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An examination of Australian gold mining firms’ exposure over the collapse of gold price in the late 1990s

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Abstract

Purpose – The purpose of this study is to examine the exposures of Australian gold mining firms in the highly volatile period from 1995 to 2000. This period has been characterized by significant changes in gold price due to bulk sale of gold by collective central banks. Specifically, the paper aims to investigate several firm-specific factors that are hypothesized to carry substantial influence on gold beta.

Design/methodology/approach – To estimate gold beta, we use the following multifactor model: $R_{g,t} = \alpha + \beta_g GPR_t + \beta_x FXR_t + \beta_m R_{m,t} + \epsilon_t$, where $R_{g,t}$ is the return on the gold stock Index at time $t$, GPR$_t$ is the gold price return denominated in US dollar at time $t$, FXR$_t$ is the foreign exchange return of Australian dollar in terms of US dollar at time $t$, $R_{m,t}$ is the market return at time $t$, and $\epsilon_t$ is the random error term at time $t$.

Findings – The paper finds that the values of gold beta are consistently greater than one, implying the sensitive nature of firms’ stock returns to gold price changes. This also suggests that investors holding gold mining stock would receive higher percentage increases in stock returns from a percentage increase in gold price returns, as opposed to investors holding gold bullion. Furthermore, these values have changed substantially over time with significant changes in gold price volatility. The most important and consistent relationship that we find is the impact of firms’ hedging behavior on their respective gold betas. This is consistent with Tufano’s study. It implies that firms, which hedge a greater proportion of their gold reserves, are less sensitive to movements in gold prices. The finding therefore supports the risk management theory that hedging increases shareholder's wealth. However, cash operating costs, cash reserves and the level of gold production seem to influence very little on the firms’ exposure to gold price changes.

Originality/value – This study is of interest and important to the stock mining companies and investors because the extent of the effect of gold price movements on the stock returns of gold mining companies has significant impacts on returns for both firms and investors especially in their risk management and investment decisions, respectively.

1. Introduction

The history of gold prices has been characterized by significant changes, particularly after 1996. Following the economic meltdown in many parts of Asia and the bulk sale of gold collectively by central banks in 1997, notably the Belgian, Dutch Central Banks and Reserve
Bank of Australia, gold prices have plunged to historical lows. The perceptions of gold as an idle asset with no diversification benefits and as an ineffective hedge against inflation were some of the reasons that have prompted large gold sellouts by central banks[1]. Such adverse climate in the gold market also diminishes the demand for gold by investors. Therefore, the combined reduced demand for gold by central banks and investors caused gold prices to spiral downwards.

In 1999, however, there was a surprising resurgence in gold prices. In an attempt to reverse the long-term slump in gold prices to its 20-year lows and thereby putting gold producers around the world under extreme pressure, the European Central Bank decided to cap the sales and the lending of gold from their reserves. Coupled with the International Monetary Fund's decision not to sell gold to fund its debt relief initiative, and the USA not selling its gold since the late 1970s, the European decision was pivotal in reviving the gold market. This was because these three groups accounted for an 80 per cent holding of official sector gold. With the drastic reduction in the amount of central bank gold likely to be sold worldwide, gold prices began to soar. In October 1999, the gold price in London rose by US$20.40 an ounce, the largest increase in dollar or percentage terms in more than 17 years[2].

This period of extensive gold price volatility has repercussions for both gold producers and investors in the gold mining industry. According to Maiden (1997), those Australian gold producers with poor hedging positions between 1997 and 1998 period, have suffered losses that account for 40 per cent of the whole industry. These losses incurred by those gold mining companies were reflected in their respective depressed stock prices. In many instances, gold stocks had been thumped down to the point where their exploration ground was valued at zero. These include major Australian mining companies such as Resolute, Aurora and Kidston. In Lihir and Goldfields Ltd, the exploration grounds were actually given negative values (see Skyes, 1998) and was reflected in the negative stock returns as well. Conversely, when gold prices heightened in 1999, mining companies flourished, and so too did their investors. The gold beta, the extent of the effect of gold price movements on the stock returns of gold mining companies, therefore has significant implications for both firms and investors especially in their risk management and investment decisions, respectively.

