Capital Expenditures, Financial Constraints, and the Use of Options

Tim Adam*

M.I.T. - Sloan School of Management
50 Memorial Drive, E52-403A
Cambridge, MA 02142, USA

Tel.: (617) 253-5123
Fax: (617) 258-6855
E-mail: *tadam@mit.edu*

May 2006

*I would like to thank Greg Brown, Kalok Chan, Gunter Dufey, Joseph Fan, Chitru Fernando, Charles Hadlock, David Haushalter, Dirk Jenter, Alberto Moel, Tim Opler, Peter Tufano and seminar participants at the University of Michigan, University of Oklahoma, the Hong Kong University of Science & Technology, and Nanyang Technological University of Singapore for valuable comments and suggestions. I claim responsibility for any remaining errors and omissions. I am also grateful to Ted Reeve for providing me with his derivatives surveys.

Capital Expenditures, Financial Constraints, and the Use of Options

Abstract

This paper investigates why and how firms in the gold mining industry use options strategies to hedge their gold price exposures. I find that firms with extensive investment programs and firms that focus on gold mining activities only are more likely users of options strategies. Among these firms the largest and least financially constrained firms tend to buy put options (insurance strategies), while more financially constrained firms use collar strategies or sell call options. Firms' hedging instrument choices are also correlated with current market conditions. When gold prices decline firms shift away from hedging with forwards and buy put options instead. When gold prices increase firms sell more call options on gold.

JEL Classification: G32

1 Introduction

The use of options as risk management tools is widespread among corporations. For example, the Wharton/CIBC 1998 risk management survey reports that 68% of non-financial firms that use derivatives also use options. The gold mining industry is no exception: 62% of derivatives users hedge their gold price exposures with options, and the average fraction of the future gold production that has been hedged with options is 33%.

Options positions are clearly an important part of the risk management strategies of many firms. However, our knowledge as to why and how firms use options is quite limited. This study tries to shed light on this topic. It comprehensively evaluates options strategies in the North American gold mining industry, and focuses on three main questions: First, are there cross-sectional differences between firms that use options strategies and firms that use linear hedging strategies? Second, among option users why do some firms buy options while others sell options? Third, do market conditions affect firms' hedging instrument choices?

There are several theoretical models that predict when firms should use options to hedge their risk exposures. For example, Froot, Scharfstein and Stein (1993) show that if a firm is financially constrained and if its future capital expenditures are a non-linear function of some risk exposure, then options may be necessary to achieve the value-maximizing hedge. Adam (2002) extends the Froot, Scharfstein and Stein (1993) model to an inter-temporal setting, and shows that financially less constrained firms tend to buy options, while financially more constrained firms tend to sell options. Adler and Detemple (1988) show that borrowing and short-selling constraints can cause exposures to be non-linear and hence create a demand for options. Stulz (1996) argues that large, financially stable firms are the most likely to

incorporate market views into their hedging programs. Since options strategies allow a hedger to maintain significant exposures, firms that incorporate their market views may find options strategies particularly attractive.

In addition to these financial constraints based theories, a few authors have examined the impact of non-hedgeable risks and real options on the demand for options. Adler and Detemple (1988), and Moschini and Lapan (1995) show that the optimal hedging portfolio contains options if hedgeable and non-hedgeable risks are correlated. Brown and Toft (2002) show that this result can hold even if hedgeable and non-hedgeable risks are uncorrelated. Finally, Moschini and Lapan (1992) consider a firm's option to choose certain production parameters after product prices are observed. Assuming hedging is desirable, hedging this production flexibility (a real option) optimally requires non-linear hedging instruments, i.e., options. Common to all theories is the general insight that if the exposure is non-linear then the optimal hedging strategy is also non-linear.

In order to test the empirical relevance of the above theories, I examine the use of options strategies in the North American gold mining industry over a 10 year horizon, between 1989 and 1999. The gold mining industry represents an excellent laboratory for this study because gold mining firms share a relatively simple risk exposure, the future price of gold, but make use of a range of different hedging strategies.[1] Therefore, differences in hedging strategies are more likely the result of differences in certain firm-specific characteristics rather than differences in exposures. Furthermore, to my knowledge no other industry reveals similarly detailed information about their derivatives portfolios that would allow the study of instrument choice.

I find that gold mining firms with high capital expenditures are more likely to

[1]The four primary hedging strategies are: selling forward, buying put options (insurance strategies), buying collars, and selling call options.

hedge their future gold sales using options strategies. They also use options to a larger extent. These results support the Froot Scharfstein and Stein (1993) model, in which financially constrained firms hedge in order to match their cash inflows with their cash outflows (capital expenditures), which may be non-linear functions of the future gold price. In addition, I find that financially constrained firms tend to sell options while financially unconstrained tend to buy options, which is consistent with Adam's (2002) extension of the FSS model. Thus, while both financially constrained and unconstrained firms may have incentives to use options, they use different options strategies: Financially unconstrained firms buy puts to hedge their future capital expenditures, while financially constrained firms sell calls to raise funds to support their current capital expenditures.

I also find that the use of options strategies is negatively correlated with firms' business diversification. Firms that focus exclusively on gold mining activities are the most likely users of options strategies. It is often claimed that there are investors who hold gold mining stocks primarily to gain gold price exposure, often referred to as 'gold bugs.'. Firms that focus exclusively on gold would be the primary targets for these investors. The existence of a gold investor clientele may also drive the use of options strategies, since options allow a firm to hedge while at the same time maintain significant exposure to gold prices. Insurance strategies (long put positions) maintain the most upside exposure. However, they require the up-front payment of the insurance (option) premium. I find that the largest and least financially constrained firms are the most extensive users of insurance strategies. Firms that are somewhat more financially constrained are more likely to hedge using collars, i.e., finance the puts by selling calls.

I find no evidence that uncertainty of the exposure (presence of production risks) or the existence of real options (production flexibility) motivate firms to use options

strategies. However, I find that firms' hedging instrument choices are correlated with current market conditions. When gold prices decline, firms reduce their use of linear hedging strategies (forwards) and switch towards options strategies instead. In particular, they hedge their future gold sales by buying put options. When gold prices increase, firms increase their short call positions. These results are consistent with mean-reversion in the gold market. When gold prices decline firms prefer not to lock in the relatively low price with a forward contract, but hedge the downside risk with a put option in order to maintain the upside potential.[2] When gold prices rise firms sell calls in the hope that they will expire worthless.

There are no comprehensive studies on the corporate use of options as hedging instruments. Tufano (1996) describes the different risk management strategies used by gold mining firms. Consistent with the results in this paper he finds that large firms are more likely to use options. A couple of papers examine other types of derivatives used as part of their analyses. For example, Geczy, Minton and Schrand (1997) find that firms are more likely to use currency swaps if they have more foreign-denominated debt, while they are more likely to use other foreign currency derivatives (such as forwards, futures and options) if they receive more income from foreign sources. In a clinical study of a durable goods manufacturer Brown (2001) finds that concerns about accounting treatments and the firm's competitive position affect its hedging instrument choices.

In contrast to the lack of studies on firms' hedging instrument choices, there are several studies that examine hedging strategies in the gold mining industry. Tufano (1996) analyzes the determinants of the decision and the extent of hedging. He finds that hedge ratios are higher among firms that keep less liquidity and lower

[2]This rationale is also cited by Merck & Co., Inc. "Given the possibility of exchange rate movements in either direction, we were unwilling to forgo the potential gains if the dollar weakened; so options were strictly preferred." (see Lewent and Kearney, 1990, pp. 26-27)

among firms that reward their executives with more stock options but less shares of the company. In a second paper, Tufano (1998) studies the gold price exposures of a cross-section of gold mining firms, and finds that hedging has only a marginal effect on a firm's stock price sensitivity to gold prices. Petersen and Thiagarajan (2000) show that differences in operating cost structures can lead some firms to use financial hedges and others to use operational hedges to mitigate gold price risk. Chidambaran, Fernando, and Spindt (2001) show that Freeport MacMoRan was able to obtain better financing terms by issuing gold-linked notes rather than regular debt. Brown, Crabb and Haushalter (2005) examine whether gold mining firms adjust their hedge ratios due to their expectations about future gold prices, and find some supporting evidence. Finally, Adam and Fernando (2006) find that gold mining firms earn significantly positive cash flows from their derivatives transactions, which they link to the existence of a risk or forward premium in the gold market.

The rest of the paper is organized as follows. Section 2 describes the sample and risk management strategies in the gold mining industry. Section 3 summarizes the theoretical foundations of why firms should or should not use options. Section 4 presents the empirical results, and Section 5 concludes.

2 The Sample

The sample firms are those included in the *Gold & Silver Hedge Outlook*, a quarterly survey conducted by Ted Reeve of Scotia Capital from 1989 to 1999. The survey contains information on the gold derivatives positions of 118 gold mining companies, which represent most firms in the North American gold mining industry. Firms that are not included tend to be small and privately held corporations. The appendix

provides an example of the survey data.[3]

Most financial data are obtained from the Active, Canadian, and Research tapes of the Compustat database. Financial data of firms included in the survey but not covered by Compustat are collected by hand from firms' annual reports and 10-K forms. Operational data, such as metals production and cash production costs are also collected by hand from firms' annual reports and 10-K forms. Financial market data, such as gold prices, futures prices, and interest rates, are obtained from Datastream. The regressors and data definitions are summarized in Table 1.

Table 2 provides descriptive statistics of the 101 sample firms for which financial data was available. The distribution of the market value of assets is highly skewed and indicates that the gold mining industry consists primarily of small firms and a few large producers. The market value of assets ranges from $3 million to about $12 billion, while the mean and median values are $1,039 million and $235 million respectively. The two Herfindahl indices show that most gold mining firms do not operate in other business segments, and exclusively mine for gold. The mean Herfindahl index based on asset segments is 0.95, while the mean Herfindahl index based on metals production is 0.87.[4]

In the 1990's, the average profit margin over cash production costs (excluding non-cash items such as depreciation, amortization and depletion) was only 47%, and some companies were not even able to recover their cash production costs. The high risk nature of gold mining, the little diversification, and slim profit margins argue for conservative financial policies. Indeed, most gold producers maintain very low leverage levels, relatively high cash balances and pay no dividends. The median

[3]Firms also report their derivatives positions in the footnotes to their financial statements. This alternative source provided a way to check the accuracy of the survey data.

