GOLD PRICES, EXCHANGE RATES, GOLD STOCKS AND THE GOLD PREMIUM

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ABSTRACT

This paper studies the exposure of the stock prices of Australian gold mining firms to changes in gold prices and the valuation effects of gold price exposure. Gold-mining firms have significant gold price exposure; the price of the average gold-mining stock moves 0.76% for each 1.00% change in Australian-dollar-denominated gold prices. Evidence from the behavior of stock price sensitivities suggests that gold-mining firms can be represented as a portfolio of gold assets and embedded real options. Simple discounted cash flow models systematically underestimate the price of gold stocks. The evidence suggests that the valuation error is due to both the failure of discounted cash flow models to reflect managerial flexibility that is embedded in the operation of gold mines and the misuse of discounted cash flows techniques.

INTRODUCTION

Firms routinely analyze investment opportunities, which include opportunities to vest in real assets potentially favorable conditions at some future t in time. These investment opportunities are called real options. For example, the initial investment in research and development, exploration and access to new markets. Equally true, analysts are required to value firms that can be characterized as a portfolio of such projects. These projects share three important characteristics: they are discretionary and whether or not they are undertaken depends upon uncertain future conditions, the firm learns more about the value of the project over time as uncertainties are resolved, and the firm has a great deal of flexibility to adapt to this new information. For example, the mining firm can choose to suspend exploration when the gold price falls below the level necessary to make the lease economically viable.

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The same firm may choose to defer exploration or the development of the false. These options are referred to as invest flexibility.

This concept of the flexibility with which management adapts to this new information can be generalized to most projects and firms, if we recognize that management can revise operating decisions in response to market conditions. For example, the manager of a gold mine has the ability to expand in good times or to contract, 'monthball' or abandon when times are bad. The implication is that management use flexibility through decisions, which limit the firm's exposure to losses while retaining profit potential – an asymmetric payoff. These options are referred to as operating flexibility.

Empirically evidence suggests that valuations of firms or projects incorporate managerial flexibility, with the asset price exceeding the discounted cash flow valuation and the difference being consistent with optional pricing.[1] Davis (1996) summarizes the empirical research on the size of the real option premiums in the mining industry, documenting that the discounted cash flow valuation of the 10 major US and Canadian gold-mining firms is on average 30% below their market capitalization.

In adopting a discounted cash flow model to value gold-mining firms, we assume that the firm is characterized by a production profile that it cannot alter. That is, the company owns a fixed quantity of gold reserves that it expects to mine at a production rate, which is specified at time zero and remains unaltered over the life of the mine.

In valuing gold mines, this fixed-production model is poorly specified in that gold mines offer classic examples of firms with managerial flexibility and/or real options. At one extreme, when the gold price falls below the firm's marginal production costs, the firm can choose to temporarily or permanently suspend production. In general terms, gold companies hold a portfolio of option on gold, with the exercise price being their marginal production costs. As well as the choices presented by investment flexibility, gold-mining firms can exploit operating flexibility as well. For example, the firm can mine higher or lower grade ore, stockpile ore or processed gold, or change the rate of production.

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[1] Paddock, Siegal and Smith (1988) apply real option techniques to the evaluation of investments in offshore petroleum leases, finding that the actual bids exceed the discounted cash flow valuations by 23%. Berkman (1998) applies real option techniques to the valuation firms in the New Zealand forestry industry, finding that the market price exceeds the discounted cash flow valuations by 6%. While Schwartz and Moon (2000) apply the concept of real options to technology companies, where the majority of their value is thought to come from their real option value.

It follows from identifying gold companies as represented by a portfolio of gold assets and embedded real options that the sensitivity between the changes in company value and changes in the gold price will vary systematically with the level of the gold price. This paper studies Australian gold-mining firms and their exposures to fluctuations in gold prices. This paper measures the size of these exposures, establishing the relationship between US-dollar-denominated (USDD) gold prices and the Australian dollar/US dollar exchange rate. The results indicate that on average a 1.00% change in Australian-dollar-denominated (AUDD) gold prices will induce a 0.76% change in the price of listed gold-mining stocks.