Not surprisingly, the literature has documented that changes in gold price carry a significantly positive effect on stock returns of gold mining firms. For example, McDonald and Solnik (1977) find that the returns on 25 South African and 10 North American mining companies are positively correlated to gold. Blose and Shieh (1995) and Blose (1996) report that gold beta values tend to be greater than one, implying that the values of the gold mining firms are quite sensitive to gold price movements. In particular, Tufano (1998) observes that gold mining firms in North America have substantial stock price exposure to gold prices. For one per cent return in gold, the mean and median gold firm's stock return moves by about two per cent. Furthermore, firms’ exposure to gold prices is negatively related to their hedging and diversification activities, to gold price levels, and gold return volatility.

Khoury (1984), however, argues that non-gold related risks associated with the stocks disrupt the influence of gold price changes on the price of securities. Hence, the potential increase of gold stock prices is no longer as high as those of gold bullion and coins in bull markets. Consequently, the price elasticity of gold stocks under these circumstances is less than one, as compared to gold bullion and coins, which have a gold elasticity of one. Supporting such views, Rock (1988, p. 201) argues that “… gold mining stocks and the funds that invest in them are probably the worst way to buy gold from the investor's point of view”, given the
non-gold price-related risk associated with the mining stocks. Oechsle (1976) and Train (1978) also find that investing in gold stocks is not a good alternative given the apparent price inelasticity of these gold stocks. They conclude that the co-integration between gold stock return and gold price would not be equivocal.

While the sensitivity of a mining company's stock returns to gold prices remains an issue, how firms manage their gold exposure due to large price risk remains largely unanswered. It has been suggested that gold mining companies that ultimately survive and thrive would be those characterized by low average operating costs, high production growth, sound hedging positions (large hedge books) and a strong balance sheet with little debt (see Forkey, 1998; Skyes, 1998; Tufano, 1998). While there has been a few studies, to our knowledge, that look into the determinants of risk exposure using gold mining companies, they are however concentrated in the USA. Therefore, little is known about the sensitivity of gold price changes and the hedging behavior of firms outside the USA, especially when non-US gold producers face additional foreign exchange risk as gold is priced in US dollars. To our knowledge, only Chan and Faff (1998) conduct a similar study in Australia[3]. They find that gold prices are increasingly positively related to gold stock returns over time. However, they do not consider the effect of firm's hedging practices on the stock price exposure.

In this paper, we investigate the exposure of Australian gold mining firms from 1995 to 2000, which has been characterized by significant changes in gold price due to bulk sale of gold by collective central banks. This period therefore provides a fertile ground and great impetus to test for the determinants of gold betas, given falling gold prices in the initial stages and the large volatility of gold prices within the time frame. Furthermore, our study is the most comprehensive to date in that we not only examine the effect of gold price changes on gold stock return, but we also attempt to explain the degree of sensitivity of gold price on gold stock return due to the firm-specific characteristics. The examination of a firm's hedging practices has been made possible following the implementation of the Australian Accounting Standard AAS 33 in 1997, which requires firms to adopt transparent risk management practices by disclosing their hedging profiles as well as all off balance sheet activities. Our study therefore can also be seen as an extension of Chan and Faff (1998). In addition, the empirical findings in the Australian context can be served for comparative purposes with the USA counterparts.

The remaining paper is comprised four sections, structured in the following manner. Section 2 describes the data, and discusses model specification and firm-specific variables. The methodology undertaken to calculate firms’ hedge ratio is also explained in greater detail. Section 3 provides a detailed analysis of the results in relation to the hypotheses established in section 2. Section 4 concludes the paper.

2. Model specification and data description

2.1 General framework

To estimate gold beta, we use the following multifactor model[4]: (Equation 1) where \( R_{g,t} \) is the return on the gold stock index at time \( t \), \( GPR_t \) is the gold price return denominated in US dollars at time \( t \), \( FXR_t \) is the foreign exchange return of Australian dollars in terms of US dollars at time \( t \), \( R_{m,t} \) is the market return at time \( t \), and \( \varepsilon_t \) is the random error term at time \( t \). Data are collected on weekly basis from Datastream from 1995 to 2000. For market returns, we use the Australian All Ordinaries Index as the proxy.
To determine whether gold betas have changed significantly over the 1995-2000 time period requires a two-stage process. We divide our sample period into three non-overlapping sub-periods on the basis of gold price volatility, particularly during the period of 1997-2000. To separate such dominant effects, the three sub-periods chosen are:

1. January 1995 to December 1996;
2. January 1997 to December 1998; and

The first sub-period is the time interval just prior to the gold plunge, caused by the large sell-out of gold by central banks. The second sub-period encompasses the drastic reduction in gold prices, following the increased activity of major central banks selling substantial amounts of gold reserves. The final sub-period is characterized by the recovery of gold prices, as a consequence of the European Central Bank capping gold sales.

