is no clear

consensus of the magnitude of financial distress costs are we use debt at an absolute level, as determined by the company, as a proxy for financial distress. Production costs may be known, or can be estimated by the company from past operations or industry benchmarks. Variability is introduced into the model through the future price of gold. This is a random variable whose parameters may be determined from historical observation, by estimation, or by intuition.

3. A proposed model

Our approach to determining the optimal level of forward selling uses discrete-event simulation to model the returns of a mining company over its effective lifetime. The simulated company will make profits and distribute dividends to shareholders in good years; accrue debt when adverse changes in the gold price result in losses; and fail through bankruptcy in the most adverse of situations. The model calculates the Present Value of future earnings distributed as dividends in order to determine the value of the company from an owner's or investor's perspective, as a multiple of the current value of the company's production. By simulating multiple instances of a company operating with varying levels of forward selling, it is possible to determine the relative profitability and survival rates as a function of the amount of production forward sold. This then allows the optimal hedge ratio to be determined by a manager or investor based on their assessment criteria.

Inputs to the model are:

- The current forward gold price, that is, the hedged gold price. We assume this to be 1 by default in this study and all other terms in the model are scaled against this. We assume the time period to be one year.

- The one-year actual price of gold, that is, the unhedged price of gold one year hence. This is a random variable representing the true price of gold and may be derived

from historical data or estimated. We model this as a normally distributed random variable having a known mean and variance in this study.

- The company's ability to carry debt, that is, the company's permitted maximum Debt to Equity (DE) ratio.

- The expected cost of production as a proportion of the hedged sale price. This assumes that at the start of the production period the miner commits to produce gold at a known proportional cost of production. The actual unhedged gold price at the time of sale may vary.

- The proportion of production that is forward sold (hedged).

- The time at which the forward sale contract is settled. In this study, we assume for simplicity that all forward sales are for one year only.

- The required return on investments (the discount rate for future earnings).

The output of the model is the number of years the company operates until failure, and the present value (PV) of all earnings over the operating period, determined as

$$PV = \sum_{i=1}^{n} \frac{d_i}{(1+k)^i} \tag{1}$$

where

n = the number of periods a company operates until bankruptcy
d_i = the dividend earned in year i
k = the required rate of return on investments (the discount rate).

Equation (1) is the PV of the company, that is, the accumulated returns from the investment ignoring the cost of the initial investment. Consequently, PV has the simple interpretation as the amount that one would reasonably pay for the investment, based on a required return of K percent per annum. The proposed model is similar in derivation to (Tufano, 1998) however we eliminate the quantity of production as a variable with the

effect that our model is scaled against the per-unit forward sale price of gold (implicitly assumed to be 1) and thus inputs and calculated values are ratios of this price. Like Tufano, we assume that all distributable earnings accumulate at the prevailing discount rate. By scaling against the forward price of gold, we exclude year to year changes in the base price of gold from affecting the calculation of the PV. This allows us to compare the effect of different hedging ratios relative to costs, maximum allowable debt and the variability in the gold price without the distorting effect of longer term changes in the price of gold.

The discrete-event simulation cycles through the sequence of events given in Table 1 represent, in general terms, the main financial events for the company during each production year. The model's output is the PV of distributed dividends over the life of the simulated company, and the number of years the simulated company operates until failure. By simulating multiple instances of a company operating under the same parameters it is possible to determine expected returns to a required accuracy. Borrowing an approach from actuarial risk modelling, we use the survival rates to determine a lifetime profile for simulated companies from which the risk of company failure can be determined (Beard et al., 1984).