Accepting that these real options have positive value, then ignoring the options embedded in mine operating decisions will tend to understate the value of the gold-mining firm. This underestimation of the gold-mining firm's value is termed the gold premium. This paper examines the determinants of the gold premium. Formally, the gold premium is defined to be the difference between the gold firm's stock prices and its value determined using a discounted cash flow valuation model, discounting expected cash flows using a constant risk-adjusted discount rate. The estimated gold premium is large and positive, with the average premium for the sample of gold-mining firms being 51.9%. The results suggest that the principal determinants of the gold premium are market capitalization and the volatility of the gold price.

However, the paper also evidences that the premium is in part explained by the misuse of the discounted cash flow techniques.

The remainder of this paper is divided into four sections. Section 2 describes the sample. Section 3 provides descriptive statistics. Section 4 estimates the gold price exposure of the gold industry index and a sample of firms using gold return betas. In the context of the determinants of real option values, section 5 examines the sensitivity of gold stocks to gold price variation. Section 6 considers the determinants of gold premium using two models for valuing gold-mining firms, one based on a discounted cash flow model assuming a fixed-production schedule, and the second based on a flexible-production or real-option schedule. Finally, Section 7 concludes the paper.

SAMPLE

This paper initially studies the exposure of 12 gold-mining firms over the period January 1985 to December 1998, to changes in the gold price, denominated in both US dollars and Australian dollars. This sample includes gold firms listed on the Australian Stock Exchange that meet the following criteria.

1. The firm's only assets are their gold mines;

2. The firm's weekly stock return data is reported on Reuters 3000; and
3. The firm is included in analysts' valuation reports of the selected broking firms.

This paper also examines the exposure of all gold firms listed on the Australian Stock Exchange (ASX), over the same sample period. The weekly rate of return on all listed gold firms is estimated using the ASX gold industry accumulation index.

The weekly rate of return on the Australian domestic equity market is estimated using the ASX All Ordinaries accumulation index, while the weekly rate of return on the US domestic equity market is estimated using the S&P 500 index.

Closing weekly values for the indices, USDD gold prices and the Australian dollar/US dollar exchange rates are obtained from LIM.

The same sample of gold-mining firms is used to estimate the gold premium over the period 1994 to 1997. Estimates a firm value using a discounted cash flow valuation model calculated using a constant risk-adjusted discount rate, are taken from the analyst's reports on the gold sector for 8 broking firms.

DESCRIPTIVE STATISTICS

Prior to examining the exposure of gold firms to changes in the gold price, evidence is presented on the properties of the distribution of the levels and rates of return for the closing weekly values of the USDD gold prices, AUDD gold prices and the Australian dollar/US dollar exchange rate.

Table 1 provides descriptive statistics for the USDD gold prices, AUDD gold prices and the Australian dollar/US dollar exchange rate over the sample period. Estimates of the first four moments, the minimum value and the maximum value are reported for the weekly levels and rates of return for the USDD gold prices, AUDD gold prices and the Australian dollar/US dollar exchange rate.

The results presented in Table 1 suggest that the mean rates of return and volatility for the USDD and AUDD gold prices are approximately equal.

An examination of the skewness and kurtosis suggest that the generating distributions for the weekly levels and rates of return for the USDD gold prices, AUDD gold prices and the Australian dollar/US dollar exchange rate are not normal. Normality is rejected at the 1% level for all three generating distributions.

Table 2 presents the autocorrelation functions for the weekly rates of return on the USDD gold prices, AUDD gold prices and the Australian dollar/US dollar exchange rate exhibit statistically insignificant first order autocorrelation.

Table 3 presents the correlation between the weekly rates of return for the USDD gold prices and the Australian dollar/US dollar exchange rate.

Not surprisingly, the weekly rates of return for USDD gold prices, AUDD gold prices and the Australian dollar/US dollar exchange rate are statistically significantly correlated. However, Table 4 suggests that this relationship has varied considerably over time.

Table 1

Gold Prices and Exchange Rates Descriptive Statistics

This table provides descriptive statistics for the USDD gold prices, AUDD gold prices and the Australian dollar/US dollar exchange rate over the period January 1985 to December 1998. Estimates of the first four moments, the minimum value and the maximum value are reported for the weekly levels and rates of return for the USDD gold prices, AUDD gold prices and the Australian dollar/US exchange rate.