To accommodate the sub-period analysis, we modify equation (1) as follows: (Equation 2)

where $D_j$ is the dummy variable and takes a value of one for periods January 1995 to December 1996, January 1997 to December 1998 and January 1999 to December 2000 when $j = 1, 2$ and 3, respectively, and zero otherwise.

To determine the equality of the sub-period gold betas, the following hypotheses are tested: (Equation 3).

If the results indicate that the gold betas have changed over the sample period, then we can conclude that the sub-period gold betas are time-varying.

### 2.2 Estimating individual gold beta values

For individual mining companies, however, we modify equation (1) as follows: (Equation 4)

where $R_{i,t}$ refers to the stock returns for individual mining companies within the industry.

To ensure data consistency, weekly share prices of individual companies listed in the Australian Stock Exchange are sourced from Datastream from 1997 to 2000[5]. The sample consists of 49 listed gold mining companies where gold mining is a primary source of activity between 1997 and 2000[6].

To adjust for biased beta estimates induced by non-synchronous or infrequent trading (see Scholes and Williams, 1977; Dimson, 1979), we use Dimson's (1979) aggregated coefficient method and the Fowler and Rorke (1983) procedure. Given that Australian stock markets are generally liquid in nature, specifying one lead and lag term for the models used in the procedures above would be optimal[7]. Hence, the model incorporating the Dimson and Fowler–Rorke procedural adjustments with one lead and one lag term can be specified in the following generalized form: (Equation 5) where $k$ denotes the number of leads and lags.

According to the Fowler and Rorke (1983) adjustment technique, weights are assigned to each lead and lag term, hence the gold beta is: (Equation 6) where $w_1 = 1 + \rho_1/1 + 2 \rho_1$ and $\rho_1 = 1$th order serial correlation coefficient between $R_{m,t-1}$ and $R_{m,t}$.

Upon adjusting for gold beta values of individual firms, a multivariate model can then be used to test for the relation between firm-specific factors and gold beta.
Following the separate regression model of Tufano (1998), the individual gold beta can be expressed as:

\[
\beta_{ig} = \alpha_g + \Phi_{j} \cdot F_{j,i} \tag{Equation 7}
\]

where \(\beta_{ig}\) is the gold beta of individual firm \(i\), and \(F_{j,i}\) is the firm-specific factor \(j\) affecting gold beta (\(j = \text{financial distress, operating efficiency, production level and hedging percentage}\)).

From the model, tests can be conducted to ascertain whether coefficient \(\Phi_{j}\), which indicates the relation between each factor and gold beta, is consistent with predicted signs for these variables. Due to the relatively small sample size of gold mining companies obtained per year, a pooled regression is used to run gold beta values against annual firm-specific factors over the four-year period. In relation to the factors denoted by \(F_{j,i}\) above, the financial distress factor acts as a barometer of firms’ financial health and is measured by the yearly cash reserves level scaled by market capitalization. Operating efficiency is proxied by the firm's yearly cash costs, representing the cost incurred per unit of gold ounce produced. Annual production quantity, measured in terms of million ounces of gold, serves as a proxy for the production level factor. Lastly, the hedging percentage, which measures the extent of risk management activity undertaken by the firm in controlling for commodity (gold) price risk, is obtained by calculating individual firm's delta-percentage-of-reserves. This value represents the percentage of future production (proved and probable reserve) known at the balance sheet date that has been sold forward[8]. Data collected for each respective variable are from Australian Annual Reports via Connect 4.

An “all-in” model proposed by Tufano (1998) is also used in this study. It seeks to obtain a joint estimation of betas and its determinants in one step, by substituting the linear expression in equation (6) for the betas in equation (3), and conducting a single estimation. In doing so, model efficiency is increased. The equation is specified as follows:

\[
\alpha_g + \alpha_{fx} + \alpha_m = \alpha_{g,j} \cdot GPR_t + \alpha_{fx,j} \cdot EEX_t + \alpha_{m,j} \cdot MKT_t + \Phi_{g,j} \cdot F_{j,i,t} + \Phi_{fx,j} \cdot EEX_t \cdot F_{j,i,t} + \Phi_{m,j} \cdot MKT_t \cdot F_{j,i,t} \tag{Equation 8}
\]

\(\alpha_g, \alpha_{fx}, \alpha_m = \) intercept of the interaction terms, representing the product of the firm-specific variable listed times the gold price return, exchange rate return and market return, respectively; \(\Phi_{g,j}, \Phi_{fx,j}, \Phi_{m,j} = \) coefficient indicating the relation between firm-specific factor \(j\) and gold return, exchange rate return and market return, respectively; \(F_{j,i,t} = \) firm-specific factor \(j\) affecting gold beta at time \(t\) (financial distress, operating efficiency, production level and hedging percentage).