[4]In fact, 88% of firms focus exclusively on gold mining, and 57% do not extract any metal other than than gold.

leverage ratio is 0.17, while the median quick ratio is 1.62. If dividends are paid, the payout ratios are generally low: 10% of the operating cash flow on average. Furthermore, most gold mining firms have no credit rating (84%), and if a rating exists it tends to be below investment grade. The fact that most firms have little debt outstanding indicates that most firms are not sufficiently credit worthy to attract significant amounts of debt. In fact, a relatively high debt level signals that a firm's cash flows are sufficiently stable to support debt. It is typically the largest firms, which operate many different mines, and hence have the most predictable cash flows, that also have the highest debt levels. Cases of overleveraged companies are rare in the gold mining industry.

Firms' investment programs are substantial. The average firm spends 24% of its invested capital or 50% of its sales (not reported) on capital expenditures each year. About 11% of sales are spent on acquisition activities.

In summary, a typical gold mining firm is a fairly small enterprise, which focuses exclusively on gold mining and operates under a slim profit margin. To support its investment program it raises external financing mostly in form of equity. The average firm pursues a conservative financial policy, has no public debt outstanding, and pays no dividends.

2.1 Risk management in the gold mining industry

Gold mining companies face two principal risk exposures: Gold price risk, which arises from the firms' major asset: the gold reserves in the ground, and production risk. In contrast to price risk, production risk is usually not hedgeable or insurable due to moral hazard or adverse selection. Gold price risk can be hedged, however, and the hedging of it is widespread. Between 1989 and 1999, on average 70% of gold mining companies used derivatives. Despite relatively similar risk exposures hedging

strategies differ tremendously. To manage gold price risk mining firms have been using forwards, spot-deferred contracts, gold loans, put and call options. Figure 1 shows that options are an important part of firms' derivatives portfolios, constituting approximately 40% of all outstanding derivatives positions.[5] Table 2 shows that about 62% of firms that use derivatives use options. The average fraction of the future gold production that has been hedged with options is 33%.

Option usage is not a recent phenomenon. Figure 2 shows that the fraction of firms that use both options and linear strategies has increased from 30% in 1989 to 55% in 1999, while the fraction of firms that use linear strategies only has been generally declining.

Figure 3 depicts the payoff profiles of the four principal risk management strategies in the North American gold mining industry as functions of the future gold price. Note that all strategies generally yield positive cash flows if the gold price declines, indicating that gold mining firms reduce their gold price exposures. 39% of firms use, like Teck Corp., exclusively linear contracts (forwards, SDC, and gold loans), 12% use, like Hecla Mining, puts and forwards, 39% use, like Miramar Mining, puts, calls and forwards, and 10% use, like Glamis Gold, forwards and calls. The resulting payoff profiles are linear, convex, concave, or both convex and concave (collars).

In order to derive testable predictions, it is important to understand the major differences between these four risk management strategies. Each strategy has different implications with respect to the elimination of downside risk and upside potential, the initial cash flow impact, and the flexibility in structuring the hedge. For example, while selling a forward contract fully eliminates both the downside risk and the upside potential, buying an (out-of-the-money) put option only partially hedges the

[5] The aggregate risk management portfolio consists of the derivatives positions of all firms in the sample. Its characteristics differ from the sample statistics because the aggregate portfolio is skewed towards the larger hedgers.

downside, while it maintains all of the upside. Selling an (out-of-the-money) call option hedges none of the downside risk, but eliminates part of the upside. Buying a collar partially eliminates both the downside risk and the upside potential. Thus, options strategies allow the hedger to maintain exposure to the gold price to varying degrees. A firm that uses puts or calls maintains most exposure, while a firm that uses forwards eliminates all exposure (on a per ounce of gold hedged basis). Firms that use collars maintain some exposure to gold prices.

The four strategies also differ in terms of their initial cash flow impacts. While a forward strategy is self-financing, buying puts requires a cash payment, and selling calls yields a cash inflow. Buying collars can be self-financing, depending on the choice of strike prices and the number of options involved. Thus, a firm that uses options strategies shifts cash flows not only across states of nature, but also across time periods. It makes both intra-temporal and inter-temporal decisions and therefore must consider the marginal benefit of funds across states and across time.

Finally, options strategies provide more flexibility in structuring a hedge than linear strategies, because options are available for many different strike prices, while in the forward market only one contract price is available at any point in time. This is why options are more suitable to hedge non-linear exposures. Table 3 summarizes the differences between the four primary hedging instruments.

3 Should Firms Use Options?

There are several theories as to why firms should hedge using options strategies. Common to all theories is the general insight that if the exposure to be hedged is non-linear, then non-linear instruments, i.e., options, are necessary to obtain the optimal hedge. This section reviews the relevant literature, and derives testable

implications with respect to the four primary hedging strategies used by gold mining firms, summarized in Table 4.

Froot, Scharfstein and Stein (1993) argue that firms, which are financially constrained, may hedge their future capital expenditures, so as to reduce their dependence on external capital markets. If firms' investment expenditures are non-linear then the optimal hedging strategy may require non-linear instruments.[6] Figure 4 illustrates an example. It depicts a firm's operating cash flow and its capital expenditures as functions of the gold price. If the gold price drops below x, then the firm's internal cash is insufficient to finance its capital expenditures. Given a forward price of F the funding risk cannot be fully hedged with a linear strategy, as shown in Panel A. However, it can be hedged with a put option or an asymmetric collar, as shown in Panel B. Had the capital expenditures been generally lower, then a linear strategy could have sufficed. Thus, based on the Froot, Scharfstein and Stein (1993) model, we should expect that firms with large investment programs are more likely to use options strategies.

The following statement is consistent with a relationship between capital expenditures and options strategies.

> "In periods of capital expenditure or loan finance, the Company secures a floor price through simple forward contracts and options whilst maintaining significant exposure to spot prices." (Randgold Resources Corp, 2001 Annual Report)

Chacko, Tufano, and Verter (2001) discuss an example of hedging future capital

[6] MacKay (2005) has shown that production costs in the oil industry are a non-linear function of the oil price. In the gold mining industry investment expenditures are likely to be non-linear also. Consider a mining company, which would develop an existing gold reserve only if the gold price were to rise above some threshold. The firm would need to raise capital to build the mining facilities, etc. only if the gold price rose above that threshold, but would have no financing needs if gold prices remained low. Thus, the firm's capital requirement is a step function.

expenditures at Cephalon, Inc. The firm was waiting for approval to market a particular drug. If approval were granted, the firm would face significant cash needs. Management expected that approval would cause the firm's share price to rise significantly. To guarantee sufficient funds should the approval for the drug be granted, Cephalon's management decided to purchase call options on its own stock. The options would payoff handsomely should approval be obtained and Cephalon's share price rise.

Adam (2002) extends the Froot, Scharfstein and Stein (1993) model to an inter-temporal setting in order to capture the fact that options strategies affect cash flows in multiple periods. In his model firms equalize the marginal benefit of cash by shifting cash flows not only across states of nature but also across time. A financially constrained firm is characterized by a currently high marginal benefit of funds. It will shift cash flows from future states, in which the marginal benefit of cash is low, to the present. For a gold mining firm this objective can be achieved by selling calls on gold. A financially unconstrained firm is characterized by a currently low marginal benefit of funds. It will shift cash flows from the present to future states, in which the marginal benefit of cash is high. For a gold mining firm this objective can be achieved by buying puts on gold. If the marginal benefit of cash is already equalized across time, then firms shift cash flows only across states of nature by using standard forwards or zero-cost collars.

Why is it optimal for firms to shift cash flows inter-temporally using options rather than using traditional forms of borrowing and lending? This is because with state-contingent contracts the marginal benefits of funds can be equalized more efficiently. For example, state-contingent debt can reduce credit risk and hence offer a cheaper form of funding for a financially constrained firm. An example of this case is discussed by Chidambaran, Fernando, and Spindt (2001). Similarly, it is more efficient for a

financially constrained firm to shift cash flows only to those states in the future, in which the marginal benefit of cash is high. Regular lending would shift cash flows to all states in the future. Thus, the model by Adam (2002) predicts that financially unconstrained firms buy (put) options, while financially constrained firms sell (call) options. Average firms use either collar or linear strategies.

Stulz (1996) argues that large, financially stable companies have a comparative advantage in bearing certain financial risks. For example, a firm that believes it has an informational advantage may decide to maintain some exposure if its financial condition is sufficiently stable so that a negative outcome would not jeopardize its operations. As discussed in the previous section, options strategies allow the hedger to maintain varying degrees of exposures. Most exposure to gold prices is maintained if firms use either puts or calls. Less exposure is maintained if a firm uses collars, and no exposure is maintained if a firm used linear hedging strategies. Thus, Stulz's (1996) model would predict that large, financially unconstrained firms buy puts or sell calls, medium sized firms use collars, and the smallest and most financially constrained firms use linear hedging strategies.

Adler and Detemple (1988) show that in a portfolio context borrowing and short-selling constraints can cause exposures to be non-linear, and thus create a demand for options. In a corporate context such constraints may be represented more generally by financial constraints. Thus, their model would predict that financially constrained firms are more likely to choose options strategies.

A number of authors explore the effects of non-hedgeable risks on options strategies. Moschini and Lapan (1995) show that if hedgeable and non-hedgeable risks are correlated, then the optimal hedging portfolio is non-linear. Unfortunately, gold prices and production risks (non-hedgeable risks) tend to be uncorrelated, because the gold production of an individual firm has no measurable impact on the gold price,

which is determined by world demand and supply. Thus, there must be other reasons as to why gold mining firms use options. However, Brown and Toft (2002) extend Moschini and Lapan's (1995) work and show that the mere *existence* of non-hedgeable risks can cause an exposure to be non-linear. This result is similar to the typical textbook recommendation to hedge an uncertain exposure with options. The greater the magnitude of non-hedgeable risks, the greater would be the incentive to use options.[7]

Franke, Stapelton and Subrahmanyam (1998) show that in the presence of non-hedgeable risks risk-averse investors prefer to buy options, while in the absence of such risks investors prefer to sell options. The intuition is similar to Leland (1980), who shows that agents whose risk tolerance increases with income purchase portfolio insurance from agents whose risk tolerance increases less rapidly. Since shareholders do not necessarily act in a risk-averse manner, it is not clear whether this theory applies in a corporate context. If it does apply, their model would predict that firms that are exposed to high production uncertainty buy put options, while firms that are exposed to little production risk sell call options.

In Moschini and Lapan (1992) a firm is given the option to choose certain production parameters *after* product prices are observed. Assuming hedging is desirable (the authors assume that the firm is risk-averse), hedging this production flexibility option (a real option) optimally requires non-linear instruments, i.e., options. In particular, to hedge the convexity of a real option, a firm would need to sell convexity, i.e., sell call options. Thus, Moschini and Lapan's (1992) model implies that the selling of calls might be related to a firm's production flexibility.