Variable	Mean	Median	Standard Deviation	Skewness	Kurtosis	Minimum Value	Maximum Value
Level A$/US$	0.732	0.739	0.056	- 0.287*	-0.161*	0.56	0.88
US$ gold price	$370.13	$372.70	$43.40	0.248&	-0.051	$274.10	$493.50
A$ gold price	$506.72	$487.47	$60.00	1.143*	1.025*	$365.57	$698.74
Rate of Return A$/ S$	-0.0004	0.0010	0.0137	-0.917*	3.712*	-0.0737	0.0499
US$ gold price	-0.0001	0.0002	0.0168	-0.087	2.827*	-0.0768	0.0890
A$ gold price	-0.0003	-0.003	0.0184	0.235*	1.493*	-0.0772	0.0776

Note : *Significant at the 1% level.

Table 2

Autocorrelation Functions for Gold Prices and Exchange Rates

This table presents the autocorrelation functions for the weekly rates of return on the USDD gold prices, AUDD gold prices and the Australian dollar/US dollar exchange rate.

Variable	First Order Autocorrelation	t-Statistic
A$/US$	-0.03	-0.89
US$ gold price	0.01	0.29
A$ gold price	0.02	0.53

Table 3

Correlation between Gold Prices and Exchange Rates

This table presents the correlation between the weekly rates of return for the USDD gold prices and the Australian dollar/US dollar exchange rate.

Variable	A$	US$ Gold Price
US$ Gold Price	0.291*	
A$ gold price	-0.485*	0.696*

Note : *significant at the 1% level.

Table 4

Gold Prices and Exchange Rates Correlation Structure

This table presents the correlation between the weekly rates of return for the USDD gold prices and the Australian dollar/US dollar exchange rate over the full sample period and selected sub periods.

Sample Period	Correlation
January 1985 – December 1998	0.291*
January 1985 – December 1991	0.264*
January 1992 – December 1998	0.336*
January 1983 – June 1988	0.262*
July 1988 – December 1991	0.265*
January 1992 – June 1995	0.163*
July 1995 – December 1998	0.465*

Note : *Significant at the 1% level.

STOCK PRICE EXPOSURE TO GOLD PRICES

Stock price exposure to gold prices is determined by calculating a gold beta for :

- a gold industry portfolio estimated using the ASX gold industry index;
- each gold-mining firm in the sample; and
- estimated against both the US and Australian equity market returns with the return on gold denominated in both US and Australian dollars.

A gold beta (β_{ig}) for each firm calculated by estimating of the following single and multi-factor market models :

$$R_{it} = \alpha_i \beta_{ig} R_{gt} + \varepsilon_t (1)$$

$$R_{it} = \alpha_i + \beta_{im} R_{mt} + \varepsilon_t (2)$$

$$R_{it} = \alpha_i + \beta_{ig} R_{gt} + \beta_{im} R_{mt} + \varepsilon_t (3)$$

where R_{it} = the weekly rate of return on either stock i or the ASX gold industry accumulation index from t-1 to t including dividends :

R_{gt} = the weekly rate of return on gold; and

R_{mt} = the weekly rate of return on either the ASX All Ordinaries accumulation index or the S&P 500 index, denominated in Australian dollars or US dollars, respectively.

The coefficient, β_{ig}, or the gold beta, represents the sensitivity of stock i's rate of return for a 1% return to holding gold, after controlling for movements in broad equity indices that affect the return on these stocks independent of gold price movements. Consistent with the denomination of gold prices in Australian or US Vol.27, No.2 Twite : GOLD PRICES, EXCHANGE RATES, STOCKS & PREMIUMS – 129 – dollars, the broad equity index is measured with reference to both the Australian and US domestic equity markets.

Table 5 presents estimated gold beats for the gold index portfolio and the sample firms, using both US dollar and AUDD gold prices.

Table 5 reveals that gold-mining firms have substantial gold price exposure. After controlling for general market movements, at the level of the gold industry portfolio a 1% return on gold, implies that the gold-mining firm's stock price moves between 1.08 and 0.76%, depending upon the currency in which the gold price is denominated, US dollar and Australian dollar,

respectively. At the individual firm level the results reveal variation in gold beats. In general, the rate of return on gold stocks is more sensitive to USDD gold prices than AUDD gold prices.

Consistent with existing empirical evidence, the exposure to the equity market is stronger for the Australian than the US equity index for both the gold industry portfolio and the sample firms.

GOLD STOCKS AND REAL OPTIONS

Brennan and Schwartz (1985), in their seminal paper on real options, use mining as an example of real options. For example, when the gold price falls below the firm's marginal production costs, the firm can choose hold a call option on gold, with the exercise price being their marginal production costs. We recognize that gold-mining firms can exploit two types of managerial flexibility.