Table 1. The sequence of stages in the discrete-event simulation

Start	The company commences operation in Year 0 with no debt.
Repeat	The company commits to hedge a certain proportion of its current year's production by forward selling at a known price.
	The company then produces gold at a cost, which is a known proportion of the hedged sale price.
	The company then sells the gold it has produced. The value of the forward sold production is known and the value of the unhedged portion is determined randomly.
	Expenses, which are a known proportion of the hedged price, are then paid.
	If the company has made a profit in the current year, then the funds are distributed in the following order: (a) Any outstanding debt is paid off. (b) The surplus is distributed as dividends which accrue at the discount rate (see Equation (1)).
	If the company has made a loss, then this debt accrues with debt from previous years.
Until	If the company's debt has not exceeded the permitted Debt to Equity ratio, then the company commences the next year's cycle.
End	If the company's debt has exceeded the permitted DE ratio the the company is deemed to have failed through bankruptcy. PV and company lifetime are reported.

The model's input parameters would all be familiar to most managers and each has a straight-forward, intuitive interpretation. Some parameters, such as the proportional cost of production could be estimated from a company's historical operations. The estimated future price of gold relative to forward prices might be estimated from market data, or estimated by a manager having a 'gut feel' for how the market was going to perform. In the simulation study that follows, the estimated future price is assumed to be a normally distributed random variable having a known mean and standard deviation however, in other situations, the model could use random variables sampled from an empirical distribution or historical data directly. Other inputs, such as the maximum permitted debt-to-equity ratio, may be set based on the company's attitude to debt and permitted borrowings. The discount rate for

investments may be determined as the company's required return on investments or based on the prevailing risk free rate for investments.

Although in practice, a company would change its hedging policy from year to year in light of its current financial circumstances, this model assumes the proportion to be hedged, and all other parameter values are constant during any one instance of a simulated company. In this way the effect of the hedging decision under the current operating conditions is seen through the repeated application of the hedging policy within an unchanging operating environment. This allows the effect of hedging on profit and survival to be determined for any given set of parameter values. The model could be rerun from year to year to take into account changing operating conditions.

4. Simulation study, results and analysis

In this section, we illustrate how company performance is affected by the degree to which it forward sells its coming year's production. We consider the effect of this decision on the company's Present Value of lifetime earnings and one-year survival probability. In the following trials we assume that an investor believes that, on average, they would get a greater return by not hedging than they would by hedging. This follows from the principle that a rational investor expects a greater return from a riskier investment all other factors being equal (Stulz, 2003). This assumption is also justified by the increase in the average price of gold over the long-run. Other input data has been chosen to create a relatively harsh operating environment due to high (but not unknown) volatility in the price of gold, high operating costs and a low debt threshold. The point of this choice of parameters is to illustrate the behaviour of the model in situations where company failure is a significant possibility rather than to accurately represent the current circumstances for a particular company. Appendix 1 presents a summary of historical variation in the gold price and

operating ratios for Australian gold miners. From these data it can be seen that the choice of parameters that follow are within range of values that could occur in reality.

Of the company performance measures, the PV of lifetime earnings has been described in Section 2 and can be interpreted as the value of the company as a multiple of the current year's sales. We also calculate the one year probability of survival. We calculate this by estimating the average lifetime for simulated companies and noting that the lifetime of simulated companies is approximately exponentially distributed. The one year probability of survival p is then calculated directly from the mean as $p = e^{-1/\theta}$ where θ is the average company lifetime. Simulation trials were censored for surviving companies at 200 years. Although this duration well exceeds the lifetime one could reasonably expect in reality, imposing a limit of 200 years means that the simulation trials operating under more risky conditions were not unduly censored, allowing an accurate estimate of lifetime distribution. The contribution of future earnings to PV for years well into the future were relatively small for example, at 100 years the discount factor is 0.0076 and at 200 years 5.78×10^{-5} meaning that for long-lived companies, the PV more or less represented the company's income in perpetuity.

4.1 Experiment 1

In the following experiment it is assumed that: a manager expects the price of gold to rise 10% per annum on average with a volatility of 30%, (this accords to the historical variation presented in Appendix 1); gold that is forward sold earns its forecast value with certainty; the proportional cost of production is 80% of the sale price; the maximum permitted debt level is 20% of the sale price; the discount rate is 5% per annum. The proportion of gold forward sold was varied from 0 to 100% in 10% intervals and that 1000 trials were run at each level.

