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Input and output Hedging and Firm Value: Evidence from the Gold Mining Industry

INavn: Chathurangi Subodha Balasuriya, Henrik Sjøvaag Bøen

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By

Henrik S. Bøen and Chathurangi S. Balasuriya

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Abstract

This study explores the relationship between firm value and the use of commodity derivatives to hedge gold output and fuel input for a sample of gold mining firms during 2009-2017. We find no empirical support for a positive association between firm value, as measured by Tobin's Q, and the extent of gold and oil price risk management among our sample miners. In fact, we document a negative correlation between fuel hedging and Tobin's Q ratios. We illustrate that this result may be explained by poor timing decisions and unfavorable movements in the oil market. We also examine whether hedgers in our sample is well described by the theoretical corporate risk management literature. Our results show that hedgers generally conform well to the value-maximization theories explaining hedging as a way for managers to reduce the cost of financial distress and the cost of underinvestment.

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3. Introduction and motivation

Empirical studies have frequently investigated the determinants of corporate risk management activities and the impact on firm value. Despite evidence showing that hedging firms tend to exhibit traits consistent with theory, there is conflicting evidence whether hedging achieves reasonable economic objectives. For instance, Allayannis and Weston (2001), in a pioneering article on the direct relationship between risk management and firm value, concluded that firms hedging the foreign currency exposure enjoyed a 4% hedging premium over those firms that did not hedge. Furthermore, Carter, Rogers, and Simkins (2006) claim that jet fuel hedging is positively related to airline firm value with their results suggesting that the hedging premium could be as large as 10%. In contrast, in a study of US oil and gas producers, Jin and Jorion (2004) did not find any empirical evidence suggesting that hedgers had a higher valuation than non-hedgers.

We contribute to the existing body of knowledge by providing additional evidence on the relation between hedging and firm value by investigating the use of commodity derivative contracts for a sample of 11 of the 15 largest gold mining companies listed on the New York Stock Exchange. The gold mining industry have served as a popular research ground for many previous studies on hedging and firm value due to certain favorable industry characteristics. In particular, the firms all share a common and volatile risk factor - the price of gold, and importantly, can manage this exposure using various derivative instruments. Most of the existing research has focused on this exposure exclusively, however, due to the energy-intensive nature of gold mining, firms are also exposed to fluctuations in fuel prices. As a distinction from previous research, we focus on both types of risk and use previously unexplored data in a hedging and value context.

We examine firms' sustainability reports, in addition to financial statement disclosures, to measure the extent to which firms hedge their gold output as well as forecasted fuel input. This enables us to investigate the relationship between hedging and value on both the cost and revenue side.

We observe a general pattern of producer de-hedging over the sample period and find that the overall use of derivative contracts to manage gold price exposure is very limited. In fact, Gold miners only hedged some of next year's gold production in 13 out of 99 firm-year observation. Furthermore, in 5 cases, the amount hedged constituted less than 10% of projected production.

Investment opportunities as measured by capital expenditure to total assets is found to be positively correlated with gold hedging ratios. This is consistent with financial constraint arguments for hedging (Froot, Scharstein, and Stein,1993). Apart from this finding, our investigation on the determinants of gold hedging and the effect on firm value produced no meaningful results. This is, in part, due to the defined scope of the study which is hedging via explicit derivative instruments only and not the full menu of risk mitigating strategies available to gold miners.

Hedging fuel input is a far more common practice in the sample. 8 out of the 11 firms in our sample used some type of derivative to hedge fuel exposure during the 2009-2017 period. Further, we find a wide variation in hedging policies. Some firms hedge a minor fraction of their fuel exposure, while others hedge upwards to a 100% and have contracts covering fuel requirement multiple years into the future. This provides some indicative evidence that fluctuating fuel prices have a material impact on profitability and value. Moreover, the variation in firms hedging ratios through time suggest that some gold miners try to time and vary the size of their hedges based on their view about future market prices.

Further, we investigate whether these differences in fuel hedging levels is associated with various firm characteristics predicted by corporate risk management literature. Our tests reveal multiple significant relationships. Fuel hedging is positively related to leverage, which is consistent with theories explaining hedging as a means to reduce financial distress cost (Smith and Stulz, 1985), realizing greater tax shield advantages (Leland, 1998), and obtaining better contracting terms (Bessembinder, 1991). Our tests also show a positive association between fuel hedging and firms' investment intensity as measured by capital expenditures to total assets. This is consistent with the underinvestment hypothesis by Froot et al. (1993). We also find that the number of shares held by the senior management team is positively correlated with higher hedging ratios. This supports the theoretical framework by Stulz (1984) and empirical evidence by Tufano (1996). Last, we find that hedging firms tend to be larger than non-hedging firms. This is in line with the economies of scale argument for risk management and empirical results in Nance, Smith, and Smithson (1993), Mian (1996), and Geczy, Minton, and schrand. (1997).

We further test whether investors recognize the fuel hedging activity of gold miners by examining if fuel hedging has an impact on firm value (proxied by Tobin's Q). Although we find that firms which hedge their fuel input match well to the predictions of the value-maximization theories, we find a negative relationship between hedging and firm value. This is contrary to most previous research which document either a positive or an insignificant effect (e.g. Allayannis and Weston (2001), Carter et al (2006), and Jin and Jorion (2004)).

By calculating the number of profitable changes in annual fuel deltas we show that this surprising result can potentially be explained by unsuccessful attempts to time the oil market. A simple experiment reveals that only 34% of the changes in delta positions was in the correct direction relative to the change in the oil price over a subsequent 12-month period. When only material changes are considered i.e. absolute changes in deltas and the oil price of 10 percentage points or more, their forecasting ability is even poorer with a success rate of only 32%

The remainder of this paper is organized as follows. Section 1 provides a review of the relevant hedging literature. Section 2 provides an analysis of the gold mining industry particularly with respect to risk exposures and the relation between price risks, cash flows and capital investments. Section 3 describes the sample selection process and the construction of the hedging variables. Section 4 looks at the determinants explaining hedging decisions. Section 5 examines the relationship between hedging and firm value. Finally, Section 6 provides a summary and conclusions.

4. Literature Review: Hedging, Firm Characteristics, and Value

In a Modigliani a Miller world, where taxes, transaction costs and asymmetric information is non-existent, corporate risk management activities involving financial contracts cannot increase firm value. Investors can trade the same financial contracts as the firm with no additional cost and can therefore undo any change the firm does to its hedging policy.

However, more recent studies have proposed different economic rationales for firms to manage risk when real world market imperfections is applied to the Modigliani and Miller model. For example, Smith and stulz (1985) suggests that hedging can create value by decreasing expected bankruptcy costs. This cost reflects the probability and all the direct and indirect costs incurred when a firm is forced to file for bankruptcy. Investors incorporate this cost in their current valuation of a firm. Hence, a risk management program can add value by stabilizing future income flows, and in doing so, the probability of default and potentially bankruptcy. In addition, they also show that higher variability in pre-tax income cause the expected tax liability to rise in a progressive tax rate environment. Hence, minimizing the expected tax-liability by hedging can increase the after-tax value of a firm

Froot, Scharstein, and Stein (1993) further build on the distress cost argument. They show that as firm become more financially constrained the discrepancy between internal and external cost of funds increase. At some point the wedge becomes so great that they are forced to pass up on the positive NPV investments. By hedging, firms can alleviate this underinvestment problem by securing a steady cash flow and thereby increasing the likelihood of having sufficient capital at hand to initiate all value-maximizing projects. Bessembinder (1991) make a similar argument by demonstrating that equity holders can have an incentive to underinvest when a disproportionately large fraction of the value from undertaking a project accrues to more senior debt claims. In addition, Bessembinder (1991) argue that hedging can reduce the number of lower-tail outcomes, i.e. outcomes where the firm is unable to meet its financial obligations, and by doing so, obtain more favorable contracting terms.

In another paper Stulz (1984) examined how managers risk aversion impacted firms hedging activities. The total risk of a firm consists of market risk (systematic risk) and firm-specific risk (unsystematic risk). An investor can easily mitigate the unsystematic risk by holding a well-diversified portfolio. A manager, on the other hand, cannot. Managers are often required to hold a certain amount of company shares as a way to align their incentives with those of the owners[1]. Many managers also choose to hold large equity stakes in the company as a personal choice. Because firm-specific risk is an important part of the total risk exposure for such a manager, it is likely to be reflected in the return they require for holding the investment. Thus, hedging on the firm level improves the welfare of the manager if it reduces the unsystematic risk exposure and thereby reduce their required rate of return.