With this setup, the coefficients on the interaction terms \((F_{j,i,t} \cdot GPR_t)\) represent the gold beta terms for company \(i[9]\).

Following the above discussion, our empirical hypotheses can be summarized as follows:

2. A firm's financial distress level, measured by the amount of cash reserves held and scaled by its market capitalization, is negatively related to the gold beta.
3. A firm's operating efficiency, measured by cash costs per ounce of gold produced, is positively related to the gold beta.
4. A firm's production level, measured in millions of ounces, is negatively related to the gold beta.
5. The degree of risk management undertaken by the firm, denoted by the level of hedging, is negatively related to the gold beta.

3. Results
We first regress gold index return on gold price return ($y_i$), foreign exchange return and market return ($\beta_{m,i}$) as presented in equation (2). Table I shows that both gold price return and market return carry significant explanatory power at the 5 per cent level across the three sampled sub-periods, with the exception that $\beta_{m,3}$ in the 3rd sub-period is marginally significant at the 10 per cent level[10]. Furthermore, the signs of these coefficients are consistent with the priors. Specifically, both gold price return and market index return are positively related to gold index return. It implies that an increase in either gold price return or market return would lead to an increase in gold stock returns. Our findings therefore reinforce those of earlier studies (e.g. McDonald and Solnik, 1977; Beckers and Soenen, 1984; Tufano, 1998). However, the effect of foreign exchange returns is inconclusive. $\beta_{FX,3}$ in the 3rd sub-period is the only coefficient that is statistically significant at the 5 per cent level, while others seem to have little impact on the gold returns. The findings therefore do not support the views of Loudon (1993) and Khoo (1994).

Focusing on the industry gold beta values, we find that the betas especially in the first two sub-periods are far greater than one. It indicates that the values of Australian gold mining firms are quite sensitive to changes in gold price. For one percentage change in gold price, there is a corresponding change of 1.85, 1.78 and 1.02 per cent in gold index returns in each of the sub-periods, respectively. The apparent elasticity of gold index price to a gold price change reported here is consistent with the findings of McDonald and Solnick (1977), Blose and Shieh (1995), Blose (1996) and Tufano (1998). However, it contradicts the views held by Train (1978) and Khoury (1984), who argue gold mining stocks to be inferior investments to gold bullion due to its gold price inelasticity.

To test whether the gold betas are time-varying, we conduct Wald tests for equality on the coefficients of gold beta from Table I. Overall, the results from Table II suggest that gold beta values are statistically different over the three sub-periods. Of particular importance is the analysis of sub-periods 1997-1998 and 1999-2000, as it has been expected that gold beta values would change following considerable gold price swings. Such conjecture appears to be consistent and the results are presented in Table II. The gold beta values over the two periods are statistically different at the 6 per cent level. The coefficient of gold beta has decreased from 1.78 in 1997-1998 to 1.02 in the following sub-period as shown in Table I. Therefore, the results confirm that gold betas change over time, particularly during the volatile period[11].

Another related observation in the behavior of gold beta is its decreasing trend over time, as reported in Table I. It implies that returns on gold mining stocks are increasingly less sensitive to gold price returns. This could be attributed to several factors. First, gold beta could be a decreasing function of gold price volatility (Tufano, 1998). To ascertain whether this holds, a comparison of beta values and gold price volatility between sub-periods is examined.

Table III results support Tufano's (1998) suggestion that gold beta values have changed significantly following periods of pronounced gold price volatility, adjudged by the standard deviation of gold prices. However, the predicted inverse relationship between gold beta and gold price volatility is inconclusive with our findings[12]. Although the predicted relationship is observed for the 1995-1996 and 1997-1998 sub-periods, where gold beta has decreased (from 1.85 to 1.78) following an increase in gold price volatility (from $7.7/oz to $23.61/oz), the pattern does not fit for the 1997-1998 and 1999-2000 sub-periods. We suspect that the anticipation of more severe gold price volatility by the gold mining industry, following
pronounced volatility in the 1997-1998 sub-period, may correspond to the underlying abnormality in gold beta value for 1999-2000 as firms responded by reducing their exposure to gold prices (i.e. gold beta). However, instead of increased gold price volatility as predicted by the mining industry for 1999-2000, gold prices became less volatile following the cap on gold sales by central banks. Hence, reduced gold betas would possibly be the result of industry overreaction to gold price volatility, rather than a reaction to actual circumstances of lessened volatility. Besides the influence of volatility on gold betas, several firm-specific factors could also in part explain the beta values. This will be discussed more extensively in the later parts of the section.