Figure 2 shows the distribution of PV as the proportion of gold sold forward varies. When the company commits 100% of its forecast production to forward sales, the PV of lifetime earnings is 4 times annual sales. This corresponds to the infinite sum of 20% of sales per annum discounted at a rate of 5%. As the proportion of gold forward sold decreases, the variability of returns increases as seen in the boxplot. As the proportion of gold forward sold decreases, the median PV increases until a maximum of approximately 5 is reached when the proportion of gold forward sold is 0.4. Table 2 shows that average PV is actually maximised when the proportion forward sold is 0.5. As the proportion of gold forward sold decreases beyond this point, the median PV decreases as the variability of future returns increases the probability of company failure.
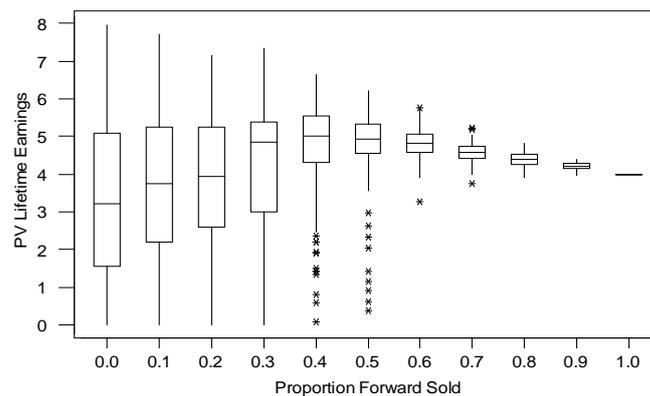

Figure 2. PV of simulated companies as a function of the proportion of forward selling

Table 2 also shows the average lifetime and the one-year survival probability of simulated companies. As the proportion of forward selling increases, the average company lifetime increases to a maximum of 200 years, being the censoring level. The one year probability of survival increases accordingly. When the proportion of forward selling is low, the average company lifetime is approximately equal to the standard deviation of company

lifetime which justifies the approximation of lifetime by the exponential distribution (Evans et al., 1993).

Table 2. Lifetime earnings and survival statistics as a function of the proportion of production forward sold

Proportion forward sold	Average PV lifetime earnings	Standard deviation PV of lifetime earnings	Average company lifetime	Standard deviation company lifetime	One year probability of survival
0.0	3.09	2.05	18.99	18.01	0.95
0.1	3.41	1.98	24.91	22.92	0.96
0.2	3.75	1.92	37.76	36.97	0.97
0.3	4.30	1.69	63.65	55.29	0.98
0.4	4.72	1.29	118.58	72.37	0.99
0.5	4.84	0.83	169.59	57.96	0.99
0.6	4.79	0.41	196.87	20.34	0.99
0.7	4.60	0.28	200.00	0.00	1.00
0.8	4.40	0.18	200.00	0.00	1.00
0.9	4.20	0.10	200.00	0.00	1.00
1.0	4.00	0.00	200.00	0.00	1.00

4. 2 Sensitivity analysis

In this section, a sensitivity analysis is performed showing the effect of changing volatility on the optimal degree of forward selling. For this experiment, the proportional cost of production, maximum allowed debt and the discount rate are those from the previous experiment. The expected annual increase in the price of gold is 10%, as used before. Volatility is varied from 10% to 50% in 10% increments.

Figure 3 shows the average PV as a function of the volatility of the one year variation in the price of gold and the degree to which a company forward sells. It is evident that when an increase in gold is expected, it is never PV maximizing to forward sell the whole year's production. The degree to which it is PV maximizing to forward sell varies as a function of volatility. When volatility is low (10%) it is optimal not to forward sell any production. As