The above theories provide different theoretical explanations for firms to hedge. A great deal of empirical work has been conducted to determine whether these theories are consistent with what we observe in the real world and which one describes the hedging activities of firms most accurately. In a paper using survey data from 169 firms, Nance, Smith and Smithson (1993) finds that firms that face more convex tax functions hedge

[1] Managers are also commonly prohibited from hedging the firm exposure on their personal account to ensure they can't circumvent the incentive-alignment feature

more which give support to the tax incentives hypothesis. They also find support for the underinvestment theory. In another paper, Mian (1996) found that hedging exhibits economies of scale but finds no evidence in support of financial distress cost models and mixed evidence for the tax incentive and capital market imperfection theories. When examining risk management activities in a sample of gold mining companies in northern America Tufano (1996) Finds support for the managerial risk aversion theory.

Greczy, Minton, and Schrand (1997) examined 372 non-financial firms in the fortune 500 index in 1990 and their use of currency derivatives. They found that firms with greater growth opportunities and tighter financial constraints were more likely to use currency derivatives. This supports the capital market imperfection hypothesis that firms with more profitable investment opportunities are more likely to hedge. They also found that the use of currency derivatives is positively related to foreign pre-tax income and foreign-denominated debt. Gerczy et al (1997) argue that the benefits of hedging are high for those firms that have a high exposure to foreign-exchange rates. The firm's choice to use currency derivatives also depends on the cost of managing foreign-exchange rate risk and how costly it is for the firm to implement the derivatives strategy.

There is some support for most of the different theoretical models in the empirical studies. However, the results vary and there is no single theory that stands out as the most accurate description of firms hedging behaviour in the real world. Additionally, although these studies finds a link between hedging and the firm characteristics predicted by theory, these studies provide no direct evidence weather firms that actively hedge is rewarded with higher valuations relative to non-hedgers.

To address this issue Allayannis and Weston (2001) used a sample of large firms in the US between 1990 and 1995 and examined the use of foreign currency derivatives and market value proxied with Tobin's Q. They divide the firms into two subsamples; one sample included multinational firms with sales in different foreign countries and the other included firms without sales in foreign countries. This was done to isolate firms with similar exchange rate exposure. In the subsample of firms with foreign sales, they found that users of foreign currency derivative had a median Q of 1.02, whereas non-users had a median Q of 0.98. The difference 0.04 implies that users had an approximate 4% hedging premium, or roughly $150 million higher value given the median firm had a market capitalization of $3.79 billion and Q of about 1.

In another study Jin and Jorion (2004) examines the use of commodity hedging instruments of 119 US oil and gas producers in the period 1998 to 2001. They argue that this sample has a number of desirable properties compared with the sample used by Allayannis and Weston (2001). For instance, their sample covers firms in the same industry and is therefore likely to be affected by the same underlying variables. Another advantage, they argue, is that the oil and gas industry report more detailed information regarding items which are relevant when assessing the value of a firm. Additionally, their sample also includes smaller firms, whereas the sample in Allayannis and Weston (2001) only includes firms with assets in excess of $500 million. This gives insight whether hedging also increase value for smaller firms.

Contrary to the results reported by Allayannis and Weston (2001) they do not find any evidence that hedgers has a higher valuation than non-hedgers. The authors propose two different explanations for their findings: 1. There is no special advantage to hedge on the firm level since It is relatively easy for investors to identify the risk exposure to commodity prices of an oil and gas producers and can therefore hedge on their own. 2. The positive relationship between derivatives use and firm value for multinationals is spurious and due to unseen factors such as operational hedges or information asymmetries.

Adam and Fernando (2006) document that the use of derivatives to manage risk have led gold mining firms to realize economically significant cash flow gains resulting in an increase in firm value. They also found that these positive cash flows are statistically significant in both rising and falling markets, implying that the derivatives transactions translate into higher firm value both during good times and bad times. They also document that selective hedging, i.e. hedging that incorporates the market views of the managers (Stulz 1996)), do not lead to statistically significant value increases.

The findings of Adam and Fernando (2006) is related to the research of Brown, Crabb, and Haushalter (2006) who conducted a study using quarterly data on the risk management practices of 44 firms in the gold mining industry. The authors discovered that the companies in their sample tend to adjusted derivatives positions based on their outlook on future gold prices. However, they did not find any evidence that this practice has led to better financial performance and economic gains for shareholders. They argue that this result have more widespread implications since nonfinancial firms in other industries are unlikely to have an information advantage which is important to be successful in selective hedging. (Stulz (1996))

Campello, Lin, Ma, and Zou (2011) explores a dimension of hedging which is different to prior studies. They attempt to gauge the impact of hedging on a firm’s access to credit facilities. They simultaneously investigate the impact of hedging on the cost of debt, the likelihood of capital expenditure restrictions and investment. Their findings indicate a negative relationship between hedging and loan spreads. The study of Campello et al. (2011) differs from prior studies in that they consider the impact of hedging on a company from creditors' perspective as opposed to shareholders' perspective. The negative relation between hedging and loan spreads shows how hedging affects financing costs. This finding provides additional rationales for derivatives usage for risk management by showing that these risk management policies are favourably valued by creditors and thus will ultimately translate into gains for all company stakeholders by facilitating investments.

5. The Gold Mining Industry

The gold mining industry offers an interesting perspective for the study of hedging behavior and the value-enhancing hypothesis for a number of reasons. First, the operating cash flows of a gold mining enterprise depend on the margin between the price the firm is able to sell its gold and the cost of producing it. The selling price is directly related to the market price of gold and costs are related to oil prices through the use of refined crude oil products such as: diesel, gasoline and heating oil. In particular, diesel fuel is usually consumed in large quantities. It is an essential energy source in practically every mining operation and is used for, among other things, to power enormous hauling trucks which transport ore and waste rock around the mine site. Many mines operating in remote areas in the world also rely on diesel generators to supply the mine with electricity when connecting the local electrical grid is infeasible or non-existent. This exposes gold producers to two common and volatile risk factor, namely the price of gold and the price of fuel.

Second, gold miners can effectively hedge both types of risks with a variety of different financial instruments. For instance, forwards, futures, and swaps can be used to fix the selling price of gold or the purchasing price of fuel in the future. Put options can be used to protect gold sales against downside risk, and call options can be used to protect fuel costs against upside risk. These contracts provide great flexibility and can be combined to customize the firm's exposure to gold and energy prices in a variety of different ways. Additionally, information on the firms use of derivative instruments is available in the notes to the firm's financial statements, which makes it possible to make reasonably accurate estimates of firms hedging ratios.

Third, most of the world's largest mining corporations have in the last 10 years started to publish various non-financial performance measures. For most of the firms we investigate, this information is in the form of a sustainability report. In the report, firms discloses things such as the use of fuel and other materials, CO2 emissions, and waste. This allows us to estimate the firm's exposure to fuel prices and the magnitude of that exposure which is hedged using financial derivatives. With this information, together with data on firms gold price risk management activities, our objective is to explore the following two hypotheses:

***Hypothesis 1**: Are gold producers which hedge their gold output rewarded with higher market values?*

***Hypothesis 2**: Are gold producers which hedge their fuel input rewarded with higher market values?*

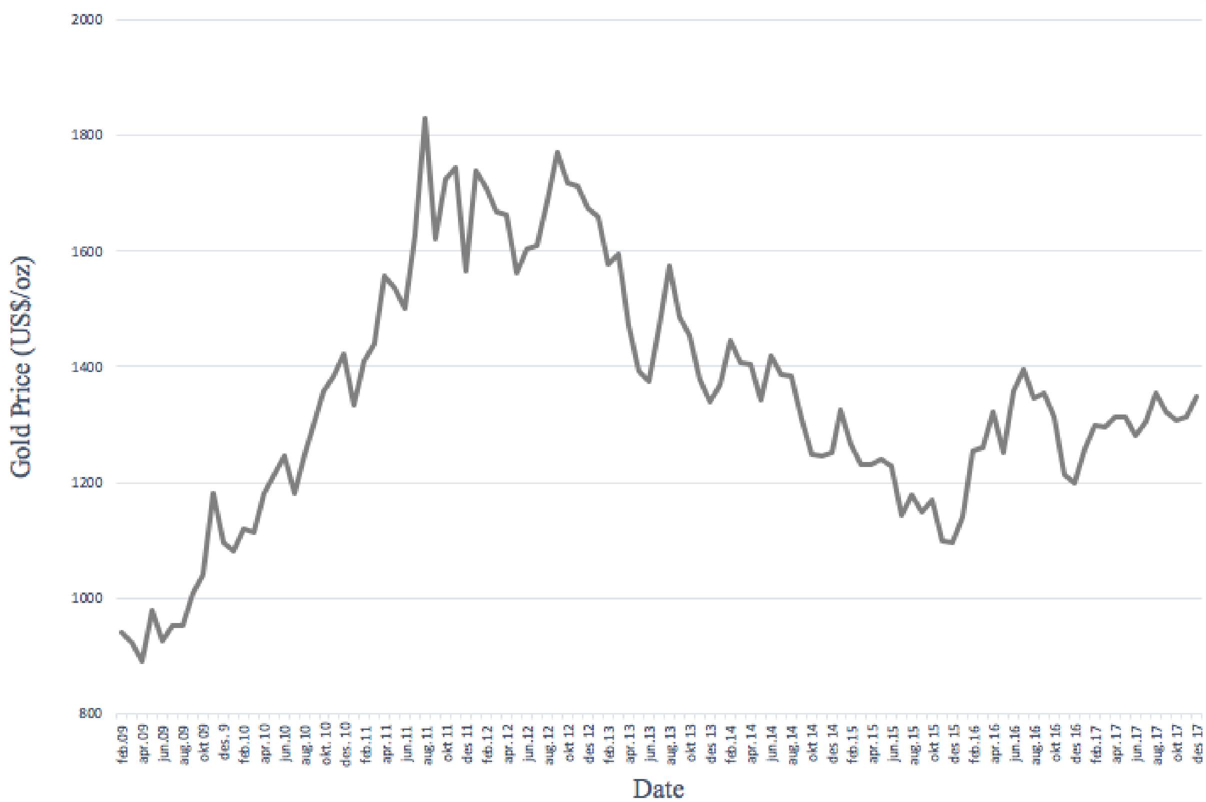
5.1 Historic Gold and Oil Prices

As background information we have taken a closer look at how the gold and oil prices have evolved over the sample period. Figure 1 plots the NYMEX front-month futures prices of gold over the period 2009-2017. The figure shows the gold price has seen some considerable swings in the sample period. Between 2009-2011 the gold was rising steadily, continuing a long-lived bull market starting all the way back in 1999. The gold price then hovered around an all-time high of $1900 in the 2011-2012 period before starting to decline in the subsequent years. Because much hedging is done to protect cash flow margins in the short to intermediate term it is informative to consider gold price variability within a comparable time frame. For instance, the monthly volatility is 4.8% and the annual volatility is 16.2%. This illustrates that, even though the long-term swings are most pronounced, there is also considerable variation in the short term.

Figure 2 plots the West Texas Intermediate (WTI) and Brent crude oil front-month futures prices in the same time interval as the gold price. As the graph illustrates, the oil prices have also seen some significant ups and downs, with the collapse in mid-2014 as a notable example. As a comparison with the gold price, the monthly and annual volatility is 7.7% and 35.5% respectively[2], roughly double that of the gold price.

Figure 1. COMEX Gold Futures prices

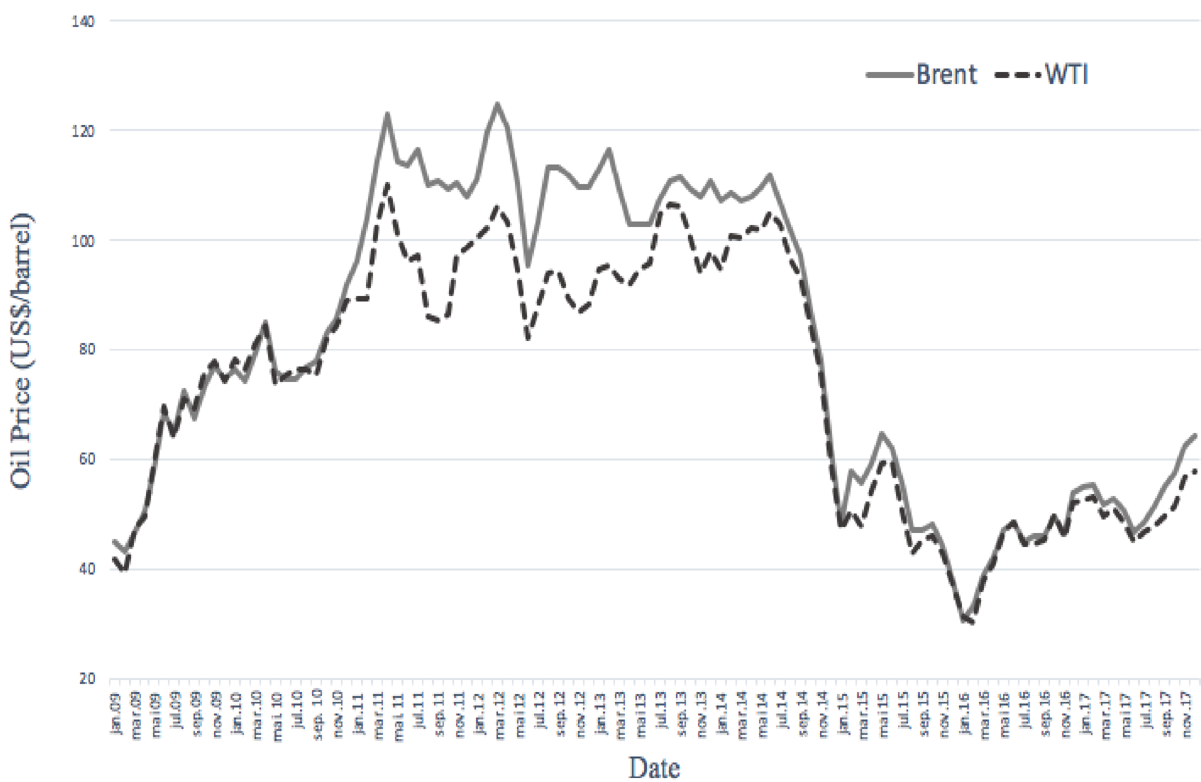
Figure 1 shows the US$ per oz gold price during January 2009 - December 2017. Prices are based on the New York Commodity Exchange (COMEX) Front-Month Futures Contract.



[2] Calculated using an equally weighted average of WTI and Brent prices

Figure 2. WTI and Brent Crude Oil Futures Prices

Figure 2 shows the US$ per barrel of West Texas Intermediate (WTI) and Brent crude oil prices during January 2009 - December 2017. WTI prices are based on the New York Mercantile Exchange (NYMEX) WTI Crude Oil Front-Month Futures and the Brent prices are based on Brent Crude Oil Front-Month Futures traded on the IntercontinentalExchange (ICE) in London. WTI serves as a benchmark for crude oil production in the US. Brent is a widely used benchmark for crude oil production globally.



6. Research Design

We start our investigation on the link between the use of commodity derivative contracts and firm value in the gold mining industry by extracting all firms with Standard Industrial Classification (SIC) code 1040[3] on the Compustat database in the period 2009-2017[4]. We further narrow the sample down by only including firms which are listed on the New York Stock Exchange and has total assets of minimum $1 billion. These initial screening criteria produce 21 firms and a possible 189 firm-year observations. Last, we only include firms where we are able to find sufficient amounts of data on fuel usage. This excludes 10 firms were we were not able to find a sustainability report or any other disclosure on fuel usage. The final sample consists of 11 firms and a total of 99 firm-year observation. The sample includes 11 of the 15 largest gold mining enterprises in terms of total assets as of 2017, and include industry leaders such as Barrick Gold Corp, Newmont Mining, and Goldcorp Inc.

In table 1 we present a summary of key statistics related to gold production and fuel usage for all sample gold miners. As we can see, the firms are very similar in terms of much revenues they derive from gold production and the fuel cost as a percentage of total production cost. This means the sample is relatively homogeneous in terms of the firm's exposure to both fluctuations in the gold price and the oil price. The only notable exceptions are New Gold Inc and Yamana Gold Inc which both make about 30% of their

[3] SIC is a four digit code system for categorizing industry areas. The first two digits 10 indicate the major group metal mining. Subgroup 1040 covers gold and silver ore

[4] Most of the gold miners start to publish non-financial data regarding fuel consumption in the years around 2009.

total revenue from the sale of non-gold metals. Consequently these firms might be somewhat less exposed to the gold price as their revenue stream is more diversified across different metals.

6.1 Hedging variable

Because disclosures on derivative instruments and risk management activities are not directly downloadable from the Compustat database we have manually searched through the notes to the firm's financial statements to obtain the desired data. In the notes, firms are under the Financial Reporting Release No. 48 (FRR No. 48) required to provide useful information regarding accounting policies and market risks inherent in financial derivative instruments. Firms can choose from 3 different disclosure alternatives: Tabular presentation, sensitivity analysis, or value at risk. Most of the firms we have investigated use the tabular alternative and describe the terms and other relevant information for each position. Below is a typical example from Yamana Gold`s annual report in 2017.

Table 1:Descriptive statistics of gold miners' production and fuel consumption

This table presents key operational statistics for all the gold mining companies in our sample. Data is gathered from the firm's annual reports and sustainability reports. Column one presents the firm's average annual gold production. Column two reports the percentage of revenue not coming the sale of gold. If the firm has not provided a breakdown of its revenue by segments we estimate the number as: 1 - (average gold price realized * total gold production) / total revenue. Column 3 reports the average annual fuel consumption and includes the following petroleum products; gasoline, diesel fuel, jet fuel, and heavy fuel oil. (A detailed description on how fuel consumption is calculated is provided in appendix A) Column four presents the average number of gallons consumed to produce one ounce of gold. Column 5 presents the annual average fuel costs as a percentage of total operating costs.