The first source of managerial flexibility is investment flexibility, which includes the ability to delay the start of exploration and/or development should prices be low, optimally timing the development of new leases.

The second source of managerial flexibility is operating flexibility, which includes any option to vary operating parameters, including shutting down, reopening, expansion, contraction, mine higher or lower grade ores, stockpile ore or bullion, abandonment, reoptimizing cut-off grade and varying production rates as a consequence of price changes. Operating flexibility can be modeled as a portfolio of call and put options on the fixed production schedule of the firm. Varying production 'above' the fixed production schedule of the firm is equivalent to exercising a call option acquiring the 'additional' production from the mine. While, varying production 'below' the fixed production schedule of the firm is equivalent to exercising a put option selling the 'surplus' production of the mine.

Identifying gold mines as represented by a portfolio of gold assets and embedded real options enables the examination of the relationship between the gold price levels and both :

- the sensitivity of the rate of return on gold stocks to changes in the return on USDD gold prices – 'gold delta', and

- the sensitivity of the rate of return on gold stocks to changes in the volatility of returns on USDD gold prices – 'gold vega'.

This table (Table 5) presents estimated gold betas for the sample firms and the gold index portfolio, using both US dollar and AUDD gold prices. A gold beta (β_{ig}) for each firm calculated by estimating the following single and multi-factor market models :

$$R_{it} = \alpha_i \beta_{ig} R_{gt} + \varepsilon_t (1)$$

$$R_{it} = \alpha_i + \beta_{im} R_{mt} + \varepsilon_t (2)$$

$$R_{it} = \alpha_i + \beta_{ig} R_{gt} + \beta_{im} R_{mt} + \varepsilon_t (3)$$

where : T_{it} = the weekly rate of return on either stock i or the ASX gold industry accumulation index from t-1 to t including dividends;

R_{gt} = the weekly rate of return on gold; and

R_{mt} = the weekly rate of return on either the ASX All Ordinaries accumulation index or the S&P 500 index, denominated in either US dollars or Australian dollars. T-statistics are given in parentheses.

Table 5

Gold Price Exposure for Gold-Mining Companies

	Gold Beta (β_{ig})	**Market Beta (β_{im})**
US$ denominated with the market measured as the S&P 500		
Gold Industry Portfolio	1.080 (11.86)***	0.230 (2.72)***
	1.150 (12.66)***	0.380 (4.90)***
Company		
Acacia	2.070 (3.02)***	0.216 (0.36)
	2.080 (3.00)***	0.265 (0.49)
Delta Gold	1.237 (3.95)***	0.439 (1.50)
	1.447 (4.56)***	0.745 (2.67***)
Kalgoorlie	0.163 (0.27)	1.638 (3.55)***
	0.586 (0.97)	1.798 (3.67)***
Great Central	1.432 (3.64)***	0.306 (0.76)

	Gold Beta (β_{ig})	Market Beta (β_{im})
	1.661 (4.11)***	0.763 (1.97)**
Highlands Gold	1.367 (2.87)***	0.598 (1.25)
	1.569 (3.25)***	0.929 (1.95)**
Kidston	1.346 (5.69)***	0.154 (0.69)
	1.532 (6.30)***	0.542 (2.59)***
Mt Leyshon	1.157 (3.76)***	0.339 (1.24)
	1.401 (4.42)***	0.698 (2.57)***
North Flinders	1.321 (4.68)***	0.287 (1.61)
	1.505 (5.30)***	0.792 (2.88)***
Placer Pacific	1.640 (4.93)***	0.505 (1.73)
	2.147 (6.40)***	1.142 (4.71)***
Plutonic	1.366 (3.36)***	0.714 (2.13)***
	1.809 (4.40)***	1.162 (3.50)***
Pos Gold	1.176 (3.17)***	0.334 (0.87)
	1.302 (3.44)***	0.608 (1.60)
Sons of Gwalia	1.393 (5.71)***	0.211 (0.90)
	1.560 (6.28)***	0.574 (2.61)***

	Gold Beta (β_{ig})	Market Beta (β_{im})
A$ denominated with the market measured as the ASX All Ordinaries		
Gold Industry Portfolio	0.758 (8.66)***	1.220 (22.13)***
	0.777 (11.95)***	1.240 (24.33)***
Company		
Acacia	1.700 (2.49)***	1.910 (3.94)***
	1.170 (1.91)*	1.690 (3.94)***