volatility increases however, the optimal proportion to forward sell increases to 10% when
volatility is 20%, 50% when volatility is 30% and finally 70% for the two most volatile
cases. The maximum possible PV that can be obtained decreases as a function of volatility
as well, from a maximum PV of 6 when volatility is 10% to a maximum PV of 4.4 when
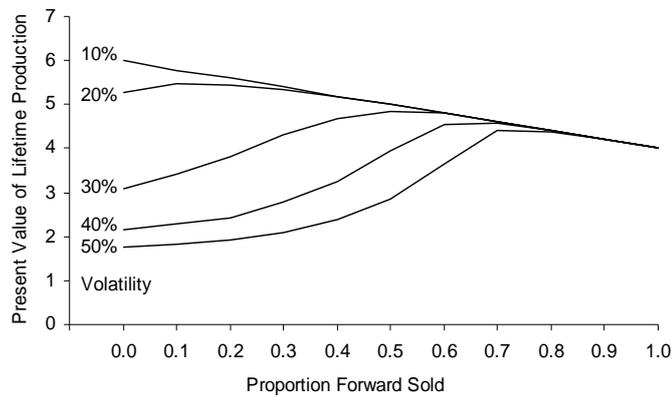volatility is 50%.

Figure 3. Average PV as a function of the volatility of the gold price and the proportion of
gold forward sold

Figure 4 shows the one-year survival probability as a function of both of the volatility of
the one year variation in the price of gold and the degree to which a company forward sells.
Looking at Figure 4 in conjunction with Figure 3, it is evident that the proportion of forward
selling that maximizes PV in each case corresponds to a probability of survival very close to
1. That is, it is never profit maximizing for the company to fail too early in its existence.
Although the probability of survival increases as the proportion of forward selling increases,
the previous figure shows that being too cautious, that is, hedging too much is not a profit
maximizing strategy. Although the precise tradeoff between risk and profitability remains to
be more fully analysed, a manager, not sure of profits but motivated by risk, might be
guided by determining the proportion of forward selling that yields a one year survival

probability in the vicinity of, say, 99%. However, this assumption depends on the ratio between profit and survival, and is a topic for further investigation.
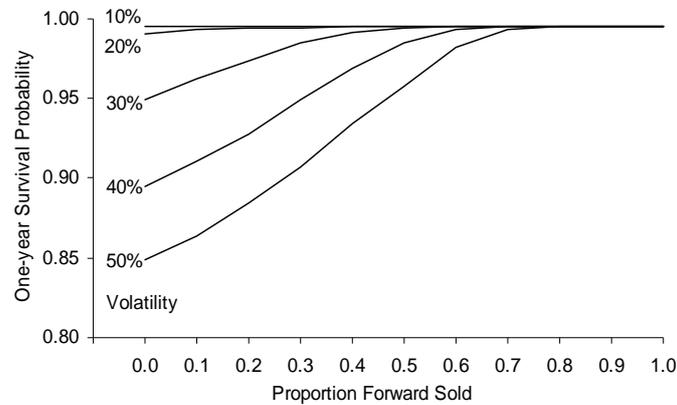

Figure 4. The one-year survival probability as a function of the volatility of the gold price and the proportion of gold forward sold

5. Summary and conclusions

This paper has presented a model to determine the optimal proportion of future gold production to forward sell in order to maximise the Present Value of future income. The model takes as its inputs, an estimate of the one year increase in the price of gold, and the volatility of that future price. These may be derived from historical data or estimated. Other inputs are: the maximum permitted debt level, the proportional cost of production and the discount rate for future earnings. The model then simulates production over a number of years, accruing income and ceasing to operate when debt reaches a certain threshold. By simulating multiple instances of companies operating with the same parameters but with varying levels of forward selling, it is possible to determine the optimal degree of hedging, the resultant Present Value of the company under that decision as well as the associated probability of survival.

The model was illustrated using data that was representative of the historical variation in the price of gold and of current company operating ratios. The sensitivity analysis showed that increasing volatility increased the optimal level of forward selling whilst reducing the optimal PV of lifetime production. In periods of relatively low variation in gold prices it is optimal to operate with low levels of hedging. As an aside, the one-year volatility of the gold price is currently approximately 10% and thus the analysis gives some insight into why producers are currently reducing their hedge books. A more thorough investigation of the relative contributions of a company's operating ratios and price variation to the optimal PV remains to be conducted.