Gold Producer	Average annual gold Production (000 ounces)	Percentage of Revenue not coming from the sale of gold (%)	Average annual fuel consumption (000 gallons)	Gallons consumed per ounce gold produced	Fuel cost as a percentage of operating cost (%)
Agnico Eagle Mines	1,232	9.7	24,115	19.4	8.7
AngloGold Ashanti	4,141	4.5	92,676	22.50	7.8
Barrick Gold Corp	6,739	12.3	177,514	27.02	9.2
Eldorado Gold Corp	592	6.1	8,362	14.34	8.3
Goldcorp	2,703	22.3	49,557	18.41	8.2
Gold Fields	2,843	5.5	38,278	14.70	6.3
Iamgold Corp	880	8.2	32,198	37.33	10.9
Kinross Gold Corp	2,578	5.7	67,161	25.69	12.1
Newmont Mining Corp	5,105	10.9	172,000	33.01	13.6
New Gold Inc	377	29.2	13,529	35.53	12.9
Yamana Gold Inc	1,131	30.9	18,332	16.34	6.1

"During the third quarter of 2017, the Company also entered into a portfolio of zero-cost collar contracts for gold with a number of counterparties. The arrangement comprises of written call and purchased put options with identical characteristics and a range of strike prices that expire over a period of six months from October 2017 to March 2018. Total notional quantities included under this arrangement amounted to 284,200 ounces of gold, of which collars worth 152,300 notional ounces had settled or expired by December 31, 2017. The weighted average strike prices of the options are $1,300 per ounce and $1,414 per ounce for the put and call options, respectively, comprising the boundaries of the collar."

Yamana Gold provides a clear and easily understandable description of the type of position they have entered into, namely a portfolio of zero-cost collar contracts. They also include the most important terms such as the total notional, weighted average strike prices, maturity, and how many notional ounces is still outstanding as of December 31. 2017. We have collected data on all explicit derivative instruments related to gold and fuel hedging.

Because of the non-linear payoff function of options it is unfortunately not straightforward to measure the exact magnitude of gold production or expected fuel consumption which is effectively hedged. To illustrate, suppose a firm has bought a gold put options with a notional amount covering 100% of their forecasted 12 month production. At first though, one might think the firm has shed all gold price exposure related to gold production in the coming 12 months. This assertion can be close to correct, but also very wrong. If the option is deep out of the money, it is very unlikely to be exercised and a small change in the gold price will only result in a marginal change in the value of the option (The probability of the option being exercised is still very low so the option value only sees a small increase/decrease). Because the gain in value on the option does not offset a substantial amount of the revenue loss if the gold price where to fall, the firm still bears a considerable amount of gold price risk. Conversely, if the put option is deep in the money, the option is almost guaranteed to be exercised, and there will be an approximately one-to-one relationship between a change in the gold price and a change in the value of the option. Thus, in this case, the firm would be close to fully hedged.

This example highlights the need to construct a measure which takes each contracts sensitivity to changes in the underlying into account. We do this by calculating the delta[5] for each position. We then multiply the delta for each position with the notional and aggregate them all up. The resulting number is a measure of a firm's total portfolio (net) delta position. This number can be interpreted as the change in the total gold or oil portfolio value with respect to a small change in the price of gold and the price of oil respectively. For instance, a gold producer with a net gold delta position of -100.000 ounces[6], will experience an approximate $100.000 increase in the portfolio value if the gold price falls by $1. This implies that 100.000 ounces of gold is effectively sold forward and been shed for all gold price exposure.

Similar to previous research in this domain, we assume a delta of 1 for long positions and -1 for short positions in contracts with a linear payoff. This includes forward, futures, and swap contracts. The delta for option contracts are calculated using the Black

[5] Delta is a measure of a derivative instruments sensitivity in value with respect to a small change in the value of the underlying

[6] A negative delta implies a position which is effectively short in the underlying asset

and Scholes model[7]. The total delta position is then scaled by the firm's expected gold production the next year and the firm's current year fuel consumption for the net gold delta and net fuel delta position respectively. (Appendix A provides 2 detailed examples of how the fuel delta is calculated) Table 2 presents an overview of the hedging activity for the firms in our sample.

The average gold net delta position is negative in all the sample years. The net delta position is also negative for all firm-year observation for firms with outstanding gold derivatives. This confirms that gold miners use gold derivatives to hedge and not to speculate. However, column 2 shows that the overall use of derivative contract to protect against gold price volatility is very limited.

[7] We assume all options are European style. When the options are stated as maturing evenly across some period of time the maturity is set at the average maturity. The risk free rate used is retrieved from https://www.treasury.gov, and corresponds to the T-bill with the closest maturity to that of the option. Movements in the gold price 90 days prior to year-end is used to calculate the annual volatility. The spot price is based on the COMEX Front-Month Futures Contract price at the last trading day of the year. The convenience yield (gold lease rate) is ignored.

Table 2: Gold and Oil Hedging Activities

This table breaks down gold and oil hedging activities for each year in the sample period. Column 1 reports the total number of firms with some type of gold derivative outstanding at year-end. Column 2 reports the average number of ounces which is effectively hedged at the year-end. Column three reports the average gold delta-percentage (hedge ratio) at year-end. The delta-percentage is defined as the net delta position scaled by the firms anticipated gold production next year. Column 4, 5, and 6 shows the same figures but for the firms fuel hedging activities. The delta-percentage is calculated based on the firm's current fuel consumption as firms generally does not provide any guidance on expected fuel requirements.

Year	Number of firms with outstanding gold derivatives	Average gold net delta position (ounces)	Average gold delta-percentage (hedge-ratio) (%)	Number of firms with outstanding oil derivative	Average oil net delta-position (000 gallons)	Average oil delta-percentage (hedge ratio) (%)
2009	3	-393,021	17.7	7	21,679	22.9
2010	3	-33,727	6.6	3	21,083	15.4
2011	1	-18,000	4.2	4	26,795	25.5
2012	1	-12,000	2.6	6	27,167	22.4
2013	0	0	0	5	36,759	29.5
2014	0	0	0	6	43,420	36.1
2015	0	0	0	7	31,870	28.8
2016	2	-14,158	2.6	6	21,940	19.1
2017	3	-69,943	3.5	6	26,615	42.7

Among the 99 firm-year observations firms only hedged some of next year's production in 13. Moreover the average position was relatively small. 2009 was the year firms hedged the most with 17.7% of next year's production sold forward. This was primarily due to AngloGold Ashanti, which had a net delta position of -3.49 million ounces. During the next year they eliminated their entire hedge book as many of the other major producers had done before them. Notably Barrick Gold which took a $5.4 billion loss to unwind its gold hedges in 2009 and Newmont Mining which paid $578 million to early settled its 1.85 million ounce price-capped forward sales contracts in 2007.

As a result of AngloGold Ashanti eliminating its gold hedging program, the average gold delta percentage fell significantly in 2010. It fell further downwards the following years and hit 0 in 2013. It then took three years before any gold miner in our sample again hedged some of its production. We acknowledge that this will make it difficult to find a positive relationship between gold hedging and firm value. One issue is the lack of cross sectional variation and high concentration of gold deltas of 0. Another potential issue is that the 2009-2012 period - where the sample miners hedged to most, was characterized by a general bullish outlook on gold prices and producers paring back on their gold hedges[8]. In light of the bullish price expectations there was likely a strong investor sentiment towards “pure-play” gold stocks to gain full upside exposure to rising gold prices.[9] Consequently, if investors viewed firms unwinding their hedging positions

[8] The trend that gold producers tend to decrease their hedging activity when prices moves against them is documented by Brown et al. (2006)

[9] Some investors might also hold gold mining stocks exactly to get exposure to the gold price. Gold producers hedging their gold output would therefore undermine the investment goals for such an investor. This would further shift the investor preference towards un-hedged producers.

positively, It would introduce a bias in our sample towards finding a positive relationship between hedging and value.

In table 2 we show the gold delta as negative to highlight the fact that firms use derivatives to sell gold forward. However, in the further analysis, we will drop the negative sign on the gold delta for computational and interpretational convenience. Correspondingly, an increase in the gold delta means more gold is hedged, as opposed to less.

Hedging fuel input is far more common in our sample. 8 of the 11 firms hedged some fuel input during the period and 4 firms had some hedging in place in all the sample years. The positive deltas also confirm that gold miners hedge to protect against rising fuel prices and don't speculate on falling fuel prices. The fact that fuel hedging is widely embraced by the firms in our sample increases the likelihood of finding a significant relationship between fuel hedging and value. In addition, other than the fact that some investors might be wary of firms hedging activities due to large losses in the past, there is no obvious reason why investor would not want firms to hedge future fuel purchases. Nor is it likely an investor would hold a gold mining stock to get exposure to oil prices.