Before we examine the relation between gold beta and the firm-specific factors, individual firm's gold betas needs to be first measured. Table IV reports the gold beta estimates according to the adjusted beta methods of Dimson (1979) and Fowler and Rorke (1983). The average estimates of gold beta and exchange rate beta appear to be quite consistent under both methods. However, the market betas tend to vary more from one estimate to another. To ensure that our results do not rely on a particular estimate, we regress both gold beta estimates on the set of firm-specific characteristics.

Columns A and B of Table V show the multivariate regression analysis based on the Dimson and Fowler–Rorke beta estimates[13]. We find that hedging undertaken by firms is the most significant factor affecting gold beta values. The significance of delta-per cent-of reserves is not only statistically significant at the one per cent level, but is also economically significant. From a firm that does not hedge to a firm that fully hedges (i.e. has a hedge ratio equivalent to one), the observed gold price exposure would fall by 0.729 (Column A) or 0.692 (Column B). It therefore suggests that the firms’ hedging behaviour is the overriding factor to the sensitivity of the stock returns to changes in gold price. On a minor note, the operating efficiency (cash costs) appears to play a marginal role in influencing gold beta. That is, although a reduction in firm's operating efficiency would increase its exposure to gold price movements, such effects tend to be minimal. Similarly, we do not find scaled cash reserves and gold production to be important in explaining gold beta. Overall, our findings are consistent with those North American counterparts by Tufano (1998).

The results in Column C of Table V are obtained from conducting a joint regression based on equation (7). Essentially, the dependent variable is the annual stock return for each mining company in the sample. Independent variables include the interaction terms representing the firm-specific variables multiplied by the annual gold index return. In these regressions, there are also interaction terms between the independent variables, the market returns and exchange rate returns, though they are not reported here. Again, we find that hedging is the only factor that captures variation in average stock returns, however at the marginal ten per cent level. Economically, a fully hedged firm, as compared to an unhedged firm, will achieve a higher average annual stock return of 8.22 per cent for its shareholders. The results thus support the classical risk management theory that hedging maximizes shareholders’ value (see Stulz, 1996).

4. Conclusion

In this paper, we examine the exposures of Australian gold mining firms in the highly volatile period from 1995 to 2000. Specifically, we investigate several firm-specific factors that are hypothesized to carry substantial influence on gold beta. We report that the values of gold beta are consistently greater than one, implying the sensitive nature of firms’ stock returns to
gold price changes. This also suggests that investors holding gold mining stock would receive higher percentage increases in stock returns from a percentage increase in gold price returns, as opposed to investors holding gold bullion. Furthermore, these values have changed substantially over time with significant changes in gold price volatility.

The most important and consistent relationship that we find is the impact of firms’ hedging behavior on their respective gold betas. This is consistent with Tufano's (1998)'s study. It implies that firms, which hedge a greater proportion of their gold reserves, are less sensitive to movements in gold prices. Our findings therefore support the risk management theory that hedging increases shareholder's wealth (Stulz, 1996). However, cash operating costs, cash reserves and the level of gold production seem to have very little influence on the firms’ exposure to gold price changes.