	Gold Beta (β_{ig})	**Market Beta (β_{im})**
Delta Gold	0.989 (3.47)***	1.100 (6.09***)
	1.150 (4.43)***	1.020 (5.37)***
Kalgoorlie	0.110 (0.20)	1.550 (4.86)***
	0.181 (0.34)	1.560 (4.85)***
Great Central	0.963 (2.36)***	1.280 (3.69)***
	1.050 (2.77)***	1.220 (3.39)***
Highlands Gold	0.758 (1.71)	1.280 (3.94)***
	0.772 (1.82)*	1.280 (3.98)***
Kidston	0.984 (4.51)***	0.936 (6.46)***
	1.130 (6.03)***	1.020 (7.71)***
Mt Leyshon	0.789 (2.83)***	1.460 (9.02)***
	1.010 (4.65)***	1.540 (10.04)***
North Flinders	0.960 (3.63)***	1.450 (8.19)***
	0.980 (4.41)***	1.450 (8.65)***
Placer Pacific	0.935 (2.76)***	1.790 (5.77)***
	1.080 (3.64)***	1.880 (6.31)***
Plutonic	0.856 (2.27)***	1.870 (9.53)***
	1.270 (4.43)***	1.980 (10.63)***
Pos Gold	1.020 (3.10)***	1.580 (6.97)***
	1.050 (3.68)***	1.600 (7.30)***
Sons of Gwalia	1.100 (4.87)***	1.060 (7.10)***
	1.260 (6.58)***	1.150 (8.51)***

Note : *, ** and ***, significant at the 10, 5, 1 present level, respectively.

Adopting a Black-Scholes option pricing approach we hypothesize that :

- the delta of the portfolio of gold assets and embedded real options will rise as the gold price rises, and
- the vega of the portfolio of gold assets and embedded real options will rise as the options become at-the-money.

Both the gold delta and vega are determined for a gold industry portfolio estimated using the ASX gold industry index estimated against the return on AUDD gold.

The gold delta (β_δ) is estimated as follows :

$$R_{it} = \alpha + \beta_\delta R_{gt} + \varepsilon_t \quad (4)$$

where R_{it} = the weekly rate of return on the ASX gold industry index from t-1 to t including dividends; and

R_{gt} = the weekly rate of return on gold, denominated in Australian dollars.

The gold vega (β_v) is estimated as follows :

$$R_{it} = \alpha_i + \beta_v \Delta\sigma_{gt} + \varepsilon_t \quad (5)$$

where : $\Delta\sigma_{gt}$ = the change in the volatility of the weekly rate of return on gold, denominated in Australian dollars. The volatility of the weekly rate of return on gold is proxied by the absolute value of the weekly rates of return.[2]

The hypothesized relationship between gold price levels and both stock price sensitivity and volatility sensitivity is non-linear over the gold price changes. Hence, the relationship is piecewise estimated by partitioning the sample by the level of the Australian dollar gold price.

The sensitivity of the rate of return on gold stocks to changes in both the rate of return and volatility of returns on AUDD gold prices as a function of the level of the gold price is shown in Table 6. The table presents estimated upon sensitivities – deltas and vegas for the gold index portfolio, using AUDD gold prices, where the level of the gold price partitions the sample.

Table 6 reveals that the estimated upon sensitivities behave as predicted by Black-Scholes. Consistent with Black-Scholes predictions :

- the estimates of delta – the sensitivity of the gold index's rate of return to changes in the gold prices increases, approaching one, as the gold price increases (return sensitivity is statistically significantly less than one for gold prices less than A$490), and
- the estimates of vega – the sensitivity of the gold index's rate of return to changes in the volatility of gold prices is insignificantly different from zero except over the range A$480 to A$520, where it is positive and statistically significant different from zero.

[2] The result is unaffected by the use of the square of the rates of return to proxy volatility.

This table presents estimated option sensitivities – deltas and vegas for the gold index portfolio, using AUDD gold prices, where the level of the gold price partitions the sample. The gold delta (β_δ) is estimated as follows :

$$R_{it} = \alpha + \beta_\delta R_{gt} + \varepsilon_t \quad (4)$$

where R_{it} = the weekly rate of return on the ASX gold industry index from t-1 to t including dividends; and

R_{gt} = the weekly rate of return on gold, denominated in Australian dollars.