7. Hedging and Firm Characteristics

In this subsection we investigate whether hedgers in our sample conforms to the principal determinants justifying corporate risk management activities frequently cited in the literature. This can provide some useful insight into understanding the channels through which hedging can have a positive impact on firms market valuations. The main theories are discussed in the literature review and can be broadly summarized into two categories:

A: Theories which explain the motivation of hedging as a means for managers to reduce various types of costs and thereby maximize firm value. This includes theories related to financial distress costs, investment policy, and taxes. B: Theories which rationalize hedging as a way for managers with a high concentration of wealth and human capital tied up in the firm they manage to reduce risk. One important distinction between the two sets of theories is their implication on shareholder value. The former implies a potential positive value effect by reducing costs, whereas the latter implies there should be no value effect.

We use a similar methodology and a subset of the variables as in Tufano (1996) Below we discuss the relevance and predictions on the level of risk management for the theories we believe, a priori, is most applicable to our sample. In the subsequent section we present and discuss the results from our analysis.

7.1 Value maximization theories

The theories related to financial distress costs is particularly interesting for our sample. During the sample period changing market conditions have had a drastic impact on firms debt levels and presumably firms debt servicing capacity. Between 2009-2012 sample miners were investing heavily to increase production and capital expenditures rose from $750 million to $1860 million. At the same time, we observe that debt levels were rising steadily implying that new projects and expansions was financed more and more with borrowed capital. In 2012 capital expenditures peaked, and, as figure 1 shows, so did the gold price. The falling gold price meant diminishing asset values, rapidly falling equity market values, and a sudden spike in debt levels across the board. To illustrate the dramatic change, in the 12 month period between 2012 and 2013, the sample miners combined market capitalization went from $160 Billion to $81 Billion, and the average leverage ratio went from 0.16 to 0.43.

In addition, we find that the average production costs rose steadily and reached record highs between 2013-2014. It is reasonable to assume that, for the average gold miner, the combination of high debt levels and tightening profit margins had a material impact on firms debt servicing capacities and the probability of experiencing financial distress. According to theory, this is when risk management is can be especially valuable. Consequently one would expect a relatively high level of hedging activity during this period and a strong link between hedging and debt, and hedging and production costs. To measure these relationships and to test their relative importance of explaining hedging behaviour, we use debt as a fraction of total assets and the total cash costs as proxies. The debt to asset ratio measures the actual cost given the assumption that the direct and indirect costs are proportional to the book value of debt. The cash cost can be thought of as a measure of the probability of financial distress. If gold prices falls, high cost producers are more at risk of financial failure.

Another distress related theory which is especially applicable to our sample is Froot et al. (1993). Froot et al. (1993) show that risk management can add value when external financing is costly and cash flows are volatile. The rational is that firms with volatile cash flows will in some periods experience a cash flow slump. Because to cost of external capital is costly exactly when the company is financially constrained, firms can be forced to scale back on planned investments. Firms can alleviate this problem by implementing hedging programs which provide positive payoffs when operating cash flows are low and thereby enabling them to grow even in the most challenging market conditions.

This theory is especially relevant to our sample as the gold mining industry have many similarities to the framework and the general assumptions which their theory is built on. First, gold miners cash flow is volatile due to gold price and oil price exposure. Second, gold mining is capital intensive. Building a new mine requires significant expenditures to finance construction and processing infrastructure. Moreover, to grow, or even sustain current levels of production, gold miners must continuously invest to improve existing operations and finance exploration activities. Thus, it is fair to assume many gold miners have planned investments programs in place, and that their motivation for risk management activities is to secure the programs funding. Last, valuable investment opportunities can arise precisely when market conditions are tough. Struggling producers can be forced to sell off distressed assets, providing hedgers the opportunity to buy assets at below market prices. This suggests, if the theory accurately describe managers incentive, that we should observe a positive relationship between hedging and investment.

As a proxy for investments we use capital expenditures scaled by total assets. In addition. we add an estimate for firm size. As an extension of the hypothesis, due smaller firms are expected to hedge more due to generally higher external financing costs relative to larger firms.

We also examine the tax argument for hedging proposed by Smith and Stulz (1985). Tax convexity is proxied by tax loss carryforwards scaled by total assets and we expect to find a positive effect on hedging levels.

7.2 Managerial Risk Aversion Theories

These theories build on the idea that hedging is driven by managers with a large stake in the future success of the company seeking to reduce firm-specific risk exposure. (e.g. Smith and Stulz (1985) and Stulz (1984)). This explanation could fit well as the majority of gold miners in our sample have policies which require managers to hold an unhedged equity position in the company. The executive compensation schemes also commonly include shares and call options or other instruments which value is derived from the share price. This type of information is disclosed in the firms proxy statement which provides shareholders with background information on important matters that will be brought up on the annual or special stockholder meeting. We collect data on the number of shares and the number options held collectively by the executive management team. We then scale both numbers by the total number of shares outstanding. The framework of Smith and Stulz (1985) imply we should observe a positive relationship between hedging levels and managers with greater stock holdings and a negative relationship between hedging levels and managers with greater option holdings.

7.3 Alternative Hedging Strategies

There are also ways a firm can substitute the need for hedging using financial derivatives. For instance, a firm can maintain financial flexibility by holding a large cash balance. This reduces the firm's need for hedging because the extra money at hand can be used to finance new projects - breaking the reliance on costly outside financing. The extra liquidity can also help the company survive in market downturns. Firm's quick ratio is used to proxy financial flexibility and is defined as the sum of the firm's cash, short-term investments, and current receivables divided by the firm's current liabilities.

Diversification benefits might also impact the firm hedging decisions. The principal product of gold mines is of course gold, but various other metals is usually also recovered in the mining process. If the revenue from the sale of these by-product metals is economically significant the firm might be less inclined to hedge since the revenue stream is more diversified. The same argument follows for gold miners which hold non-core assets. To measure this diversification effect we calculate the percentage of total revenue which comes from the sale of metals besides gold.

7.4 Univariate Test

Because the univariate analysis did not produce any meaningful results from a gold hedging perspective[10], this part will focus on the determinants impacting the extent our sample miners hedge fuel input.

[10] Firms where partitioned into two groups - hedgers vs non-hedgers. Apart from some indication that the percentage of options held by managers are higher for hedgers (p-value = 0.099) the tests reveal no significant differences in firm characteristics and we have chosen not to report the results.

Table 3. Univariate analysis of firm characteristics sorted by the level of oil hedging activity

This table presents descriptive statistics of the variables used to describe the segmented group of gold mining firms in our sample. It also includes the p-value from a two-sample t-test with unequal variance on the means for non-hedgers (delta-percentage = 0) vs moderate hedgers (0 < delta-percentage < 30%), moderate hedgers vs extensive hedgers (delta-percentage > 30%), and non-hedgers vs extensive hedgers. Significance at the 10%, 5% and 1% levels are highlighted by *,**, and *** respectively

Variable	Oil delta (%)	CAPEX to total assets (%)	debt to assets (%)	Cash cost ($ M)	Firm value ($ M)	Tax loss carry forward (%)	Manager share ownership (%)	Manager option ownership (%)	Non-gold revenue (%)	Quick ratio (%)
Panel A. Non-hedgers (Delta percentage 0%, N=44)										
Mean	0	8.5	15.3	640	10226	9.4	0.2	0.6	16.4	1.8
Std. Dev.	0	3.0	9.8	110	7578	14.0	0.2	0.6	12.3	1.9
Panel B. Moderate hedgers (Delta percentage 0-30%, N=22)										
Mean	15.0	8.2	18.2	649	15859	6.3	0.2	0.2	9.9	1.5
Std. Dev.	8.5	3.0	7.8	96	11974	10.4	0.3	0.2	8.0	0.6
P-value No vs low	-	0.70	0.23	0.75	0.02**	0.36	0.78	0.01**	0.03**	0.53
Panel C. Extensive hedgers (Delta percentage > 30%, N=22)										
Mean	84.9	10.5	21.0	645	17794	12.7	0.4	0.5	9.6	1.8
Std. Dev.	44.3	4.0	9.0	123	18949	16.1	0.4	0.5	8.1	1.0
P-value Low vs high	-	0.04**	0.28	0.90	0.69	0.12	0.21	0.02**	0.9	0,35
P-value No vs high	-	0.03**	0.03**	0.87	0.02**	0.36	0.06*	0.66	0.36	0.96

First, it is instructive to compare firms with no fuel hedging with those with some degree of fuel hedging. Furthermore, we have segmented hedgers into two categories: moderate hedgers (delta-percentage between 0-30%) and extensive hedgers (Delta-percentage above 30%). The cutoff is set approximately at the median delta-percentage of hedging firms (31.5). Next, we calculate the average for each variable in the three groups and perform a two-sample t-test on the means. The p-values and descriptive statistics are reported in table 3.

A comparison of non-hedgers with moderate hedgers reveal that moderate hedgers tend to be larger, be less diversified, and have a management team which hold less options. The larger size of moderate hedgers is contrary to predictions but is a result found in several previous empirical studies, for instance, Nance et al. (1993), Mian (1996), and Geczy et al. (1997)). These studies maintain that the positive correlation found between assets and hedging can be attributed to large fixed start-up costs and scale economy benefits.