A further motivation of selling calls may be to raise cash. For example, in 1998,

[7]Brown and Toft (2002) further show that firms should buy options if price and quantity risks are negatively correlated, and sell options if price and quantity risks are positively correlated. Unfortunately, this idea fails to explain risk management choices in the gold mining industry. As argued previously, gold price risk is uncorrelated with firms' production risks, but the use of options is widespread.

Kinross Gold Corp sold call options worth $2.1 million to partially pay for the acquisition of Amax Gold. The following year, another year of major acquisitions, Kinross sold additional calls worth $4.5 million. Other firms that have sold substantial number of call options include Cambior, IAM Gold, and Placer Dome. Financing acquisitions by selling part of the future production is also known in the oil industry. If a firm's financial condition is sufficiently weak it may be willing to give up some of its upside potential and raise cash by selling calls. I will therefore test whether acquisitions generally motivate the selling of call options in the mining industry, or whether the above are idiosyncratic cases.

In contrast to the theories of option usage stands the possibility that options are used to implement managers' market views. For example, a manager who must hedge but believes that the gold price is more likely to raise might decide to purchase puts rather than sell forwards in order to maintain the upside potential. Indeed, I conducted a survey among 30 gold mining companies, which revealed that after 'size of exposure' the most important determinants of instrument choice are market conditions, such as volatility, expected future spot prices, and liquidity of contracts. I will therefore test to what extent market conditions, such as gold prices and the gold price volatility, affect option strategies.

4 Results

The discussion in the previous section revealed that the use of non-linear (options) hedging strategies should be correlated with firms' investment expenditures, financial constraints, non-hedgeable risks, production flexibility (real options), and market conditions. To measure the magnitude of firms' investment expenditures, I define the

ratio of capital expenditures over net plant property and equipment (CAPX/PPE).[8]

To proxy for financial constraints I follow the existing empirical literature and use variables such as firm size, the market-to-book ratio of assets, diversification, leverage, dividend policy, the existence of a credit rating, and a firm's profit margin. Diversification is measured by two Herfindahl indices, one based on the value of assets allocated to different business segments, the other based on the value of different metals that a firm produces. The main metals that the sample firms produce are (in order of importance): gold, silver, copper, zinc, lead, and nickel. As explained in the introduction diversification can also inversely proxy for a gold investor clientele, and thus provide firms that focus on gold mining only with an incentive to maintain maximum gold price exposure.

As pointed out previously, leverage levels in the gold mining industry are characteristically low. The fact that a firm has debt outstanding often indicates that it was sufficiently creditworthy to attract debt. In fact, it is typically the largest firms, which operate many different mines, and hence have the most predictable cash flows, that have the highest debt levels. The case of overleveraged firms is rare in the gold mining industry. Thus, *low* leverage should be interpreted as a sign of financial constraints.

A firm's profit margin is defined by the difference between the gold spot price and the cash production costs per ounce of gold.

To capture the magnitude of non-hedgeable risks, I calculate the mean squared production forecast error defined by

$$MSE_t \equiv \frac{1}{k} \sum_{i=1}^{k} \left(\frac{\hat{y}_{t,t+i} - y_{t+i}}{y_{t+i}} \right)^2,$$

[8] In an earlier draft I also defined the ratio of exploration expenditures (expensed and capitalized) over sales. However, this variable never turned out to be significant in the analysis. Since it significantly reduces the sample size, I have dropped it from the analysis.

where $\hat{y}_{t,t+i}$ denotes the production forecast of year $t+i$ at time t, and y_{t+i} denotes the actual gold production in year $t+i$.[9] Production risk is a classic example of a non-hedgeable risk.

The existence of real options is measured by two variables: the number of mines in operation, and the standard deviation of mine production costs. The more mines a firm operates, the more it is able to shift production from one mine to another in response to changes in market conditions. Thus, such a firm should enjoy more production flexibility (real options). Of course, if all mines had the same production costs, then this production flexibility would be less valuable. I therefore include the dispersion in mine production costs as an additional regressor. Firms that operate mines with different unit extraction costs benefit from volatility in gold prices because they can adjust their production costs by shifting production from low-cost mines to high-cost mines and vice versa. Other variable definitions are summarized in Table 1.

The remainder of this section is organized as follows. Section 4.1 presents the univariate results. Section 4.2 examines differences between firms that use options strategies in general and firms that use options strategies. Sections 4.3, 4.4, and 4.5 focus on strategies involving the use of insurance (long puts), collars, and short call option positions respectively, and compare their users with firms that hedge with linear strategies. Section 4.6 compares firms that buy options with firms that sell options, and Section 4.7 evaluates to what extent market conditions affect the use of options strategies.

[9] Gold mining companies report these production forecasts in the derivatives surveys conducted by Ted Reeve from Scotia Capital. There are up to k production forecasts available at each point in time ($k_{\max} = 4$).

4.1 Univariate results

Table 5 shows descriptive statistics of the sample firms by hedging strategy. There are 143 observations (39%) of firms that hedged exclusively with linear strategies (forwards, sport-deferred contracts, and/or gold loans), 45 observations (12%) of firms that hedged using a combination of long puts and linear contracts, 141 (39%) observations of firms that hedged using a combination of collars and linear contracts, and 45 observations (12%) of firms that hedged using a combination of short calls and linear contracts.

The univariate comparisons already demonstrate significant differences between the firms in each category, especially between option buyers and option sellers. Firms that buy options tend to be the largest in the industry (based on medians), are the most diversified, and operate under the highest profit margins. They are the most likely to pay dividends, and if dividends are paid, offer the highest payout ratios. They keep the lowest cash balances, maintain the highest leverage levels, and are the most likely to have a credit rating. In short, these firms are the industry leaders, and probably face the lowest financial constraints in the industry.

In contrast, firms that sell options are on the other end of the spectrum. These firms tend to be the smallest in the industry (based on medians), are the least diversified, and operate under the smallest profit margins. They are the least likely to pay dividends, and if dividends are paid, offer the lowest payout ratios. They keep the highest cash balances, maintain the lowest leverage levels, and are the least likely to have a credit rating. Thus, options sellers tend to be the smallest and probably the most financially constrained firms in the industry. The t-statistics and z-scores in the last column of Table 5 show that most differences between option buyers and option sellers are statistically significant.

Firms that use linear hedging strategies and firms that use collar strategies are somewhere in the middle between the two extremes. In many respects linear and collar hedgers are quite similar. These results support Adam's (2002) extension of the Froot, Scharfstein and Stein (1993) model, which stipulated that financially unconstrained firms are the most likely to buy options, while financially constrained firms are the most likely to sell options. In addition, the univariate results reveal that firms that use options strategies have larger investment programs than firms that use linear strategies, which is also consistent with Froot, Scharfstein and Stein (1993), who showed that if capital expenditures are non-linear then options are necessary to obtain the optimal hedge. Interestingly, firms that sell options have the highest acquisition expenditures among the four groups of firms, but the differences are not statistically significant.

In terms of production uncertainty, there are no significant differences between linear hedgers and options users, as predicted by Brown and Toft (2002) or between option buyers and option sellers, as predicted by Franke, Stapleton and Subrahmanyam (1998). Firms that sell options operate the fewest mines with relatively low dispersion in production costs. This indicates that option sellers have the lowest production flexibility, contradicting the predictions by Moschini and Lapan (1992).

4.2 Why firms use options strategies

Table 6 contains probit estimations of the decision to use options strategies, and tobit estimations of the fraction of gold hedged with options. Since most firms that hedge with options also hedge with linear contracts, the tobit estimations provide useful robustness checks. To account for the panel nature of the data set, I estimate random-effects and population-averaged probit models. Since both estimation techniques

resulted in similar results, only the population-averaged probit models are reported.[10]

The theories presented in Section 3 predicted that firms that use options strategies have larger investment programs, and are subject to more production uncertainty. With respect to firm size and financial constraints, the predictions were ambiguous. Stulz (1996) predicts that option users are larger and less financially constrained than linear hedgers, while Adler and Detemple (1988) would predict the opposite.

Consistent with the univariate results, the multi-variate results show that firms with larger investment programs are more likely to use options strategies and use options to a larger extent. This may be because capital expenditures are inherently non-linear and firms use options to match cash inflows with cash outflows as proposed by Froot, Scharfstein and Stein (1993). With respect to financial constraints the evidence is mixed.[11] Larger firms are more likely users of options strategies, but firm size does not affect the extent of using options strategies. On the other hand, less diversified firms and firms that pay no dividends are more likely users of options and also use options to a larger extent, indicating that financial constraints motivate the use of options strategies.

The finding that firms, which concentrate on gold mining activities only, are more extensive users of options can also be explained by the gold investor clientele effect. Firms that concentrate on gold mining only are the most likely investment vehicles for gold investors who hold gold mining stock primarily because of the exposure to gold. A strong clientele effect could cause a dilemma for a firm. On the one hand the firm

[10] One caveat in this study is that the sample is relatively small due to the industry focus. Therefore the results are potentially more sensitive to changes in the sample size than in large sample studies. I address this problem in three ways. (i) All tests are performed with and without outliers. Outliers are defined as the extreme 1% of values for each variable. (ii) Variables that reduce the sample size significantly are excluded in robustness checks. (iii) All tests are performed on the full sample and a subsample which excludes marginal hedgers (firms that hedge less than 10% of output). Whenever a change in the sample size significantly affected the results, all results are reported.

[11] The results in Section 4.6, which compares option buyers with option sellers will reveal why this is the case.

may need to hedge its gold exposure to relax certain constraints. On the other hand, the firm's shareholders prefer the firm to remain unhedged. Options provide the firm with the opportunity to hedge while at the same time maintain some exposure to gold prices.

Finally, consistent with the univariate results, production risks do not seem to motivate the use of options strategies. The next three subsections evaluate the determinants of particular options strategies: insurance, collars, and the selling of (call) options.

4.3 Insurance versus hedging strategies

The theories presented in Section 3 predict that the size of the investment program, financial constraints, and production risks affect the choice between insurance and hedging strategies. Table 7 presents the multi-variate comparison between firms that use insurance strategies and firms that use linear hedging strategies. The results show that firms with large investment programs, larger firms, and firms that concentrate on gold mining only, rely more on insurance strategies than hedging strategies to hedge their gold price exposures. In addition, firms with lower market-to-book ratios are also more extensive users of insurance strategies. Production risks do not seem to motivate the use of insurance strategies.

Both firm size and the market-to-book ratio indicate that less financially constrained firms choose insurance strategies. Only the diversification result is inconsistent. If, however, concentration is not regarded as a proxy for financial constraints but as a proxy for a gold investor clientele, then the results provide a clear picture. Firms that concentrate on gold mining only, and hence are the most likely candidates to have a gold investor clientele, prefer to hedge with insurance strategies because insurance strategies preserve all of the firm's upside potential. However, insurance

strategies require the up-front payment of the insurance premium (the put premium). Only large and well established firms, i.e., those with fewer growth opportunities as measured by the market-to-book ratio, find it optimal to pay this premium. Financially more constrained firms choose linear hedges, or other options strategies as will be shown in the next sections.