The gold vega (β_v) is estimated as follows :

$$R_{it} = \alpha_i + \beta_v \Delta\sigma_{gt} + \varepsilon_t \quad (5)$$

where $\Delta\sigma_{gt}$ = the change in the volatility of the weekly rate of return on gold, denominated in Australian dollars. The volatility of the weekly rate of return on gold is proxied by the absolute value of the weekly rates of return. T-statistics are given in parentheses. The reported t-statistics are for the hypothesis that return sensitivity (β_δ) is equal to one and volatility sensitivity (β_v) is equal to zero.

Table 6

Price Sensitivities and the Level of Gold Prices

Gold Price	Return Sensitivity Gold Delta (β_δ)	Volatility Sensitivity Gold Vega (β_v)
Less than A$450	0.782	0.027
	(-2.02)***	(0.10)
A$450 to A$470	0.521	-0.482
	(-2.77)***	(-1.74)
A$470 to A$480	0.633	-0.262
	(-2.47)***	(-1.04)
A$ 480 to A$490	0.708	0.217
	(-2.31)***	(2.68)***
A$ 490 to A$520	0.890	0.198
	(1.88)*	(2.29)***
A$520 to A$560	0.913	0.165
	(-0.419)	(1.85)*
Greater than A$ 560	0.906	-0.049
	(-0.414)	(-0.170)

Note : *, ** and ***, significant at the 10, 5, 1, percent level, respectively.

The results are consistent with gold-mining companies being represented as a portfolio of gold assets and embedded real options, which arise through the existence of managerial flexibility in gold mines.

The remainder of the paper seeks to use this gold price exposure to explain the existence and valuation of managerial flexibility in gold-mining firms, focusing on USDD gold prices.

GOLD PREMIUM

It is widely accepted that gold-mining firms trade at a market capitalization that is, on average, greater than their value determined using a discounted cash flow valuation model. Table 7 presents summary statistics for the percentage differences between the market capitalization of a sample of Australian gold-mining firms and their discounted cash flow value obtained from the sample of analysts' reports.

This table presents summary statistics for the gold premium for a sample of 12 Australian gold-mining firms and their discounted cash flow value obtained from the analysts' reports of 8 broking firms over the period 1994 to 1997. The gold premium is defined to be the proportional differences between the firm's market capitalization and discounted cash flow value (Stock prices – DCF value)/Stock Price.

Table 7

Descriptive Statistics of the Gold Premium

Company	Mean	Median	Standard Deviation	Maximum	Minimum
Sample	0.519100	0.440000	0.485500	2.188406	-0.695120
Year					
1994	1.156	1.168	0.496	2.188	0.461
1995	0.685	0.803	0.639	1.621	-0.695
1996	0.456	0.406	0.414	1.794	-0.469
1997	0.402	0.314	0.429	1.632	-0.371

The results in table 7 indicate that the market, on average, values a premium into the stock price of the gold-mining firms. While the average premium for the sample of gold-mining firms is 51.9%, the premium varies considerably over time and across firms.

In adopting a discounted cash flow model to value gold-mining firms, the firm is assumed to utilize a production profile that it cannot alter. The company is characterized as owning a fixed quantity of gold reserves which it expects to mine at a production rate, which is specified at time zero and remains unaltered over the life of the mine.

The fixed-production model is poorly specified in that gold mines offer classic examples of firms with real options, arising from the existence of investment and operating flexibility.

If the market assumes that the firm optimal utilizes managerial flexibility but the fixed production profile discount cash flow valuation does not, then the discounted cash flow calculation will incorrectly value the firm.

Accepting that these real options have positive value, then ignoring the options embedded in mine operating decisions will tend to understate the value of the gold-mining firm. Formally, the gold premium is defined to be the difference between the firm's stock prices and its value determined using a discounted cash flow valuation model, discounting expected cash flows using a constant risk-adjusted discount rate.

Adoption of the real valuation approach suggests that the observed gold premium is attributable to the existence of managerial flexibility or real options.

Using a real option valuation model, we can identify factors that determine the premium over their discounted cash flow value for the sample of gold-mining firms. These factors consist of :

- Resource/reserve ratio
- Operational flexibility
- Gold price volatility
- Company size

The sensitivity of gold premium to these suggested determinants is estimated by the following regression model equation :

$$P_{it} = \alpha_i + \Sigma \ln \beta_{jd} D_{ijt} + \varepsilon_t \quad (6)$$

where : P_{it} = the gold premium on stock i for period t; and

D_{it} = the identified determinant j on stock i for period t. The regression equation is estimated in both a univariate and mutivariate specification.