Further, the results point to a negative correlation between hedging and the percentage of revenue which comes from the sale of base metals and other non-gold precious metals. A natural explanation is that firms with a more diversified revenue stream enjoy some diversification benefits because of offsetting price movements in non-gold metal prices. Less diversified firms are therefore more inclined to hedge relative to their more diversified competitors.

The last finding, that option ownership is inversely related to hedging, is in line with the predictions of the managerial risk aversion hypothesis by Smith and Stulz (1985), and empirical evidence by Tufano (1996) and Schrand and Unal (1998). However, this result is questioned when we compare moderate hedgers with extensive hedgers. For a pattern consistent with theory we would expect extensive hedgers to hold less options than moderate hedgers - opposite of what we observe in the data. The executive management of firms classified as extensive hedgers hold on average a number of options representing 0.5% of the firm's total outstanding shares. On the other hand, corporate managers of firms classified as moderate hedgers hold on average 0.2%. The difference is statistically significant with a P-value of 0.02. This inconsistency suggests that the positive finding between moderate and non-hedgers in terms of managerial option ownership can likely be attributed to chance.

A further inspection of the differences between extensive hedger and moderate hedger show that the theoretical model of Froot et al. (1993) seems to be supported in that extensive users tend to have higher ratios of capital expenditures to total assets. This is consistent with the findings of Nance et al. (1993) and Geczy et al. (1997)

Another interesting observation is that moderate hedgers and extensive hedgers are, as opposed to non-hedger vs moderate hedgers, indistinguishable in terms of size. This supports the notion that risk management programs require substantial startup costs to reach a scale which makes the program economically sensible. Intuitively, this requires the firm to be a certain size. Moderate hedgers and extensive hedgers have both reached this size. Because the risk management program is in place, the decision is no longer about whether or not to hedge, but rather, how much to hedge. This decision is much less dependent on firm size. It follows that we would expect moderate and extensive hedgers to be similar in size but significantly larger than non-hedgers, which is what we observe in the data.

Last, we compare the most avid derivative users with the non-user group. The univariate tests show that extensive hedgers tend to have (1) more debt financing, (2) senior management team with a higher equity stake, (3) higher capital expenditure to asset ratios, and (4) higher firm value. Finding 1, that extensive hedgers tend to have higher debt levels support the theories linking hedging and financial leverage (e.g. Smith and Stulz (1985), Bessembinder (1991), and Leland (1998)). Finding 2 is consistent with the hypothesis that hedging is motivated by managers seeking to satisfy personal risk preference objectives (Stulz (1984)). The last two finding is similar and in agreement with the findings which is discussed in more detail in the above paragraphs.

7.5 Multivariate test

We regress the gold delta-percentages on the lagged variables defined in sections 4.1-4.3 using a one-sided Tobit model. The Tobit model allows for estimation of linear relationships when the dependent variable is either censored from above or below (or both). Two features of our data indicate the gold delta-percentages is censored at 0. First, we have a mass of 0 observations on the dependent variable. Second, we observe no firm with a negative delta percentage. Tufano (1996) argues that gold miners generally use operational strategies to increase gold price exposure rather than use financial derivatives. If this is true for our sample, the gold delta percentage might in essence be negative but is unobservable because the delta-percentage only captures commodity price-risk management using explicit derivative contracts. Hence, latent negative values are represented by zeros in the data because of non-observability (censoring) and not because of strategic choice. This makes the Tobit analysis theoretically valid (Maddala 1991)

One might also suspect the oil delta is censored at 0. For instance, gold miners could substitute renewable energy sources with diesel fuel or other fossil fuels to increase exposure (creating a latent negative fuel delta). However, we believe this is unlikely due to the intense scrutiny over their environmental impact. Accordingly, because operationally un-hedging fuel is difficult, the cluster of zero observations are most likely due to firms choosing not to hedge rather than non-observability. Thus, in this case, the OLS regression model is more appropriate. Results are presented in table 4. Column 1 shows the result from the Tobit regression model with the gold delta as the dependent variable. Column 2 shows the OLS regression with the oil delta as the dependent variable.

The pooled OLS regression show that capital expenditure, debt, size, and managerial stock ownership is positively related to fuel hedging levels and that diversification is negatively related to fuel hedging levels. The coefficient estimates are highly significant and confirm the results from the univariate tests discussed in the above section.

The Tobit estimation reveal one statistically significant finding - the coefficient on the capital expenditure to asset ratio. This indicates that investment considerations might be the predominant factor when it comes to hedging decisions, both in terms of gold hedging and fuel hedging (as documented above). The high p-values on the other coefficient estimates indicate weak relations between the alternative firm traits and the extent of gold price risk management.

Table 4. Multivariate analysis on the determinants of gold and fuel hedging activity using financial derivatives

This table presents the results of regressions explaining the extent of gold and oil hedging activity using financial derivatives. The dependent variable in the Tobit regression model (column 1) is the gold delta with censoring at 0. The dependent variable in the OLS regression model (column 2) is the oil delta. The independent variables are the lagged firm characteristics defined in 4.1-4.3. P-values are reported in the parenthesis. Variables significant at the 10%, 5% and 1% levels are highlighted by *,**, and *** respectively.

	Tobit regression with gold delta as dependent variable (N=88)	**OLS regression with oil delta as dependent variable (N=88)**
Constant	1.4768 (0.545)	-2.606 (0.001)***
CAPEX to assets	0.0635 (0.052)*	0.0241 (0.004)***
Debt to assets	-0.0073 (0.625)	0.0196 (0.000)***
Total cash cost	-0.00001 (0.384)	-0.00001 (0.231)
Firm size	-0.0022 (0.330)	0.0031 (0.000)***
Tax loss carryforwards	0.0022 (0.814)	0.0019 (0.529)
Managerial share ownership	-0.3977 (0.286)	0.6199 (0.000)***
Managerial option ownership	-0.0450 (0.883)	0.1693 (0.127)
Non-gold revenue	0.0055 (0.555)	-0.0102 (0.004)***
Quick ratio	0.0008 (0.280)	-0.00008 (0.795)
Log likelihood	-24.7	-

8. Hedging and Firm Value

In this section we test our 2 main hypotheses whether (1) gold producers which hedge their gold output is rewarded with higher market values, and (2) weather gold producers which hedge their fuel input is rewarded with higher market values.

Before we can start the analysis we need a proxy for firm value. The standard approach in similar research is to use some variation of Tobin's Q ratio. Tobin's Q is defined as the ratio of the firm's total market value to the replacement cost of its assets. Different formulae have been suggested to calculate the ratio e.g. Lindenberg and Ross (1981), and Chung and Pruitt (1994). The former approach is a cumbersome and computation-intensive procedure. In particular, obtaining a market value of debt and the replacement cost of assets is exceedingly involved and complex. The latter is a simplified version which uses the book value of debt and the book value of assets as approximations of the market value of debt and the replacement cost of assets. This greatly reducing the data and computational requirements. Chung and Pruitt (1994) also show that their simplified Q ratio explains at least 96,6% of the variation in the more theoretically correct version by Lindenberg and Ross (1981). Hence, the approximate Q should provide sufficient accuracy in our empirical analysis.

The formula takes the following inputs: market capitalization, short-term liabilities, short-term assets, book value of long-term debt, book value of total assets, and liquidation value of preferred stock. This information is available in the firm's balance sheet statements and is retrieved from the Compustat database.

8.1 Univariate analysis

We first examine our hypotheses in a univariate framework. The results are presented in table 5. Column 1 shows the mean, median and the standard deviation of the Q ratios for firms with neither gold or oil hedges. Column 1,2, and 3 shows the same measures for fuel hedgers exclusively, gold hedger exclusively, and either gold or fuel hedgers respectively. in addition, we report the p-values from a two-sample t-test on Q ratios[11] for the group of interest vs non-hedgers. We also test the differences in median Q ratios using the Wilcoxon rank-sum test. All P-values are based on a two sided test with a 5% significance level.

A quick inspection of the table shows that Q ratios are quite different across groups. Oil hedgers have substantially lower mean Q ratios than non-hedgers, but similar median Q ratios. Gold hedger have considerably higher mean and median Q ratios than non-hedgers. Even though the differences are striking, we fail to reject the null hypothesis for any conventional significance levels. Only in the comparison of mean Q ratios between fuel hedgers and non-hedgers are the p-value somewhat close to the 10% threshold. The results, or the lack thereof, necessitate a more sophisticated statistical modelling exercise which can capture the correlations between Q ratios, hedging deltas, and alternative factors which can impact the firm's Q ratios.

[11] A visual inspection shows that Tobin's Q-ratios are positively skewed but shows to be approximately normally distributed when log-transformed. We perform the same test on the log-transformed Tobin's Q-ratios and find marginally lower p-values.