4.4 Collar versus hedging strategies

Suppose a firm would like to hedge using insurance in order to maintain the upside exposure to the gold price, but does not have the financial resources available to pay for the insurance premium up-front. A possible solution would be to finance the purchase of put options (insurance) with the sale of call options. Thus, a financially more constrained firm, which also needs to serve a gold investor clientele, might choose a collar hedging strategy. The results in Table 8 seem to support this hypothesis.

Firms that use collars are more concentrated on gold mining only, and hence are more likely to have a gold investor clientele, than firms that use linear hedging strategies. Furthermore, financial constraints appear to be slightly more important now than for firms that use pure insurance strategies. The results with respect to firm size and the market-to-book ratio disappear, and the dividend dummy becomes significant.

Consistent with the previous results, the size of firms' investment programs are also an important determinant of choosing collar strategies over linear strategies. In contrast, production uncertainty and production flexibility do not appear to motivate the use of collar strategies.

4.5 Why firms sell options

According to Adam (2002), firms that sell options are the most financially constrained. On the other hand, Stulz (1996) predicts that sellers of calls are larger and less financially constrained than linear hedgers, because short call positions retain significant exposure to the gold price. In addition gold mining firms may sell call positions in order to raise funds for acquisitions.[12] In fact, the financing of acquisitions through the forward sale of future production is common in the oil industry. Furthermore, Chidambaran, Fernando, and Spindt (2001) discuss the case of Freeport McMoRan, which sold gold-indexed notes to finance the expansion of the Grasberg mine. The embedded call options on gold lowered the credit risk of the note and provided more attractive financing terms for Freeport McMoRan. It is possible that the selling of calls by the North American gold mining industry has similar motivations.[13]

The univariate results in Table 5 provide a compelling picture. Firms that sell calls on gold tend to be the smallest, and possibly most financially constrained firms in the industry. However, there are also a number of very large firms among option sellers, as indicated by the large difference between the mean and median values for firm size. The multivariate results, presented in Table 9, are somewhat weaker, but retain a similar flavor. Consistent with Stulz (1996) larger firms are more likely and more extensive sellers of options. On the other hand diversification, leverage and dividend policy indicate that financially constrained firms are more likely to sell options than to choose linear hedging strategies. In particular, firms that are less diversified, have little leverage, and pay no dividends are more likely to sell calls. No

[12] For example, Cambior sold calls on 1.2 million ounces of gold in 1998, while Placer Dome sold calls on 2.1 million ounces of gold in 1999. Interestingly, both companies acquired new gold mines in these years: Doyon mine by Cambior in an all cash transaction worth $98 million, and the Zaldivar mine by Placer Dome.

[13] The firm's obligation from a written call is covered by its inherent long position in gold (the gold reserve in the ground), and therefore is subject to less credit risk than a traditional debt contract.

evidence could be found that gold mining firms systematically sell calls in order to raise funds to fund their acquisition expenditures.

Thus, there appear to be two motivations for gold mining firms to sell calls. First, financially constrained firms sell options in order to raise 'cheap' financing. Second, large firms sell calls, possibly in the hope that the calls will expire worthless. Since large firms have a higher ability to bear risk, they are the most likely to speculate in this way.

4.6 Who buys and who sells options

Adam (2002) predicts that financially unconstrained firms are more likely to buy options, while financially constrained firms are more likely to sell options. Thus, both constrained and unconstrained firms have incentives to use options, but use different options strategies, which would explain the weak statistical results with respect to financial constraints in Section 4.2. In addition, Franke, Stapelton and Subrahmanyam (1998) predict that firms that face more production risk are more likely to buy options while firms that face less production risk are more likely to sell options. To test these hypotheses I compare options buyers with options sellers.

The univariate tests in Table 5 show that on average sellers of options are more financially constrained than buyers of options. While buyers of options also seem to be exposed to more production uncertainty than sellers, the difference is not statistically significant.

The multivariate results, reported in Table 10, are statistically weaker, but are consistent with the univariate results. Firms that buy options are more diversified (lower Herfindahl indices), maintain higher leverage levels, and are more likely to pay dividends than firms that sell options. Thus, overall, option buyers appear to be less financially constrained than option sellers.

4.7 Do market conditions affect options strategies?

> Which instruments we use is influenced by market conditions (contango, volatility levels, spot market trends and forecasts), as well as by our shareholders." Christopher Hill, Vice President & Treasurer of Kinross Gold Corporation, 2002.

Apart from hedging and fund raising considerations, market conditions may also influence how managers hedge their exposures as the above quote indicates. For example, when the gold price declines, firms may be more reluctant to lock in the new, relatively low gold price with a forward contract, but hedge instead by purchasing put options so as to maintain the upside potential. When the gold price volatility is high, managers may refrain from buying options because options appear expensive.

The quarterly nature of the data set allows a limited time-series analysis to examine how changing market conditions affect firms' hedging instrument choices. To characterize the structure of firms' derivatives portfolios, I use two variables that have been used in the previous analysis. The fraction of gold hedged with options measures the extent of option usage, and the net option position measures the curvature of the derivatives portfolio: If the payoff of the portfolio is convex, the net option position is negative, while if the payoff is concave, the net option position is positive. See Table 10 for further details.

The time-series graphs of the two measures are shown in Figure 5 for the aggregate industry derivatives portfolio.[14] While there is no discernible trend in the extent of options strategies (fraction of gold hedged with options) in general, the gold mining industry has clearly shifted from convex strategies (buying of options) to concave strategies (selling of options) between 1989 and 1999. Over the same sample horizon,

[14]The aggregate industry derivatives portfolio consists of the derivatives portfolios of all firms in the sample, and is therefore skewed towards large firms.

the gold price generally declined. In order to remove the obvious time trend in the data the following analysis is based on changes in all variables.

Table 11 presents time-series regressions for the two variables on the gold price and the gold price volatility. All regressions are estimated using a fixed-effects model, an OLS model that includes the regressors used in the previous analysis instead of fixed-effects (called cross-section dummies), two fixed-effects models for the largest 10% of firms (in terms of market values) and the smallest 90% of firms, and a pure time-series model for the aggregate industry derivatives portfolio.

The results in Panel A show that the fraction hedged with options is negatively correlated with the gold price, although this relation does not exist for the largest 10% of firms (the industry leaders), and therefore also does not show up in the aggregate derivatives portfolio. In particular, when gold prices decline by \$10, firms increase the fraction of gold hedged with options by 1-2%. Thus, when gold prices decline, firms prefer not to lock in the relatively low gold price with forward contracts, but choose options strategies instead, which allow to firm to maintain some exposure.

Panel B shows that the net option position is negatively correlated with the gold price but uncorrelated with the gold price volatility. These results imply that when the gold price declines firms predominantly shift towards buying put options. When the gold price increases, firms increase their short call positions. One interpretation of these phenomena is that when the gold price declines hedging needs become more pressing, but firms hesitate to lock in a relatively low gold price with a forward contract. Instead, they choose to hedge with put options, and thus maintain the upside potential. When gold prices increase, protecting the downside becomes relatively less important. Firms then sell their upside potential, possibly hoping that prices are more likely to decline than to increase further.

In summary, the time-series results document a link between current market con-

ditions and the derivatives instruments firms choose to hedge their exposures. When gold prices decline firms shift away from selling forwards to purchasing put options. These effects, however, do not exist for the largest 10% of firms, and therefore do not consistently show up in the aggregate derivatives portfolio. While these results do not prove a causal link between market conditions and instrument choices, they document stylized facts that are consistent with anecdotal evidence on how firms hedge.

5 Conclusion

The use of options as risk management tools is widespread among corporations. However, our knowledge as to why and how firms use options is quite limited. This study tries to shed light on this question. It comprehensively evaluates options strategies in the North American gold mining industry, and focuses on three main questions: First, are there cross-sectional differences between firms that use options strategies and firms that use linear hedging strategies? Second, among option users why do some firms buy options while others sell options? Third, do market conditions affect firms' hedging instrument choices?

I find that firms with large investment programs are more likely and more extensive users of options strategies. They use predominantly insurance and collar strategies. Given that capital expenditures are often non-linear in nature, these results are consistent with Froot, Scharfstein and Stein (1996), who argue that financially constrained firms may find it beneficial to match cash inflows with cash outflows.

I also find that firms that concentrate on gold mining only rely more on options strategies than more diversified firms. Concentrated firms are more likely to have a gold investor clientele among its shareholders and may prefer options strategies

because they allow the firm to maintain some exposure to the gold price while at the same time hedge downside risk. In particular, the largest and least financially constrained firms are the most extensive users of insurance strategies (put options). Buying puts maintains all of the upside potential to the gold price, but requires an up-front premium. Not all firms are willing or able to pay the up-front option premium. More financially constrained firms prefer to finance the puts with selling calls, i.e., use collars. The most financially constrained firms sell call options as a way to obtain 'cheap' financing.

I find no evidence that uncertainty in the exposure, e.g., production risks, or the existence of real options (production flexibility) motivate firms to use options strategies. However, I do find that market conditions affect firms' hedging instrument choices. In particular, when gold prices decline mining firms shift away from selling forwards to purchasing put options. This result is consistent with anecdotal evidence that firms prefer options because options protect the downside while maintaining the upside potential. Maintaining the upside potential may be especially desirable when prices are relatively low.

References

[1] Adam, T., 2002, Risk Management and the Credit Risk Premium, *Journal of Banking & Finance* 26, 243-269.

[2] Adam, T., and C. Fernando, 2006, Hedging, Speculation and Shareholder Value, *Journal of Financial Economics* forthcoming.

[3] Adler M., and J.B. Detemple, 1988, Hedging with Futures and Options, *Studies in Banking and Finance* 5, 181-197.

[4] Altman, E.I., 1968, Financial Ratios, Discriminant Analysis and the Prediction of Corporate Bankruptcy, *Journal of Finance* 23, 589-609.

[5] Bessembinder, H., J.F. Coughenour, P.J Seguin, and M.M. Smoller, 1995, Mean Reversion in Equilibrium Asset Prices: Evidence from the Futures Term Structure, *Journal of Finance* 50, 361-375.

[6] Bodnar, G.M., G.S. Hayt, R.C. Marston, and C.W. Smithson, 1996, Wharton Survey of Derivatives Usage by U.S. Non-Financial Firms, *Financial Management* 25, 113-133.