Notes

1. See Fitzgerald (1997) for a more complete discussion.
2. See Burrell (1999) for a more detailed description.
3. Australia is the third largest gold producer after South Africa and the USA.
4. This model is similar to the one used by Chan and Faff (1998), except that we omit the interest rate factor which was found to have an insignificant relationship with gold stock returns.
5. Companies are required to disclosure all off-balance sheet activities following the implementation of Accounting Standard AAS 33 in 1997.
6. Some of the companies reported all derivatives usage for the full sample period while others only reported the usage for part of the sample period.
7. In his study, Sinclair (1981) concludes that at least one lagged term is required for Dimson procedure to accurately estimate betas of Australian securities. The inclusion of one lead and lag term is also utilized for the estimation of gold beta in the American context (Tufano, 1998).
8. The delta is the probability that the hedge contract will be exercised. For forward and futures contracts, the probability equals one as both parties are bound to honor the contracts. For options, an option buyer has the choice to exercise the contract depending on the market condition and the possibility is measured by \( N(d_2) \) for call options and \( N(-d_2) \) for put options from the Black-Scholes option pricing model.
9. There is a disparity in data frequency of variables. Stock, gold, exchange rate, market and interest rate returns are expressed on a weekly basis, whereas firm-specific factors are expressed on an annual basis. To accommodate these annual figures acquired from firm-specific factors, the stock, gold, exchange rate, market and interest rate returns are converted to annual returns. The model now assumes an annual form, with all data utilized of an annual type. This eradicates the problem of non-synchronous trading, since stock returns are now expressed annually. Therefore, the inclusion of lead and lag terms is no longer required. A pooled regression is thus run without these terms. The subsequent results obtained are then used to make inferences about the gold mining industry.
10. The results are obtained after adjusting for heteroskedasticity and serial correlation.
11. Our results also support the work of Chan and Faff (1998), who find gold beta values to be time-varying rather than constant.
12. The value of gold mines can be modeled as real options where the firms can suspend production due to low gold price. As a result, gold beta can be shown as a decreasing
function of volatility. See Brennan and Schwartz (1985), and Brennan (1990) for their real option models.

13. In the Appendix, the results indicate that there is no evidence of multicollinearity among the firm-specific variables.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_j$</td>
<td>$-0.0016 (-0.99)$</td>
<td>$-8.11\times10^{-5} (-0.03)$</td>
<td>$-0.0022 (-1.18)$</td>
</tr>
<tr>
<td>GPR,$_t$</td>
<td>$1.8499 (5.92)^{*}$</td>
<td>$1.7792 (5.82)^{*}$</td>
<td>$1.0190 (3.92)^{*}$</td>
</tr>
<tr>
<td>FXR,$_t$</td>
<td>$-0.0606 (-0.27)$</td>
<td>$0.0869 (0.42)$</td>
<td>$-0.4208 (-2.30)^{**}$</td>
</tr>
<tr>
<td>$R_{m,t}$</td>
<td>$1.1010 (8.46)^{*}$</td>
<td>$0.8552 (6.46)^{*}$</td>
<td>$0.3060 (1.8404)^{***}$</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.5496</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-Statistic</td>
<td>38.823</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durbin–Watson</td>
<td>1.9992</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** The multifactor model used to derive gold beta from each sub-period is as follows:

$$R_{g,t} = \sum_{j=1}^{3} \alpha_j * D_j + \sum_{j=1}^{3} \gamma_j [D_j * GPR_t] + \sum_{j=1}^{3} \beta_j [D_j * FXR_t] + \sum_{j=1}^{3} \beta_{m,j} [D_j * R_{m,t}] + \varepsilon_t$$

where $R_{g,t}$ is the return on gold stock; $D_j$ a dummy variable of $j$th sub-period, where $j = 1$ for 1995-1996, $j = 2$ for 1997-1998, $j = 3$ for 1999-2000. GPR$_t$ is the gold price return, FXR$_t$ is the return on the exchange rate of AUD/USD and $R_{m,t}$ is the return on the market. T-statistics are in parentheses. *, ** and *** denote statistical significance at the 10 per cent, 5 per cent and 1 per cent levels, respectively.

**Table I** Sub-period analysis of gold beta values for the gold mining industry

<table>
<thead>
<tr>
<th>Hypothesis in equation form</th>
<th>Wald test statistic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma_1 = \gamma_2 = \gamma_3$ (<em>H1</em>)</td>
<td>2.7002</td>
<td>0.0688</td>
</tr>
<tr>
<td>$\gamma_1 = \gamma_2$ (<em>H1a</em>)</td>
<td>0.0264</td>
<td>0.8709</td>
</tr>
<tr>
<td>$\gamma_2 = \gamma_3$ (<em>H1b</em>)</td>
<td>3.5792</td>
<td>0.0695</td>
</tr>
</tbody>
</table>

**Notes:** This table shows the results obtained from the Wald tests, which ascertains whether the values of gold beta have undergone significant changes from 1995 to 2000, following a period of pronounced gold price volatility. $\gamma_1$, $\gamma_2$ and $\gamma_3$ denote the gold betas from 1995 to 1996, from 1997 to 1998, and from 1999 to 2000, respectively. A higher Wald statistic is indicative of distinct differences between the gold betas of each sub-period.