Table 5. Comparison of Tobin's Q for firms with different risk management strategy

This table presents the mean, median, and the standard deviation of Tobin's Q ratio for firms subdivided into groups based on their hedging activity. P-values in row 4 are from a two-sample t-test on mean Q ratios for the group of interest vs non-hedgers. P-values in row 5 are from a Wilcoxon rank-sum test on differences in median Q ratios for the group of interest vs non-hedgers.

	Non-hedgers (N=43)	**Fuel hedgers (N=50)**	**Gold hedgers (N=13)**	**Fuel or oil hedgers (N=56)**
Mean	1.00	0.86	1.11	0.90
Median	0.79	0.81	1.23	0.81
Std. Dev.	0.58	0.39	0.44	0.39
P-value vs Non-hedgers (difference in means)	-	0.17	0.53	0.31
P-value vs Non-hedgers (difference in median)	-	0.36	0.32	0.64

8.2 Multivariate Analysis

Below we describe the various control variables that we use to isolate the causal effect of hedging on Q ratios. We also briefly discuss the reasoning behind their inclusion. The control variables used here are adapted from Allayannis and Weston (2001).

- Size (ln assets)

  The effect of firm size is important since large firms are more likely to use hedging than small firms. We use the log of total assets to control for the size effect.

- Profitability (ROA)

  Profitable firms are more likely to have higher Tobin's Q ratios than less profitable firms because profitable firms tend to trade at a premium to less profitable ones. The proxy used for profitability is the return on assets (ROA) defined as the ratio of net income to total assets.

- Leverage (Debt/total assets)

  A firm's value may also depend on its debt levels. As a proxy for leverage we use a variable defined as the book value of long-term debt over the book value of total assets

- Investment opportunities

  The value of the firm is also impacted by the available future investment opportunities. The proxy used is the ratio of capital expenditure over total assets.

- Production cost (total cash cost)

  Total cash cost generally refers to the total on-site cost of mining and processing gold as well as general and administrative costs. Total cash cost is a non-GAAP measure so there might be some discrepancy between each firms method of calculation.

- Diversification (non-gold revenue)

  Industrial diversification can impact the firm value as the company will have different revenue streams from diversified segments. To control for this effect we use the percentage of total revenue that is not from gold as a proxy.

8.3 OLS regression model

We estimate 3 different pooled OLS regressions. In all three regressions the dependent variable is the natural logarithm of the firms Q ratios. On the right-hand side, we include the variables controlling for size, profitability, leverage, investment opportunities, production cost, and diversification. Model 1 includes the gold delta, model 2 includes the oil delta, and model 3 includes both. Results are reported in table 6.

8.4 Gold hedging and firm value

The slope coefficient of the gold delta is 0.0032 which is insignificant as indicated by the P-value of 0.301. Furthermore, the estimated confidence interval is [-0.50, 0.61]. The breath of the interval shows our data supports a wide range of parameter values and provide little indication on whether the true effect is near the null, (hedging gold is value-neutral), far below (hedging gold is value destroying), or far above the null (hedging gold is value creating). Obviously, this provides very little insight on the potential value effect from hedging.

The unsatisfactory results can be partly attributed to the low statistical power[12] due to the few non-zero observations in our sample. In an attempt to remedy this issue we have examined the annual report for an additional 9 firms[13]. These firms represent the remaining gold miners listed on the New York Exchange with available data on the

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[12] Statistical power refers to the likelihood of detecting an effect when there is an effect there to be detected. With fewer observations (independent pieces of information) the precision of the parameter estimates, and the probability of finding a significant relationship decrease.

[13] The firms are: Alamos Mining Inc, DRDGOLD Ltd, Harmony Gold Mining Co Ltd, Hecla Mining Co. McEwen Mining Inc, Minas Buenaventura SA, Pretium Resources Inc, and Seabridge Gold Inc.

Compustat database for the full sample period. Only 2 of the additional 9 firms hedged some gold exposure. Harmony Gold entered into two forward contracts in 2017 covering about 36% of anticipated 2018 production, and Alamos Gold held option contracts covering about 10% of projected production at fiscal year-end 2016 and 2017. Not surprisingly, the expanded sample size did not produce noteworthily different results from the original regression.

Because the use of explicit derivative instrument to manage gold-price exposure is so limited in our sample, it is not possible to determine from the regression analysis if gold hedging accounts for any of the variation in Q ratios. To obtain more meaningful results, one must likely consider a broader range of strategies which gold miners have at their disposal to augment gold price exposure. For example, streaming agreements, gold bullion loans, and various operational hedging effects including the inherent real optionality of mining. Investigating the impact of these factors are, however, beyond the scope of this study.

Table 6. Firm value and hedging

This table presents the results from regressions of the natural logarithm of Tobin's Q ratios on gold and oil deltas and firm characteristics. (We use the absolute value of the gold deltas. This implies a positive(negative) coeffect estimate indicates a positive(negative) relationship between gold hedging and Q). Model 1 includes the gold deltas and controls, model 2 includes the oil deltas and controls, and model 3 includes both the gold and oil deltas and controls. P-values are reported in the parenthesis. Variables significant at the 10%, 5% and 1% levels are highlighted by *,**, and *** respectively.

	Model 1: Pooled OLS Gold delta + controls (N=99)	**Model 2: pooled OLS Oil delta + controls (N=99)**	**Model 3: pooled OLS Gold and oil delta + controls (N=99)**
Constant	0.9007 (0.221)	0.9131 (0.200)	0.7577 (0.295)
Gold delta	0.0032 (0.301)	-	0.0034 (0.263)
Oil delta	-	-0.0023 (0.032)**	-0.0023 (0.029)**
LN (Total assets)	0.0351 (0.602)	0.0460 (0.485)	0.0608 (0.365)
Long term debt to assets	0.0001 (0.980)	0.0032 (0.577)	0.0034 (0.546)
CAPEX to assets	-0.0017 (0.559)	--0.0008 (0.777)	-0.0014 (0.628)
Non-gold revenue to total revenue	-0.0061 (0.201)	-0.0086 (0.074)*	-0.0082 (0.087)*
Total cash cost	-0.0020 (0.000)***	-0.00217(0.000)***	-0.0021 (0.000)***
ROA	0.0232 (0.000)***	0.0230 (0.000)***	0.0230 (0.000)***

8.5 Fuel hedging and firm value

The coefficient estimate on the fuel delta is -0.0023 for both model 1 and 2 with a P-value of 0.032 and 0.029 respectively. Remembering that the independent variable is the natural logarithm of Q ratios and that the dependent variables are all in their original scale, we can make quick interpretations of the coefficient estimates using the following approximate relationship: $e^\wedge\beta(hat) \approx 1 + \beta(hat)$ [14]. This implies that a one unit change in the independent variable will, on average, lead to a 100 * $\beta(hat)$ % change in the dependent variable[15]. With this in mind, a 1% (one unit) increase in the fuel delta is expected to decrease the firm's Q ratio by approximately 0.23%[16] (100*0.0023). Alternatively, we can say that a firm hedging 1% of next year's production trades at 0.23% discount to a firm hedging nothing[17].

The direction and the effect size is quite surprising given our initial expectations and the belief that hedging is a value-adding strategy. What's more is that the WTI and Brent crude oil prices have increased by roughly $20 over the sample period. One would think that this has been beneficial for hedgers and resulted in, on average, positive payoffs. We have taken a closer look at firms fuel hedging activity in an attempt to find a potential explanations to this somewhat puzzling finding. Specifically, we have examined whether selective hedging as described by Stulz (1996) might be a contributing factor.

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[14] This approximation works well for small values of β(hat)

[15] The exact interpretation of the coefficient estimates in a log-linear specification is that a one-unit increase in the independent variable is expected to produce a β(hat) unit increase in the log-transformed dependent variable Ergo, the expected increase in the untransformed independent variable is (e^β(hat)-1)

[16] The exact number is 0.3405% (e^0.0034 - 1).

[17] Assuming the two firms are identical in all other aspects

As discussed in the previous sections there are a number of theories hypothesizing a positive relationship between hedging and firm value by smoothing out the variability in cash flows. However Stulz (1996) notes that if managers incorporate their market views into their price risk management policies based on an incorrect perception of having an informational advantage, it can actually lead to more volatile cash flows and potentially reduce shareholder value. In two recent papers Adam and Fernando (2006) and Brown et al. (2006) document that gold miners do in fact selectively hedge their gold price exposure, but find no compelling evidence that it translates to significant economic gains for shareholders. If selectively hedging gold, where gold miners presumably have some informational advantages over other gold market participants, is, at best, a value neutral activity, it is hard to argue why gold miners would be successful at favorably adjusting oil deltas. Thus, If this form of speculative hedging is in fact common practice in our sample - witch the variation in hedging ratios suggests[18], it is possible that the negative correlation between fuel hedging and value can be explained by poor market timing and generally bad hedging decisions.