[7] Bodnar, G.M., G.S. Hayt, and R.C. Marston, 1998, 1998 Survey of Financial Risk Management by U.S. Non-Financial Firms, *Financial Management* 27, 70-91

[8] Brown, G.W., 2001, Managing Foreign Exchange Risk with Derivatives, *Journal of Financial Economics* 60, 401-448.

[9] Brown, G.W., P.R. Crabb, and D. Haushalter, 2005, Are Firms Successful at Selective Hedging? University of North Carolina, working paper.

[10] Brown, G.W. and K.B. Toft, 2002, How Firms Should Hedge, *Review of Financial Studies* 15, 1283-1324.

[11] Chidambaran, N.K., C. Fernando, and P. Spindt, 2001, Credit enhancement through financial engineering: Freeport-McMoRan's gold-denominated depositary shares, *Journal of Financial Economics* 60, 487-528.

[12] Chacko, G., P. Tufano, and G. Verter, 2001, Cephalon, Inc. Taking Risk Management Theory Seriously, *Journal of Financial Economics* 60, 449-485.

[13] Franke, G., R.C. Stapleton, and M.G. Subrahmanyam, 1998, Who Buys and Who Sells Options: The Role of Options in an Economy with Background Risk, *Journal of Economic Theory* 82, 89-109.

[14] Froot, K.A., D.S. Scharfstein, and J.C. Stein, 1993, Risk Management: Coordinating Corporate Investment and Financing Policies, *Journal of Finance* 48, 1629-1658.

[15] Géczy, C., B.A. Minton and C. Schrand, 1997, Why Firms Use Currency Derivatives, *Journal of Finance* 52, 132-154.

[16] Leland, H.E., 1980, Who Should Buy Portfolio Insurance?, *Journal of Finance* 35, 581-594.

[17] Lewent, J., and A.J. Kearney, 1990, Indentifying, measuring, and hedging currency risk at Merck, *Journal of Applied Corporate Finance*, 19-28.

[18] MacKay, Peter, and Sara B. Moeller, 2005, The Value of Corporate Risk Management, HKUST working paper.

[19] Moschini, G., and H. Lapan, 1992, Hedging Price Risk with Options and Futures for the Competitive Firm with Production Flexibility, *International Economic Review* 33, 607-618.

[20] Moschini, G., and H. Lapan, 1995, The Hedging Role of Options and Futures under Joint Price, Basis, and Production Risk, *International Economic Review* 36, 1025-1049.

[21] Petersen, M.A. and S.R. Thiagarajan, 2000, Risk Measurement and Hedging: With and Without Derivatives, *Financial Management* 29, 5-30.

[22] Stulz, R.M., 1996, Rethinking Risk Management, *Journal of Applied Corporate Finance* 9, 8-24.

[23] Tufano, P., 1996, Who Manages Risk? An Empirical Examination of Risk Management Practices in the Gold Mining Industry, *Journal of Finance* 51, 1097-1137.

[24] Tufano, P., 1998, The Determinants of Stock Price Exposure: Financial Engineering and the Gold Mining Industry, *Journal of Finance* 53, 1051-1052.

[25] Whited, T.M., 1992, Debt, Liquidity Constraints, and Corporate Investment: Evidence from Panel Data, *Journal of Finance* 47, 1425-1460.

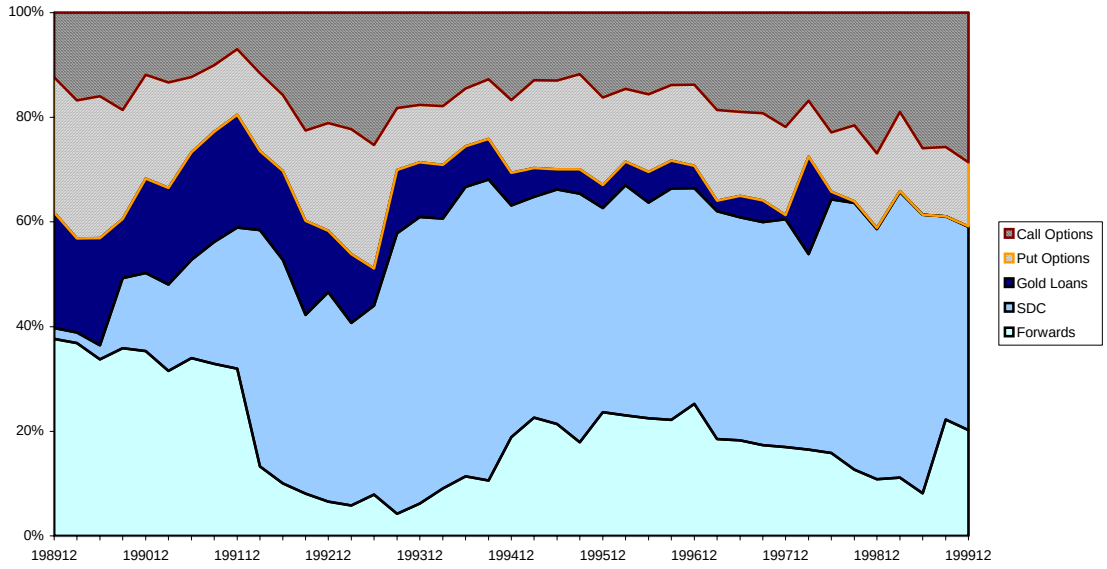

Figure 1: Composition of the Aggregate Derivatives Portfolio
This graph shows the main derivatives instruments used by firms in the North American gold mining industry to hedge their gold price exposure, and how the composition of the aggregate derivatives portfolio evolved over time. The aggregate derivatives portfolio is calculated by summing all derivatives positions of the sample firms. Percentages refer to the notional principal of the derivatives positions. SDC stands for spot-deferred contracts, which are similar to forward contracts except that delivery of the underlying asset can be deferred.

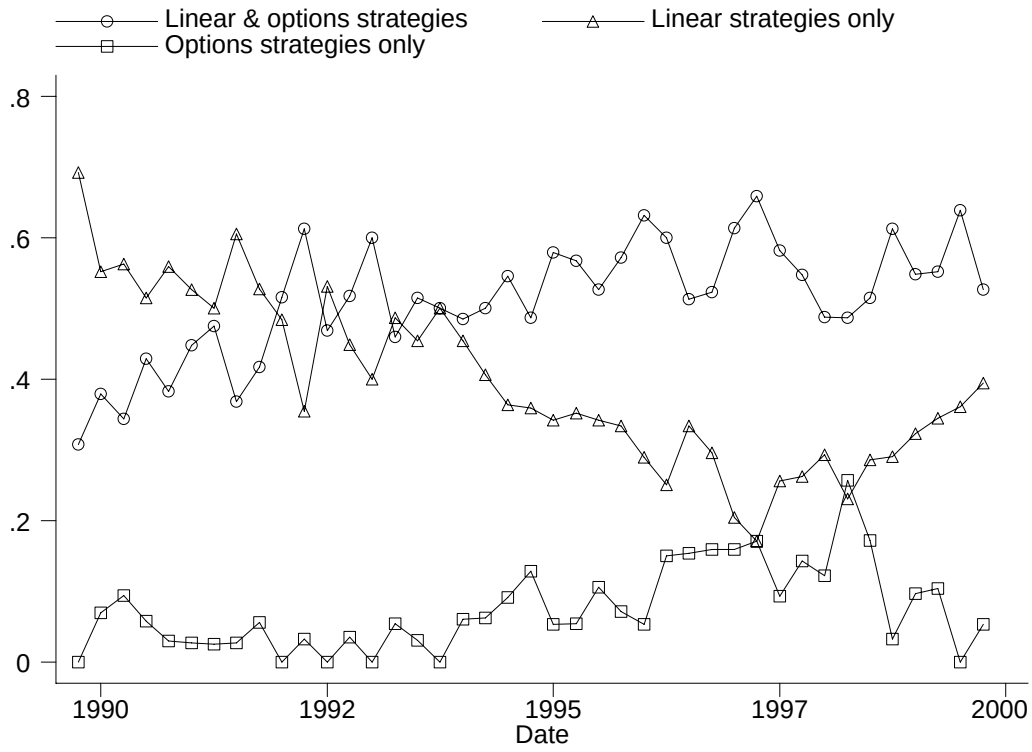

Figure 2: Fractions of Firms that Use Linear and Options Strategies
This figure shows the fraction of firms (among derivatives users), which use only linear strategies (forwards, spot-deferred contracts, and gold loans), only options strategies, and both linear and options strategies.

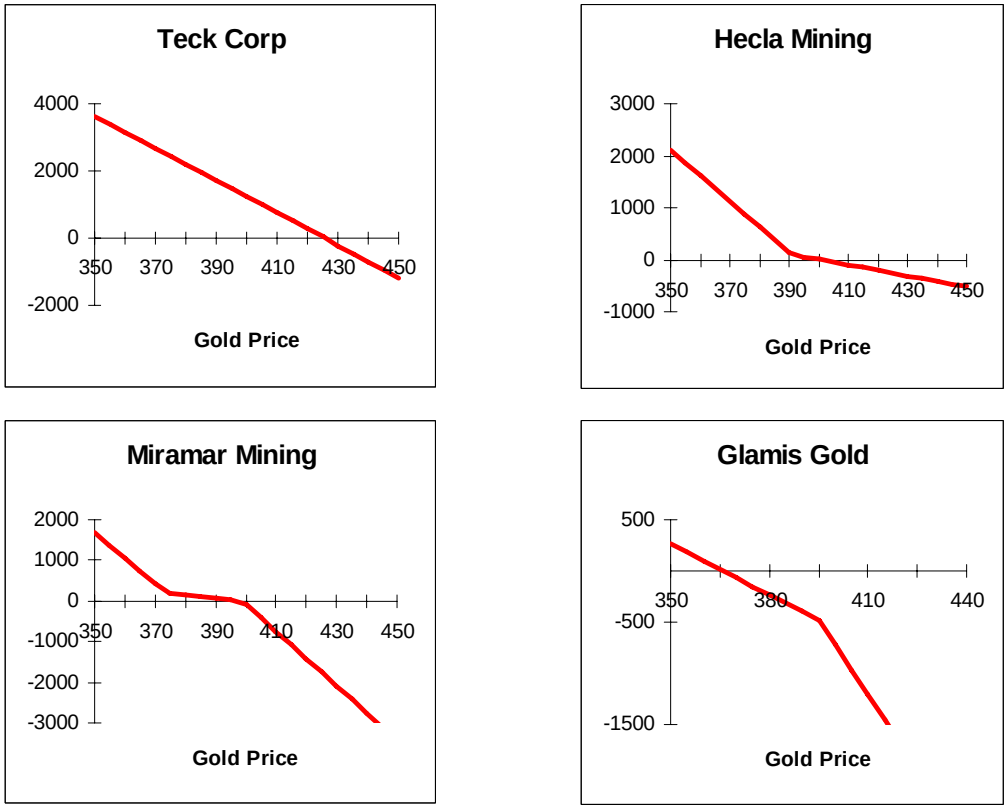

Figure 3: The Principal Hedging Strategies in the Gold Mining Industry
This figure shows the payoff profiles, as functions of the future gold price, of the four principal hedging strategies in the North American gold mining industry.