RESOURCE/RESERVE RATIO

Gold companies have a wide variety of resource to reserve levels. Resources are estimates of gold deposits based on data that provides a low level of confidence. Much more work is needed to convert these resources in to reserves. This work usually involves further drilling and appraisal activities. It is reasonable to expect that the market would take a view on how successful a company would be in converting resources to reserves. The gold premium is attributed to both the potential for resources to be upgraded to reserves and then mined and the potential for the firm to discover an economically viable reserve from within the existing and potential exploration assets. It is reasonable to expect that the more resources a firm have, the higher the premium.

Estimates of resources and reserves where obtained from company annual reports and analyst reports.

Table 8 presents the relationship between the gold premium and the resource/reserve ratio for the sample of companies. This demonstrates that there is no statistically significant relationship between the amount of resources a company possesses and its premium.

This suggests that for the sample of firms examined, over the sample period the gold premium is not linked to any development upside that a company may possess. A potential explanation lies in the difference between the costs of conversion and exploration and the gold price, where the difference suggests that during the sample period these real options were deep in-the-money options.

This table presents the estimated coefficients from the regression model in equation (6)

$$P_{it} = \alpha_i + \Sigma \ln \beta_{jd} D_{ijt} + \varepsilon_t \quad (6)$$

where : P_i = the gold premium on stock i for period t; and

D_{it} = the identified determinant j on stock i for period t. The determinants consists of the resource/reserve ratio, operational flexibility – proxied by the number of operational mines, and the amount of hedged production, gold

price volatility and company size. Estimates of the risk-adjusted discount rate obtained from analyst reports were included to examine the explanation that discounted cash flow techniques are downward bias due an overstating of firm's beta. The regression equation is estimated in both a univariate and multivariate specification. T-statistic are given in parentheses.

Table 8

Determinants of the Gold Premium

Determinants	Coefficient	
	Univariate	Multivariate
Resource/Reserve Ratio	-0.011	-0.006
	(-1.13)	(-0.70)
Number of mines	0.006	-0.027
	(0.36)	(-1.17)
Hedging score	0.0007	0.0004
	(2.35)***	(1.29)
Gold price volatility	0.0009	0.0006
	(4.47)***	(2.40)***
Gold price	3.786	1.967
	(5.08)***	(2.08)***
Company size	0.187	0.191
	(2.69)***	(2.18)**
Discount Rate	6.492	4.280
	(2.46)***	(2.05)***

OPERATIONAL FLEXIBILITY

The operational flexibility covers all the options that a gold producer has with regards to varying their production levels. These options should add value to the company. An analysis of the options available to a company includes the number of operational mines and the amount of forward sold (or hedged) production that a company has.

1. Number of Operational Mines with the variation in gold prices, the more flexibility that a company has in its operations, the better able it will be to manage its assets. One suggestion of a measure of flexibility is the number of operational mines that a given company has. With more operations comes a supposed increased ability to shut-in production at one mine, especially if it high cost.

   Estimates of the number of operational mines where obtained from company annual reports and analyst report.

   Table 8 reveals that there is no statistically significant relationship between the number of operating mines and the gold premium. This is to be expected, as mining operations are not necessarily very flexible. The actual process of shuting in production is capital and time intensive. The same conditions apply to a re-start of the mine. The benefits of a shut down would therefore have to be large to justify this action. The premium is therefore unlikely to be linked to the number of mining operations that a company has, but it is possible that the cross-sectional variation between the mines in terms of operation levels, extraction method and ore grade may better explain gold premiums.

2 Amount of Hedged Production Gold companies usually follow a policy of hedging a certain amount of their production over the short term (often three years). This provides income stream stability and allows them minimum debt coverage.

   The unhedged production should provide a premium to the discounted cash flow value of the firm. This is due to the volatile nature of gold prices; the unhedged production is the component that provides operating flexibility to the firm.

   The unhedged production must be adjusted for the debt of the company. This is because the gold premium is applied to the equity in the company and hedging levels may be designed to match the debt requirements. It is the hedged production over the debt that will reduce the premium applied to the company's equity.

   Estimates of the level of hedging and capital structure where obtained from company annual reports and analyst reports.