Appendix 1

This section presents an analysis of data relevant to the assumptions made in choosing representative parameters for the illustration of the model in Section 4. The analysis shows that the parameter values we have chosen could reasonably have come from a contemporary mining company. Similarly, variations in the one-year price of gold also reflect recent history. The section concludes with an illustration of the changes in the proportional cost of producing gold in recent times.

Variation in the one year price of gold

Using the gold price ($US/oz 1970 – 2006) data, from which Figure 1 was derived, we calculate the one-year change in the gold price relative to the base year. This annual percentage change in the price of gold is shown in Figure 5. These data have mean of 1.1 and a standard deviation of 0.30 – corresponding to a 10% increase in gold on average per annum and a standard deviation from year to year of 30%. These annual changes do not exactly represent the difference between the gold future price and the unhedged price taken

by a forward seller because in practice, the forward seller would obtain the base (spot) price of gold plus the risk free rate of interest (approximately 5% over the period studied) less a gold lease fee (approximately 2%). See Levy (2001) for a sample calculation. Subtracting the annual risk free interest rate less the gold lease fee means that a non-hedger, over the period studied would expect to make approximately a 7% increase over the hedged price but bearing a risk of around 30%. Interest rate variations over the period would increase the volatility by a small degree but these have not been factored in.
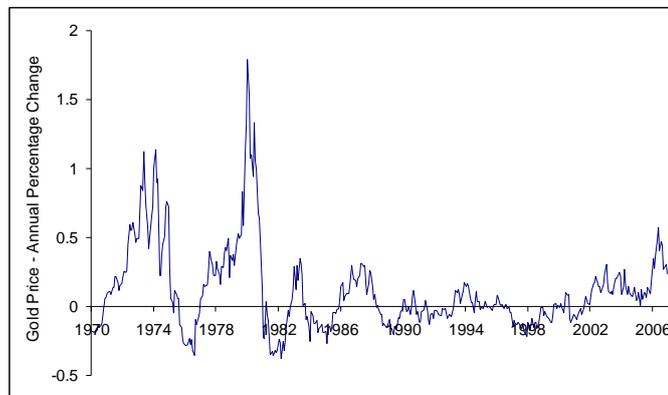

Figure 5. Gold price 1970 - 2006, annual percentage change
Source: COMEX, London Bullion Market Association

Company benchmarks

Using company data from Australian Stock Exchange (ASX) listed companies from 1997 to 2005 we estimate the cost of production as a proportion of the average sale price for gold over that year. Production costs in Australian dollars were converted to US dollars at the average exchange rate over the given year. We also model companies' Debt to Equity (DE) ratios using company annual report data obtained over the years 1979-1999. The criteria for including company data in this analysis were that (a) the company be listed with the ASX, (b) the company's main activity was listed as gold mining, and (c) the company

had produced gold in a given year and published an annual report. A summary of descriptive statistics for these are given in Table 3.

Table 3. Summary of benchmark data

Statistics	Cost of production as a proportion of average sale price	Debt to equity ratio
No. of observations	220	89
Average	0.704	0.463
Standard deviation	0.248	0.488
Minimum	0.270	0.000
Lower quartile	0.520	0.120
Median	0.692	0.318
Upper quartile	0.840	0.645
Maximum	1.960	2.351