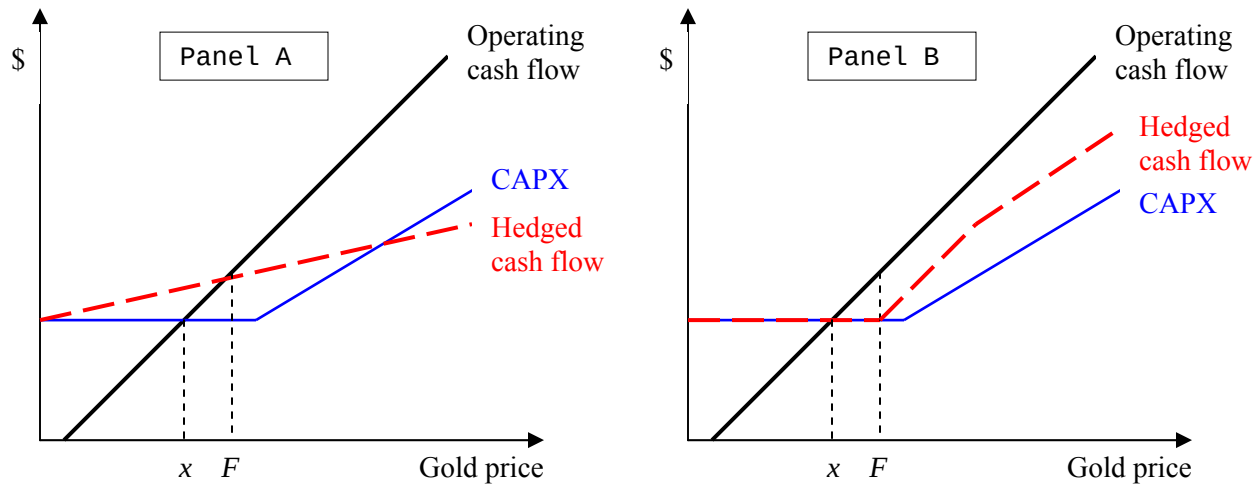

Figure 4: Hedging with Linear Strategies vs. Collars
This figure compares linear hedging strategies with collar hedging strategies. The graphs depict a firm's operating cash flow and its capital expenditures (CAPX) as functions of the gold price. If the gold price falls below the threshold *x*, the firm would need to raise external funds in order to close the funding shortfall. To hedge this funding risk a firm could short forward contracts (Panel A) or purchase an asymmetric collar (Panel B). Given the current forward price *F*, a linear strategy cannot fully hedge the risk of a funding shortfall, while with an asymmetric collar the risk of a funding shortfall can be fully hedged.

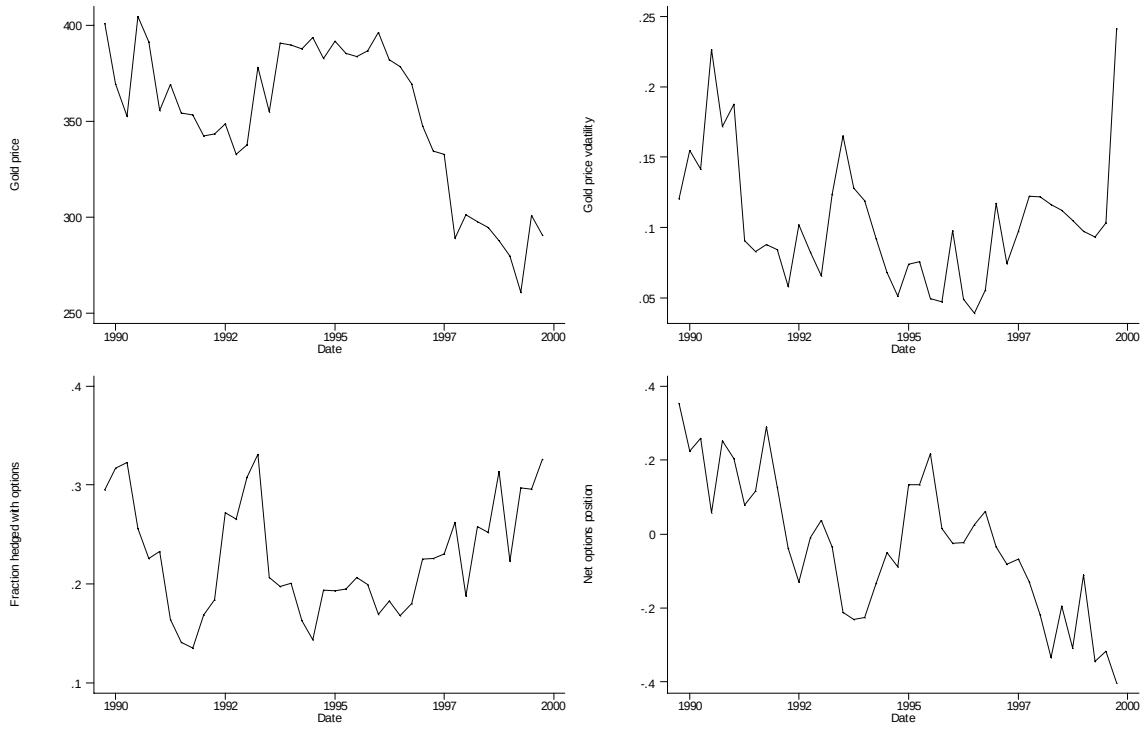

Figure 5: Time-Series Characteristics of the Aggregate Derivatives Portfolio
The first two graphs depict the gold price and the gold price volatility between 1989 and 1999. The gold price is given in US$/oz of gold. The gold price volatility is the annualized standard deviation of daily gold price returns over the previous 60 trading days. The 'fraction hedged with options' is defined as the number of ounces of gold hedged with options divided by the total number of ounces of gold hedged. The 'net option position' measures whether the derivatives portfolio consists of predominantly of puts or calls. This measure is bounded between 1 (100% puts) and -1 (100% calls). Definitions of these variables can be found in Table 1.

Table 1: Variables

This table list all regressors used in the analysis and describes their constructions. The principal data sources are Compustat, and annual reports & 10-K forms. Market data is obtained from Datastream.

Variable	Construction of variable
CAPX / PPE	The size of the investment program is measured by a firm's capital expenditures divided by net plant property and equipment.
Acquisition expenditures	The ratio of acquisition expenditures over net sales.
Acquisition dummy	Dummy variable that equals 1 if a firm engaged in acquisitions, and zero otherwise.
Market value of assets	Real market value of assets in 1999 dollars. Market value of assets equals book value of assets minus book value of common stock plus market value of equity. The producer price index for commodities is from the Bureau of Labor Statistics.
Market-to-book ratio of assets	Market value of assets divided by book value of assets. Market value of assets equals book value of assets minus book value of common stock plus market value of equity.
Herfindahl index (asset segments)	Defined by $\sum_{i=1}^{N}\left(\frac{q_i}{q}\right)^2$, where q_i is the book value of assets of industry segment i, and q is the total book value of all reported industry segment assets (non-reported assets such as financial assets are ignored). N is the total number of industry segments.
Herfindahl index (metals production)	Defined by $\sum_{i=1}^{N}\left(\frac{s_i}{s}\right)^2$, where s_i is the revenue contribution of each metal (estimated as metal production × spot price), and s is the total metal sales for the year. N is the total number of metals produced by the firm. If metal production is zero, a missing value is assigned. Metal prices are from Datastream.
Profit margin	Difference between gold spot price and cash costs divided by cash costs. Cash costs are the per-ounce extraction costs of gold.
Dividend dummy	Dummy variable that equals one if a firm paid cash dividends and zero otherwise.
Dividend payout ratio	Cash dividends paid during the fiscal year, divided by operating net cash flow. If the operating net cash flow is negative, a missing value is assigned.
Quick ratio	Liquidity is measured by a firm's quick ratio, which is defined by (cash + cash equivalents + receivables) / current liabilities.

Variable	Construction of variable
Leverage	Book value of long-term debt divided by the book values of preferred stock, common equity, and long-term debt.
Credit rating dummy	Dummy variable that equals one if a credit rating exists and zero otherwise.
Listing on secondary exchange only	Dummy variable that equals one if a firms' shares are exclusively traded at a secondary Canadian stock exchange, i.e., the Vancouver stock exchange.
Production uncertainty	Production uncertainty is measured by the mean squared production forecast error defined by $\frac{1}{n}\sum_{i=1}^{n}\left(\frac{y_{t,t+i}-y_{t+i}}{y_{t+i}}\right)^2$, where y_{t+i} denotes the actual gold production in year $t+i$, and $y_{t,t+i}$ denotes the production forecast for year $t+i$ at time t. There are up to n production forecasts available at each time (n_{max} = 4). Production forecasts are inferred from the Gold and Silver Hedge Outlook (1989 – 1999)
Number of operating mines	Number of operating mines per firm.
Standard deviation of production costs	Standard deviation of the production costs of each operating mine.