**Table II** Wald tests for non-stationary gold betas
Table III: Comparison between gold betas and the corresponding gold price volatility for each sub-period

<table>
<thead>
<tr>
<th>Sub-period</th>
<th>Gold beta value</th>
<th>Standard deviation ($/oz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995-1996</td>
<td>1.8499</td>
<td>7.7082</td>
</tr>
<tr>
<td>1997-1998</td>
<td>1.7792</td>
<td>23.617</td>
</tr>
<tr>
<td>1999-2000</td>
<td>1.0190</td>
<td>13.964</td>
</tr>
</tbody>
</table>

Notes: This table aims to identify the relationship between gold beta values for the gold mining industry and the corresponding gold price volatility across the three sub-periods. Volatility is measured by the standard deviation of gold prices ($/oz).

Table IV: Dimson and Fowler–Rorke adjusted gold betas of individual mining companies from 1997 to 2000

<table>
<thead>
<tr>
<th>Method</th>
<th>Mean</th>
<th>Median</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel A: gold betas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimson</td>
<td>1.56</td>
<td>1.22</td>
<td>1.92</td>
</tr>
<tr>
<td>Fowler–Rorke</td>
<td>1.54</td>
<td>1.26</td>
<td>1.85</td>
</tr>
<tr>
<td>Panel B: exchange rate betas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimson</td>
<td>-0.49</td>
<td>-0.51</td>
<td>2.28</td>
</tr>
<tr>
<td>Fowler–Rorke</td>
<td>-0.53</td>
<td>-0.47</td>
<td>2.36</td>
</tr>
<tr>
<td>Panel C: market betas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimson</td>
<td>0.24</td>
<td>0.12</td>
<td>1.24</td>
</tr>
<tr>
<td>Fowler–Rorke</td>
<td>0.18</td>
<td>-0.04</td>
<td>1.84</td>
</tr>
</tbody>
</table>

Total number of observations in each panel: 570

Notes: The multifactor model used to derive unadjusted gold beta values is specified as:

\[ R_{i,t} = \alpha + \beta_{tg} \times GPR_t + \beta_{FX} \times FXR_t + \beta_{um} \times R_{m,t} \]

The multifactor model used to derive Dimson and Fowler–Rorke adjusted gold beta with one lead and lag term is specified as:

\[ R_{i,t} = \alpha + \sum_{k=-1}^{k=1} \beta_{tg} \times GPR_{t+k} + \sum_{k=-1}^{k=1} \beta_{FX} \times FXR_{t+k} + \sum_{k=-1}^{k=1} \beta_{um} \times R_{m,t+k} \]
Table V: Multivariate analysis of factors affecting the gold betas of gold mining firms

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Pred. sign</th>
<th>Dimson beta (A)</th>
<th>Fowler–Rorke beta (B)</th>
<th>Stock return (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td></td>
<td>0.498 (0.60)</td>
<td>0.406 (0.65)</td>
<td>0.176 (0.59)</td>
</tr>
<tr>
<td>Delta-per cent-of reserves</td>
<td></td>
<td>-0.729 (0.01)*</td>
<td>-0.692 (0.01)*</td>
<td>8.216 (0.09)**</td>
</tr>
<tr>
<td>Cash costs</td>
<td>+</td>
<td>0.004 (0.122)</td>
<td>0.004 (0.10)**</td>
<td>-0.336 (0.683)</td>
</tr>
<tr>
<td>Cash reserves/Mkt capitalization</td>
<td></td>
<td>-0.454 (0.533)</td>
<td>-0.414 (0.554)</td>
<td>-0.245 (0.802)</td>
</tr>
<tr>
<td>Gold production</td>
<td>-</td>
<td>0.25 (0.255)</td>
<td>0.264 (0.210)</td>
<td>-0.631 (0.824)</td>
</tr>
<tr>
<td>No. of observations</td>
<td></td>
<td>113</td>
<td>113</td>
<td>113</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td></td>
<td>0.062</td>
<td>0.064</td>
<td>0.147</td>
</tr>
<tr>
<td>F-statistic</td>
<td></td>
<td>2.473</td>
<td>2.534</td>
<td>4.234</td>
</tr>
<tr>
<td>Durbin–Watson</td>
<td></td>
<td>1.995</td>
<td>1.997</td>
<td>2.005</td>
</tr>
</tbody>
</table>