Figure 6 shows the proportional cost of production over the survey period on a per-year basis. From this boxplot it can be seen that from a minimum median cost in 2000 and 2001, corresponding to a recent local minimum gold price, the proportional cost of gold production has been increasing as mining companies have turned to lower yielding ore during the current period of increasing gold prices. Clearly, with production costs greater than 100% of the sale price for some miners, this trend will not continue.
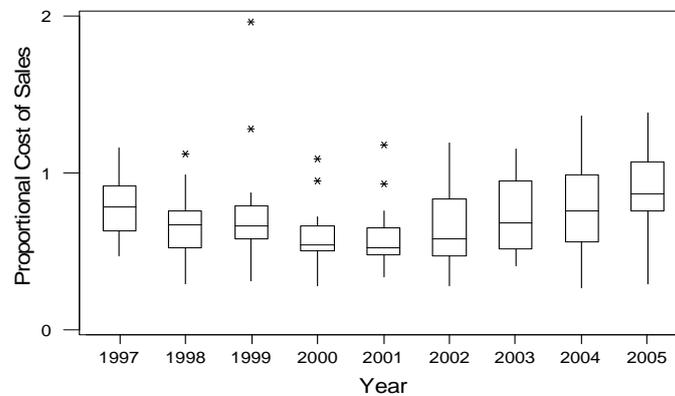

Figure 6. Proportional cost of sales 1997 - 2005

References

Bartholomeusz, S. (2004) Sons of Gwalia's gold hedging had big holes. Sydney Morning Herald, Sydney.

Beard, R.E., Pentikäinen, T., Pesonen, E. (1984) Risk Theory: The Stochastic Basis of Insurance. Chapman and Hall, London.

Berkman, H., Bradbury, M.E. (1996) Empirical evidence on the corporate use of derivatives. Financial Management, 25(2), 5-13.

Bernstein, P.L. (1996) Against the Gods: The Remarkable Story of Risk. John Wiley & Sons, New York.

Dionne, G., Garand, M. (2003) Risk management determinants affecting firms' values in the gold mining industry: New empirical results. Economics Letters, 79, 43-52.

Dunn, J. (2001) Through the currency hedge and down the mine. The Australian, Sydney.

Easton, S. (2006) Sons of Gwalia: Errors in speculation and hedging. The Australian Economic Review, 39, 453-456.

Evans, M., Hastings, N., Peacock, B. (1993) Statistical Distributions. John Wiley & Sons, New York.

Francis, J., Stephen, J. (1993) Characteristics of hedging firms: an empirical investigation. In Schwartz, R.J., Smith, C.W. (Eds.) Advanced Strategies in Financial Risk Management. New York Institute of Finance, New York.

GFMS (2007) Global Hedge Book Analysis Q4-2006. GFMS, London.

Haushalter, G.D. (2000) Financing policy: Basis risk, and corporate hedging: Evidence from oil and gas producers. The Journal of Finance, 55(1), 107-152.

Judge, A. (2003) Why do Firms Hedge? A Review of the Evidence. Middlesex University Business School, The Burroughs, Hendon.

Judge, A. (2006) Why and how UK firms hedge. European Financial Management, 12, 407-411.

Kingsgate (2006) Kingsgate Consolidated Limited Annual Report. Kingsgate Consolidated Limited, Sydney.

Levy, I. (2001) Hedging at its most basic. AIG Journal, 2001, 1-3.

Mcclure, R. (2001) Pegasus Gold - from Boom to Bankruptcy. Seattle Post, Seattle.

Nguyen, H., Faff, R. (2002) On the determinants of derivative usage by Australian companies. Australian Journal of Management, 27, 1-24.

Reeve, T., Cross, J., Fraenkel, M. (2003) The gold hedge indicator. The Alchemist, 31, 15-16.

Smith, C.W., Stulz, R. (1985) The determinants of firms' hedging policies. Journal of Quantitative Finance, 20, 391-405.

Stulz, R. (2003) Risk Management and Derivatives, Mason, South-Western.

Tufano, P. (1996) Who manages risk? An empirical examination of risk management practices in the gold mining industry. The Journal of Finance, 51, 1097-1137.

Tufano, P. (1998) The determinants of stock price exposure: Financial engineering and the gold mining industry. The Journal of Finance, 80, 1015-1052.

Weiss, L.A. (1990) Bankruptcy resolution: Direct costs and violation of priority of claims. Journal of Financial Economics, 27, 285-314.

Zonneveldt, M. (2007) Hedging hangs in the balance. Herald Sun, Melbourne.