Table 2: Descriptive Statistics of the Sample Firms

	Mean	*Median*	*Std. dev.*	*Min*	*Max*	*Obs.*
Use of derivatives (dummy variable)	0.698	1	0.459	0	1	2085
Use of options (dummy variable)	0.615	1	0.487	0	1	1444
Fraction of gold hedged with options	0.333	0.202	0.363	0	1	1455
Market value of assets (in 1999 $ million)	1039	235	1867	2.85	11619	534
Market-to-book value of assets	1.84	1.56	1.06	0.30	5.91	534
Herfindahl index (asset segments)	0.95	1	0.16	0.23	1	585
Herfindahl index (metals production)	0.87	1	0.21	0.28	1	498
Profit margin	0.46	0.40	0.41	-0.53	1.87	470
Dividend (dummy variable)	0.43	0	0.50	0	1	546
Dividend payout ratio	0.10	0	0.19	0	0.97	528
Quick ratio	3.41	1.62	6.01	0.01	35.62	531
Leverage	0.23	0.17	0.25	0	1.26	541
Credit rating (dummy variable)	0.16	0	0.37	0	1	585
S&P credit rating		BB+		B-	A	94
Capital expenditures / PPE	0.24	0.19	0.23	0	2.72	539
Acquisition expenditures / sales	0.11	0	0.48	0	4.92	471
Production uncertainty	0.23	0.03	0.64	0.00	3.64	251
Number of operating mines	3.86	3	3.05	1	18	268
Standard deviation of production costs	65.20	58.35	44.11	4.95	285.67	179

Table 3: Characteristics of the Primary Hedging Instruments

	Forwards	Long puts	Collars	Short calls
Payoff profile	Linear	Convex	Convex & concave	Concave
Downside risk	Fully hedged	Partially hedged	Partially hedged	Fully exposed
Upside exposure	Fully eliminated	Fully exposed	Partially eliminated	Partially eliminated
Initial cash flow impact	Self-financing	Requires cash payment (option premium)	Can be self-financing	Yields cash inflow (option premium)
Flexibility in structuring the hedge	Low, because only one contract price is available	High, because strike price can be chosen	High, because strike prices can be chosen	High, because strike prices can be chosen

Table 4: Principal Hedging Strategies in the Gold Mining Industry and Testable Predictions

	Linear contracts only	Long puts + linear contracts	Collars + linear contracts	Short calls + linear contracts
Froot, Scharfstein and Stein (1993)	Low CAPX	High CAPX	High CAPX	High CAPX
Adam (2002)	Average financial constraints	Low financial constraints	Average financial constraints	High financial constraints
Stulz (1996)	Small, fin. constrained firms	Large, fin. unconstrained firms	Medium-sized firms	Large, fin. unconstrained firms
Adler and Detemple (1988)	No financial constraints	Financial constraints	Financial constraints	Financial constraints
Brown and Toft (2002)	Low production uncertainty	High production uncertainty	High production uncertainty	High production uncertainty
Franke, Stapelton and Subrahmanyam (1998)		High production uncertainty		Low production uncertainty
Moschini and Lapan (1992)	Low production flexibility	Low production flexibility	High production flexibility	High production flexibility

Table 5: Descriptive Statistics by Hedging Strategy

This table lists descriptive statistics of the sample firms for each hedging strategy separately. The top figure in each row represents the mean, while the bottom figure represents the median. Variable definitions can be found in Table 1.

	Linear contracts only	Long puts + linear contracts	Collars + linear contracts	Short calls + linear contracts	t-statistics z-scores			
	I	II	III	IV	II vs. I	III vs. I	IV vs. I	II vs. IV
Firm-year obs.	143	45	141	37				
CAPX / PPE	0.198 0.154	0.270 0.246	0.246 0.200	0.245 0.227	2.651*** 3.363***	2.226** 2.710***	1.530 2.008**	0.710 0.984
Acquisition expenditures / sales	0.025 0	0.026 0	0.026 0	0.032 0	0.068 0.020	0.058 -0.699	0.383 0.164	-0.250 -0.106
Book value of assets	692.4 175.5	624.3 324.4	585.9 265.7	687.3 170.9	-0.514 2.463**	-0.956 0.689	-0.022 -0.171	-0.265 2.267**
Market-to-book ratio of assets	1.631 1.348	1.853 1.598	1.665 1.494	1.943 1.796	1.287 1.686*	0.304 1.061	1.734* 2.262**	-0.408 -0.713
Herfindahl index (asset segments)	0.892 1	0.890 1	0.973 1	0.987 1	-0.059 0.499	3.907*** 3.651***	4.162*** 2.830***	-2.496** -2.193**
Herfindahl index (metals production)	0.861 1	0.866 0.983	0.889 1	0.959 1	0.130 -0.978	1.167 0.689	3.390*** 2.772***	-2.423** -3.435***
Dividend dummy	0.514 1	0.644 1	0.425 0	0.222 0	1.555 1.521	-1.504 -1.500	-3.559*** -3.130***	4.192*** 3.767***
Dividend payout ratio	0.131 0.002	0.168 0.092	0.083 0	0.053 0	0.885 1.365	-2.010** -1.789*	-2.783*** -2.671***	2.721*** 3.176***
Quick ratio	2.705 1.611	1.783 1.382	2.515 1.618	2.840 2.059	-2.113** -0.730	-0.423 0.161	0.224 1.356	-2.008** -1.895*

	Linear contracts only	Long puts + linear contracts	Collars + linear contracts	Short calls + linear contracts	t-statistics z-scores			
	I	II	III	IV	II vs. I	III vs. I	IV vs. I	II vs. IV
Leverage	0.254 0.202	0.266 0.243	0.228 0.192	0.137 0.049	0.365 1.093	-0.945 -0.499	-3.318*** -2.967***	3.243*** 3.400***
Credit rating dummy	0.208 0	0.239 0	0.204 0	0.079 0	0.433 0.447	-0.080 -0.081	-2.327** -1.837*	2.067** 1.949*
Profit margin	0.496 0.409	0.526 0.484	0.465 0.418	0.402 0.296	0.442 0.910	-0.635 0.143	-1.162 -1.111	1.359 1.580
Listing on secondary exchange only	0.266 0	0.156 0	0.206 0	0.162 0	-1.669* -1.507	-1.192 -1.190	-1.444 -1.303	-0.080 -0.081
Production uncertainty	0.225 0.021	0.119 0.045	0.308 0.020	0.074 0.035	-1.529 0.233	0.804 -0.074	-2.267** -0.834	0.994 1.041
Number of operating mines	4.526 3	3.86 4	4.99 4	2.786 3	-1.382 0.403	0.810 1.220	-3.170*** -1.548	2.272** 2.173**
Standard deviation of production costs	70.74 69.65	65.44 64.15	68.03 53.63	49.11 57.66	-0.540 -0.499	-0.319 -0.903	-2.168** -1.627	1.448 0.858

Table 6: Why Firms Use Options Strategies

The regression results in this table show the sensitivities between firm-specific characteristics and the use of and the extent of using options strategies. The use of options strategies is a dummy variable that equals 1 if a firm used options, and 0 if it used linear hedging instruments only. A missing value is assigned if a firm did not use any derivatives. The fraction of gold hedged with options is defined by $\frac{\max\{\text{puts}, \text{calls}\}}{\text{all linear contracts} + \max\{\text{puts}, \text{calls}\}}$. All positions are measured in ounces of gold. The max function ensures that collars, which consist of both puts and calls, are not double counted. Definitions of the regressors can be found in Table 1. The models are estimated with and without outliers (defined by the extreme 1% of values). Reported results are based on the estimations without outliers. Figures in parentheses denote t-statistics. Standard errors are calculated using the Huber/White/sandwich estimator, assuming that firm-year observations are independent across firms but not across years.

	Use of options strategies (dummy variable)		Fraction of gold hedged with options	
	Population-averaged probit models		Random-effects tobit models	
ln(CAPX / PPE)	0.311***	0.502***	0.055*	0.058*
	(2.65)	(3.67)	(1.92)	(1.75)
ln(book value of assets)	0.197**	0.217*	-0.003	0.011
	(2.08)	(1.85)	(-0.10)	(0.42)
Market-to-book ratio of assets	0.069	0.115	-0.040*	-0.031
	(0.60)	(0.87)	(-1.67)	(-1.18)
Herfindahl index (asset segments)	1.639**	1.938**	0.226	0.346*
	(2.00)	(2.23)	(1.30)	(1.84)
Herfindahl index (metals production)	0.371	-0.492	0.007	-0.121
	(0.59)	(-0.63)	(0.05)	(-0.74)
Dividend dummy	-0.520**	-0.886***	-0.097	-0.174**
	(-2.12)	(-2.94)	(-1.59)	(-2.56)
Leverage	-0.314	-0.195	0.070	0.085
	(-0.63)	(-0.32)	(0.64)	(0.62)
Credit rating dummy	0.349	0.140	0.019	0.001
	(1.30)	(0.45)	(0.30)	(0.01)
Listing on secondary exchange only	-0.139	-0.193	-0.098	-0.097
	(-0.59)	(-0.64)	(-1.33)	(-1.19)
Production uncertainty		-0.048		0.005
		(-0.28)		(0.14)
Wald test	27.52	45.36	17.19	26.10
Sig. level	0.001	0.000	0.046	0.004
Adj. R^2 from OLS	0.091	0.120	0.054	0.087
Total observations / number of firms	323 / 71	230 / 55	323 / 71	230 / 55

Significance at the 1%, 5% and 10% levels is denoted by ***, ** and * respectively.

Table 7: Insurance versus Hedging Strategies

The regression results in this table evaluate the differences between firms that use insurance strategies and firms that use hedging (linear) strategies only. The use of insurance strategies is a dummy variable that equals 1 if a firm used put options, and 0 if it used linear hedging instruments only. A missing value is assigned if a firm had any calls outstanding or did not use any derivatives. The extent of insurance strategies is defined by $\frac{\text{puts}}{\text{linear contracts} + \text{puts}}$. All positions are measured in ounces of gold. Definitions of the regressors can be found in Table 1. The models are estimated with and without outliers (defined by the extreme 1% of values). Reported results are based on the estimations without outliers. Figures in parentheses denote t-statistics. Standard errors are calculated using the Huber/White/sandwich estimator, assuming that firm-year observations are independent across firms but not across years.

	Use of insurance strategies (dummy variable)		Extent of using insurance strategies	
	Population-averaged probit models		Random-effects tobit models	
ln(CAPX / PPE)	0.445***	0.682***	0.033	0.064*
	(2.88)	(3.33)	(1.20)	(1.85)
ln(book value of assets)	0.317**	0.232	0.044**	0.066**
	(2.26)	(1.57)	(2.11)	(2.33)
Market-to-book ratio of assets	-0.058	-0.032	-0.051**	-0.059**
	(-0.35)	(-0.15)	(-2.24)	(-2.49)
Herfindahl index (asset segments)	0.855	1.839**	0.284***	0.309***
	(0.75)	(2.24)	(2.78)	(2.86)
Herfindahl index (metals production)	0.403	-0.775	0.286***	0.127
	(0.55)	(-0.82)	(2.82)	(1.20)
Dividend dummy	-0.143	-0.296	-0.021	-0.169***
	(-0.42)	(-0.77)	(-0.34)	(-2.67)
Leverage	0.301	0.292	0.034	-0.134
	(0.46)	(0.32)	(0.30)	(-1.12)
Credit rating dummy	0.001	0.005	0.012	0.030
	(0.00)	(0.01)	(0.21)	(0.60)
Listing on secondary exchange only	0.031	0.094	0.002	-0.028
	(0.09)	(0.21)	(0.04)	(-0.47)
Production uncertainty		-0.674		0.001
		(-1.38)		(0.02)
Wald test	16.72	19.76	32.14	36.27
Sig. level	0.053	0.032	0.000	0.000
Total observations / number of firms	164 / 60	118 / 44	164 / 60	118 / 44

Significance at the 1%, 5% and 10% levels is denoted by ***, ** and * respectively.