Notes: The multifactor model used for the separate regression procedure is specified as:

$$\beta_{it} = \alpha + \sum_{j=1}^{N} \Phi_{j,t} F_{j,t} + \varepsilon_i$$

The multifactor model used for the joint regression procedure is specified as:

$$R_{it} = \alpha + \sum_{k=1}^{h} \left( \alpha_{g} + \sum_{j} \Phi_{gj} F_{j,i,t} \right) * GPR_{i+k}$$

$$+ \sum_{k=1}^{h} \left( \alpha_{FX} + \sum_{j} \Phi_{FXj} F_{j,i,t} \right) * FXR_{i+k}$$

$$+ \sum_{k=1}^{h} \left( \alpha_{m} + \sum_{j} \Phi_{mj} F_{j,i,t} \right) * R_{m,i+k}$$

This table reports the results of multivariate analysis of the factors affecting the gold beta of Australian mining firms. The dependent variables in columns A and B (separate regression) are the Dimson and Fowler–Rorke adjusted gold betas, respectively. These are then run against the corresponding firm-specific independent variables. In column C (joint regression), the dependent variable is the annual stock market return for stock i, and the independent variables are the interaction terms representing the product of the variable listed and the annual gold price return. This corresponds to the notation $F_{j,i,t} * GPR_{i+k}$ in equation (2) above. In the joint regression, there are also interaction terms between the independent variables and the exchange rate return as well as market return, which are not reported. p-values are reported in parentheses. *, and ** denote statistical significance at the 10 per cent and 1 per cent levels.

Table V: Multivariate analysis of factors affecting the gold betas of gold mining firms

<table>
<thead>
<tr>
<th></th>
<th>Prod</th>
<th>Cashpos/Mkt cap</th>
<th>Hedge ratio</th>
<th>Cash cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prod</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cashpos/Mkt cap</td>
<td>-0.0151</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hedge ratio</td>
<td>-0.1275</td>
<td>-0.0625</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Cash cost</td>
<td>-0.3136</td>
<td>-0.0652</td>
<td>0.0846</td>
<td>1</td>
</tr>
</tbody>
</table>

Table A1: Correlation amongst various firm-specific factors
\[ R_{g,t} = \alpha + \beta_g \text{GPR}_t + \beta_x \text{FXR}_t + \beta_m R_{m,t} + \varepsilon_t \]  

\[ R_{gt} = \sum_{j=1}^{3} \alpha_j \cdot D_j + \sum_{j=1}^{3} \gamma_j[D_j \cdot \text{GPR(USD)}_t] + \sum_{j=1}^{3} \beta_{FX,j}[D_j \cdot \text{FXR(USD/AUD)}_t] + \sum_{j=1}^{3} \beta_{m,j}[D_j \cdot R_{mt}] \]  

\[ H1. \quad \gamma_1 = \gamma_2 = \gamma_3 \]
\[ H1a. \quad \gamma_1 = \gamma_2 \]
\[ H1b. \quad \gamma_2 = \gamma_3 \]

\[ R_{i,t} = \alpha + \beta_{i,g} \text{GPR}_t + \beta_{i,fx} \text{FXR}_t + \beta_m R_{m,t} + \varepsilon_t \]

\[ R_{it} = \alpha + \sum_{k=-1}^{+k} \beta_{i,g,k} \text{GPR}_{t+k} + \sum_{k=-1}^{+k} \beta_{i,fx,k} \text{FXR}_{t+k} + \sum_{k=-1}^{+k} \beta_{m,k} R_{m,t+k} + \varepsilon_{it} \]

\[ \beta_{i,g,k} = w_1 \beta_{i,g,-1} + \beta_{i,g,0} + w_1 \beta_{i,g,1} \]

\[ \beta_{ig} = \alpha + \sum_{j=1}^{N} \Phi_j F_{ij} + \varepsilon_i \]
\[ R_{it} = \alpha + \sum_{k=1}^{H} \left[ \alpha_{g} + \sum_{j} \Phi_{gj} F_{ij} \right] GPR_{t+k} + \sum_{k=1}^{H} \left[ \alpha_{f} + \sum_{j} \Phi_{fj} F_{ij} \right] FRR_{t+k} + \sum_{k=1}^{M} \left[ \alpha_{m} + \sum_{j} \Phi_{mj} F_{ij} \right] R_{m,t+k} + \varepsilon_{it} \] (7)

Equation 8

References


**Appendix**

Table AI

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