To examine this further we test gold miners timing ability with a simple method similar to Brown et al. (2006). This method entails comparing the number of instances where a change in the hedge ratio was correct (profitable) based on the price at a subsequent point in time. Correct in our case, refers to an instance where the change in the delta and the change in the price of oil in the subsequent period was in the same

[18] The high variation in oil deltas is not direct evidence of selective fuel hedging. The results presented in table 4 shows that oil deltas are related to various firm-specific characteristics. As one or more of these factors change a firm's preferred hedging ratio is also expected to change. Hence, the time series variation is not necessarily due to selective hedging but rather changing firm characteristics, or a combination.

direction, either both increased or both decreased. Accordingly, incorrect refers to an instance when the change in delta and the subsequent change in the price of oil goes in opposite directions - an increase in the delta was followed by a decline in the oil price, or vice versa. We calculate the fraction of profitable delta-adjustments based on a 6 and 12 month time horizon. The results are reported in table 7, in column 1 and 2 respectively. We also check if gold miners are relatively better at forecasting major changes by only considering an absolute changes in the oil price and the hedging ratio in excess of 10 percentage-points. This estimation is based on a 12-month-ahead price change and is presented in column 3.

Table 7 shows that gold miners are not particularly good at anticipating oil price changes. The pooled success rate is only 44% based on the 6 month time horizon, and 34% for the 12 month time horizon. The latter value is significantly lower than 50% (P-value<0.05). When only material changes are considered, gold miners timing ability is even worse, with only 32% of hedging ratios going in the profitable direction.

Table 7. Gold miners fuel hedging market timing performance

This table shows the number of profitable changes in fuel hedging ratios. A change is defined as profitable if the oil price increased in the subsequent 6 month (column 1) or 12 month (column 2 and 3) period from when the change occurred. If the price declined in the following 6 (12) month period the change is defined as unprofitable. Column 1 and 2 includes all non-zero observations of hedging ratio changes. Column 3 includes observations conditional on the absolute change in hedging ratios and the price of oil is 10 percentage points or more. P-values are based on a non-parametric sign test with the null hypothesis that the observed proportion of "successes" is equal to 0.5. *,**,*** indicate significance at the 10%, 5%, and 1% levels

	6 month time horizon (N=50)	**12 month time horizon (N=50)**	**Material change (N=22)**
Profitable change	22	17	7
Unprofitable change	28	33	15
P-value	0.240	0.016**	0.067*

The significance is weaker due to the lower number of observations but still significant at the 10% level. Overall the results presented in table 7 suggest that gold producers have no ability to time the oil market. In fact, gold producers tend to lock in future oil purchases when the price is high and reduce their forward purchases when the price is low. As our results suggest, these poorly timed hedging decisions have had materially negative impact on shareholder values.

8.6 Controls

The control variables in both models are consistent and find that ROA and total cash cost have statistically significant effects on Q ratios. The sign on both coefficients are also as expected. Producers with higher costs are associated with lower Q ratios and more profitable producers are associated with higher Q ratios. The total cash cost might at first glance seem to have a weak effect on Q ratios and be economically irrelevant. However, that is not the situation when one takes into account how cash cost is defined - US$ per ounce gold sold. This can vary by several hundreds of dollars from one producer to the next. For example, the average cash costs for the miners in our sample range from a low 509 to a high 738. This is a difference of 229 and implies that, if the two producers are identical in all other aspects, the low cost producer would have a higher Q ratio relative to the high cost producer of 0.48. This difference is certainly not economically insignificant.

The parameter estimate on ROA is roughly 2.3 and implies we expect to find an approximate 0.023 increase in the Q ratio for every 1%-point increase in ROA. This result is not surprising as one would expect that higher profitability translates to higher firm value.

9. Summary and conclusions

In this study we have investigated the risk management activities and the impact on firm value for a sample of gold mining companies. More specifically we have looked at the use of commodity derivatives to manage two types of risk exposures. These exposures are the price of gold and the price of oil. The managers of the firms most actively engaged in hedging these risks appears to be motivated by a combination of two objectives. One is to maximize the value of the firm in the interest of shareholders. The other is to align the firm's total risk exposure closer to the preferred risk in their own equity stake in the company. These arguments are supported by our empirical findings of a positive relationship between investment opportunities, leverage, and the number of shares held by the senior management.

By using Tobin's Q as a measure of firm value, we have also tested whether hedging firms are rewarded by investors with higher valuations. Because of a limited amount of data we were unable to produce any convincing evidence on the connection between gold hedging and value. We do, however, document a negative correlation between fuel hedging and Q ratios. This refutes the notion that hedging is beneficial for shareholders by increasing the total value of the firm. Instead of systematically hedging fuel exposure, there seems to be a tendency that managers let their market views influence the hedging decisions. We argue that gold miners are very unlikely to be successful at this market-timing behaviour and show that the majority of changes in the fuel delta have been in the losing direction and ultimately been detrimental to shareholder value.

We would like to point out that we have not formally tested whether gold miners selectively hedge fuel exposure. This argument is simply set forth as one potential explanation for our findings based on the observed variability in hedging ratios. More research will have to be done to determine if this is actually true. Moreover, there is little understanding on how changes in managerial views and firm-specific factors are related to changes in optimal hedging ratios. Filling this gap can potentially be an interesting topic for future research.

Our findings are important for the gold mining industry and potentially other commodity-based industries. The results suggest that giving managers too much leeway to implement hedges and to adjust hedging ratios based on market views can lead to economic losses over time. Our general recommendation is to ensure that any hedging program is subject to well-articulated objectives and clear guidelines. This can help to resolve uncertainty related to the implementation of hedging programs and limit the impact of subjective market views influencing hedging decisions.

10. Appendix

10.1 Appendix A: Fuel delta computation

This appendix provides two examples of how fuel consumption and fuel price risk disclosures are reported and the procedures to calculate the fuel deltas. The first example is based on information from Agnico Eagle in 2017 and the second is based on information from Newmont Mining in 2017.

10.2 Example 1: Agnico Eagle

Calculating the fuel delta is a two-step process. First we search the sustainability report to find information on fuel usage. In their 2017 report Agnico Eagle report the following:

"Total diesel fuel use increased from 104.8 million liters (ML) in 2016 to 110.3 ML in 2017. Of that quantity, 71.4 ML (65%) were used for mining equipment, 38.5 ML (35%) were used for power generation, and 0.4 ML (<1%) were for other uses"

No other type of liquid fuel is reported. Agnico Eagle use million liters (ML) as their unit of measure. We first convert it into US gallons – which we use as a common metric.

110.3 million liters is equivalent to 29,138,177 gallon. (Conversions are based on the U.S. Energy Information Administration (EIA) conversion calculators)

The next step is to search in the notes to the annual report for disclosures regarding fuel hedging. In note “20. Derivative Financial Instruments” we find the following:

“To mitigate the risks associated with fluctuating diesel fuel prices, the Company uses derivative financial instruments as economic hedges of the price risk on a portion of diesel fuel costs associated with the Meadowbank mine’s diesel fuel exposure as it relates to operating costs. There were derivative financial instruments outstanding as at December 31, 2017 relating to 5.0 million gallons of heating oil (2016 – 1.0 million)”

Agnico Eagle provide no additional information on the type of instrument it has entered into so we assume a delta of 1. This gives a net delta position of 5,000,000 gallons and a fuel delta-percentage (hedge ratio) of 17.2% (5,000,000/29,138,177)

10.3 Example 2: Newmont Mining

Newmont report their energy consumption in terms of direct and indirect energy sources. Direct energy sources refer to on-site use of fuels and generated electricity. Indirect energy refers to purchased grid electricity. The table below show Newmont’s reported direct energy use in million gigajoules (GJ). In addition they separately report the use of 0.6 GJ of diesel to generate electricity.

Coal	Diesel	Waste oil	Gasoline	Natural gas	Propane	Heavy fuel oil	Aviation fuel
10.4	22.6	0	0.2	2.2	0.2	1.4	0

We include. Diesel, heavy fuel oil, and gasoline in the calculation. We convert the figures to gallon and add them up. This gives a total liquid fuel consumption of 171,295,336 gallons (23.2 GJ of diesel translates to 160,061,154 gallons, 0.2 GJ of gasoline translates to 1,575,319 gallons, and 1.4 GJ of heavy fuel oil is 9,658,863 gallons).

Next we search for info on hedging activities. In the note "ITEM 7A. QUANTITATIVE AND QUALITATIVE DISCLOSURES ABOUT MARKET RISK" Newmont disclose the following:

We had the following diesel derivative contracts in Nevada, within North America, outstanding at December 31, 2017:

	Expected Maturity Date		
	2018	**2019**	**Total/Average**
Diesel Fixed Forward Contracts:			
Diesel gallons (millions)	16	2	18
Average rate ($/gallon)	1.63	1.72	1.64

In total 18 million gallons of diesel is hedged using fixed forward contracts. We assume a delta of 1 for all forward contract and obtain a fuel delta of 10.5% (18,000,000/171,295,336)

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