Table 8: Collar versus Hedging Strategies

The regression results in this table evaluate the differences between firms that use collar strategies and firms that use hedging (linear) strategies only. The use of collar strategies is a dummy variable that equals 1 if a firm used put and call options, and 0 if it used linear hedging instruments only. A missing value is assigned if a firm used only puts or only calls, or did not use any derivatives. Definitions of the regressors can be found in Table 1. The models are estimated with and without outliers (defined by the extreme 1% of values). Reported results are based on the estimations without outliers. Figures in parentheses denote t-statistics. Standard errors are calculated using the Huber/White/sandwich estimator, assuming that firm-year observations are independent across firms but not across years.

	Use of collar strategies (dummy variable)		
	Population-averaged probit models		
ln(CAPX / PPE)	0.290**	0.553***	0.667**
	(2.19)	(3.37)	(2.39)
ln(book value of assets)	0.157	0.213	0.452
	(1.50)	(1.56)	(1.25)
Market-to-book ratio of assets	0.057	0.121	-0.003
	(0.46)	(0.82)	(-0.03)
Herfindahl index (asset segments)	2.455***	2.274**	1.669
	(3.41)	(2.40)	(1.16)
Herfindahl index (metals production)	0.142	-0.731	-2.018
	(0.22)	(-0.86)	(-1.66)
Dividend dummy	-0.523*	-0.847**	-1.376*
	(-1.84)	(-2.23)	(-1.70)
Leverage	-0.112	0.112	-0.188
	(-0.22)	(0.17)	(-0.12)
Credit rating dummy	0.537**	0.215	-0.386
	(1.98)	(0.69)	(-1.03)
Stock listing on secondary exchange only	-0.126	-0.325	-0.677
	(-0.48)	(-0.94)	(-1.26)
Production uncertainty		0.055	0.347
		(0.65)	(0.99)
Number of operating mines			-0.050
			(-0.55)
Standard deviation of production costs			0.001
			(0.20)
Wald test	28.41	43.68	50.12
Sig. level	0.001	0.000	0.000
Total observations / number of firms	249 / 67	178 / 49	91 / 26

Significance at the 1%, 5% and 10% levels is denoted by ***, ** and * respectively.

Table 9: Why firms sell options

The regression results in this table evaluate the differences between firms that sell call options and firms that use hedging (linear) strategies only. Selling calls vs. selling forwards is a dummy variable that equals 1 if a firm sold call options, and 0 if it used linear hedging instruments only. A missing value is assigned if a firm had any puts outstanding or did not use any derivatives. The extent of selling calls is defined by $\frac{\text{calls}}{\text{linear contracts} + \text{calls}}$. All positions are measured in ounces of gold. Definitions of the regressors can be found in Table 1. The models are estimated with and without outliers (defined by the extreme 1% of values). Reported results are based on the estimations without outliers. Figures in parentheses denote t-statistics. Standard errors are calculated using the Huber/White/sandwich estimator, assuming that firm-year observations are independent across firms but not across years.

	Selling calls vs. selling forwards (dummy variable)		Extent of selling calls	
	Population-averaged probit models		Random-effects tobit models	
ln(CAPX / PPE)	0.194 (1.14)	0.195 (1.09)	0.027 (0.99)	0.036 (1.26)
Acquisition dummy	0.077 (0.27)		0.025 (0.60)	
Acquisition expenditures / sales		1.338 (1.08)		0.296 (1.32)
ln(book value of assets)	0.439** (2.26)	0.399** (2.11)	0.037* (1.74)	0.039* (1.75)
Market-to-book ratio of assets	0.259 (1.64)	0.299* (1.81)	0.034 (1.23)	0.035 (1.26)
Herfindahl index (asset segments)	15.435*** (9.34)	16.539*** (-6.37)	0.057 (0.40)	0.069 (0.47)
Herfindahl index (metals production)	0.700 (0.71)	0.602 (0.63)	-0.093 (-0.78)	-0.103 (-0.85)
Leverage	-1.573*** (-2.86)	-1.628** (-2.01)	-0.291*** (-2.65)	-0.301*** (-2.70)
Credit rating dummy	0.177 (0.29)	-0.018 (-0.03)	0.005 (0.08)	0.003 (0.05)
Dividend dummy	-1.573*** (-2.86)	-1.563*** (-2.88)	-0.254*** (-4.17)	-0.252*** (-4.10)
Listing on secondary exchange only	-0.437 (-1.45)	-0.396 (-1.29)	-0.129 (-2.10)	-0.123** (-1.99)
Wald test χ^2	170.84	747.79	30.13	30.78
Significance level	0.000	0.000	0.001	0.001
Observations / number of firms	141 / 53	137 / 53	141 / 53	137 / 53

Significance at the 1%, 5% and 10% levels is denoted by ***, ** and * respectively.

Table 10: Who Buys and Who Sells Options?

The regression results in this table evaluate the differences between firms that buy (put) options and firms that sell (call) options. Buy vs. sell options is a dummy variable that equals 1 if a firm bought put options only, and 0 if a firms sold call options only. A missing value is assigned if a firm had both puts and calls outstanding, used linear hedging strategies exclusively, or did not use any derivatives. The net option position is defined by $\frac{\text{puts} - \text{calls}}{\text{puts} + \text{calls}}$, and measures the size of the put position relative to the call position. It is bounded between 1 (100% puts) and -1 (100% calls). Definitions of the regressors can be found in Table 1. The models are estimated with and without outliers (defined by the extreme 1% of values). Reported results are based on the estimations without outliers. Figures in parentheses denote t-statistics. Standard errors are calculated using the Huber/White/sandwich estimator, assuming that firm-year observations are independent across firms but not across years.

	Pred. sign	Buy vs. sell options (dummy variable)		Net options position	
		Probit models		Tobit models	
ln(book value of assets)	+	-0.504** (-2.30)	-0.484 (-1.43)	-0.150* (-1.93)	-0.229** (-2.32)
Market-to-book value of assets	-	0.078 (0.20)	0.003 (0.01)	0.058 (0.56)	0.132 (1.11)
Herfindahl index (asset segments)	-	-1.759* (-1.73)	0.402 (0.30)	-0.994* (-1.70)	-0.093 (-0.13)
Herfindahl index (metals production)	-	-4.290* (-1.87)	-3.671 (-1.29)	-0.481 (-1.02)	-0.852 (-1.51)
Dividend dummy	+	1.218** (2.46)	1.984*** (3.33)	0.401* (1.95)	0.633*** (2.62)
Leverage	+	5.100*** (3.18)	4.055*** (3.39)	1.364*** (3.22)	0.934* (1.89)
Credit rating dummy	+	0.628 (1.02)	0.935 (0.96)	-0.048 (-0.23)	0.105 (0.43)
Profit margin	+	0.672 (0.90)	0.016 (0.02)	0.147 (0.56)	-0.150 (-0.44)
Listing on secondary exchange only	-	-0.252 (-0.33)	-0.966** (-2.11)	-0.035 (-0.15)	-0.110 (-0.39)
Production uncertainty			2.229 (0.98)		0.026 (0.34)
Wald test		26.24	38.42		
Significance level		0.003	0.000		
Pseudo R^2		0.402	0.487	0.064	0.076
Observations / number of firms		59 / 31	39 / 22	171 / 48	121 / 36

Significance at the 1%, 5% and 10% levels is denoted by ***, ** and * respectively.

Table 11: The impact of market conditions on firms' hedging strategies

This table evaluates how option hedging strategies are affected if market conditions, such as the gold price, the gold price volatility, and the basis in the gold market change. The dependent variables are the fraction of gold hedged with options, defined in Table 6, and the net options position, defined in Table 10. The gold price is measured in US$/oz, the gold price volatility is the annualized standard deviations of daily gold returns over the previous 60 trading days, and the basis is the percentage difference between the 1-year forward price and the current spot price. To eliminate time-trends, all regressions are estimated on changes in all variables.

Panel A: Dependent variable: Fraction of gold hedged with options

		Cross-section dummies	Top 10% (market value)	Bottom 90% (market value)	Industry portfolio Time-series
Intercept		-0.026 (-1.66)			-0.001 (-0.14)
Gold price	-0.001*** (-2.79)	-0.002** (-2.51)	-0.001 (-0.69)	-0.002*** (-2.65)	-0.000 (-1.34)
Gold price volatility	-0.127 (-0.54)	-0.023 (-0.09)	0.449 (1.20)	-0.256 (-0.95)	0.150 (0.87)
Fixed effects	Yes		Yes	Yes	
Obs.	758	690	131	627	40
R^2	0.015	0.017	0.044	0.020	0.061

Panel B: Dependent variable: Net options position

		Cross-section dummies	Top 10% (market value)	Bottom 90% (market value)	Industry portfolio Time-series
Intercept		-0.012 (-0.30)			-0.017 (-0.89)
Gold price	-0.003** (-2.24)	-0.003** (-2.28)	-0.000 (0.04)	-0.003** (-2.17)	0.000 (0.00)
Gold price volatility	0.352 (0.52)	0.049 (0.09)	-0.820 (-0.97)	0.541 (0.68)	-0.771* (-1.69)
Fixed effects	Yes		Yes	Yes	
Obs.	456	426	77	379	40
R^2	0.018	0.015	0.002	0.019	0.07

Appendix
Hedge Positions of Placer Dome as of December 31, 1998

The first column in each panel lists the number of ounces of gold that must be delivered under various contracts. The second column lists the respective delivery prices, and the third column records the percentage of future gold production that has been hedged. The maturity year of all contracts is given on top of each panel. SDC stands for spot-deferred contracts. A spot-deferred contract is like a forward contract except that delivery can be deferred for several years at the discretion of the deliverer. If delivery is deferred, the new delivery price is set to equal the prior contract price plus the current contango premium.

	1999			2000			2001		
	Ounces	Price (US$/oz)	Percent of Prod.	Ounces	Price (US$/oz)	Percent of Prod.	Ounces	Price (US$/oz)	Percent of Prod.
Forwards	649,000	503		213,000	504		188,000	458	
SDC	390,000	397		737,000	440		442,000	441	
Puts	298,000	298		127,000	303				
Total	**1,337,000**		**44.0%**	**1,077,000**		**37.0%**	**630,000**		**23.5%**
Calls	521,000	310		115,000	371		100,000	365	

	2002			2003 and beyond			
	Ounces	Price (US$/oz)	Percent of Prod.	Ounces	Price (US$/oz)	Percent of Prod.	
Forwards	30,000	429					
SDC	886,000	360		886,000	360		
Puts	200,000	300					
Total	**1,116,000**		**40.1%**	**886,000**		**32.3%**	
Calls	200,000	365					

Source: Gold & Silver Hedge Outlook, Fourth Quarter 1998, Scotia Capital Markets