   By ranking the various companies by their debt equity ratios and hedging levels at the time of the given valuation and then multiplying the debt equity and hedging rankings together, a score is created for the company

at that time relative to other companies. Table 8 reveals the relationship between the gold premium and this score.

Using a univariate test the hedging score is statistically significant related to the gold premium. However, the multivariate regression shows that there is no statistically significant relationship between the amount of unhedged production that a company has and the gold premium.

It is possible that anticipated production and reserve levels also impact the hedge ratio.

3 Twelve Month Volatility

The more variance in a given commodity, the higher the value of an option on that commodity. This suggests that the volatility in gold prices should be related to the gold premium. Assuming that the movements in the gold price are random, then the best predictor of the future is the present. This implies that the best estimate of the volatility over the next year is the past year's volatility.

Volatility is estimated using the prior 12 monthly returns on gold, calculated using AUDD gold prices. The result is unaffected by the use of AUDD or USDD gold prices.

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Table 8 presents the relationship between the firm's gold premium and the twelve-month gold price volatility, evidencing a statistically significant relationship between the gold price volatility and the gold premium.

4 Gold Price Another component of the 'option element' of gold is the actual price itself.

Tables 5 and 6 reveal that gold-mining firms have substantial gold price exposure. It follows that changing gold prices will influence both the discounted cash flow value and the option value of the gold-mining firm. However, within the context of viewing the gold premium as a real option, the issue remains as to whether the gold premium itself is influenced by the gold price as predicted by the option model.

The relevant gold price is the log of the closing AUDD gold price at the date the analysts' report was prepared. The result is unaffected by the use of AUDD or USDD gold prices.

Table 8 presents the relationship between the firm's gold premium and the log of gold prices, evidencing a significant relationship between the gold price and the gold premium.

5 Company Size

It is possible that the premium is related to the size of the firm. The larger the company, the greater the likelihood that it has more flexibility in its operations – more options available. These options should increase with the size of the firm. Accepting that a portfolio of options (the large – multiple mine – firm) is more valuable than an option on a portfolio of assets (the small – single mine – firm) we would expect the gold premium to increase with the size of the firm.

Firm size is estimated using the log of total assets in the financial year that the analysts' report was prepared. Estimates of total assets where obtained from company annual reports.

Table 8 presents the relationship between the firm's gold premium and the log of its total assets. There is a statistically significant relationship between firm size and the gold premium.

DISCOUNT RATE

A counter proposal is that discounted cash flow techniques are potential accurate when applied to gold-mining firms, but misused. Here the downward bias in discounted cash flows analysis is due to underestimation of cash flows or too high a discount rate compared to the values used in the market place. The negative gold premiums evidence in table 7 is consistent with this explanation. An expression of this view is the suggestion that the firm's beta should be below its estimate using a domestic index so as to reflect the international character of the gold-mining industry.

Estimates of the risk-adjusted discount rate where obtained from the analyst reports.

Table 8 presents the relationship between the risk-adjusted discount rate used by the analyst and the firm's gold premium. There is a statistically significant relationship between the discount rate and the gold premium.

This suggests that the premium is in part explained by the misuse of the discounted cash flow techniques.

CONCLUSION

This paper investigates the exposure of the stock prices of Australian gold-mining firms to changes in gold prices. The paper documents that there is substantial exposure to gold prices and stock price behavior is consistent with gold-mining companies being represented as a portfolio of gold assets and embedded real options.

The paper then uses two competing models of gold-mining firm valuation to examine the determinants of the observed gold premium. There are many possible explanations for the gold premium that reflects the difference between the discounted cash flow valuation of a gold-mining firm (as calculated by the various gold analysts using a constant) risk-adjusted discount rate) and the actual market value of the company. These explanations include the misuse of the discounted cash flow techniques and those drawn from the existence of real options – resources/reserve ratio, number of operational mines, hedging levels, level and volatility of gold prices and firm size.

The documentation of the gold premium reveals the limitations of disconnected cash flow models to capture to an underestimation of firm values.

However, the evidence regarding the explanation of the gold premium as reflecting the value of these real options is mixed. While the paper evidences a strong association between the gold premium, firm size and the volatility of gold prices as predicted by the option model. No relationship exists between the gold premium and other identified option characteristics – resources/reserve ratio, number of operational mines, hedging levels and the level of gold prices. Further, the paper evidences that the premium is in part explained by the misuse of the discounted cash flow techniques.

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