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What Drives the Commodity Price Beta of Oil Industry Stocks?

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Abstract

We test theoretical drivers of the oil price beta of oil industry stocks. The strongest statistical and economic support comes for market conditions-type variables as the prime drivers: namely, oil price (+), bond rate (+), volatility of oil returns (–) and cost of carry (+). Though statistically significant, exogenous firm characteristics and oil firms' financing decisions have less compelling economic significance. There is weaker support for the prediction that financial risk management reduces the exposure of oil stocks to crude oil price variation. Finally, extended modelling shows that mean reversion in oil prices also helps explain cross-sectional variation in the oil beta.

Keywords: commodity beta; oil price; oil industry

JEL: G12

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1. Introduction

This paper theoretically models and tests the determinants of the commodity beta (i.e. *stock price sensitivity with respect to output/commodity price*, in this case oil) of oil industry stocks. Given imperfect capital markets, the risk associated with fluctuations in crude oil prices is fundamentally important to the managers and investors of firms within the oil and gas sector. Moreover, growing demand, geopolitical pressures and challenging resource allocation continue to drive uncertainty across the global energy landscape and this is prominently manifested through oil prices. Thus, by enhancing our understanding of the key drivers underlying the risk exposures of oil stocks, both managers and investors will be better placed to optimally manage/respond to the commodity-price risk facing their respective decision-making contexts. These considerations are the core motivations for our study.

Several studies have examined the exposure of oil stocks to fluctuations in the oil price within the North American, UK and Australian equity markets, however, to date the results do not provide conclusive statistical evidence (see, for example, Chen et al., 1986; Hamao, 1989; Kaneko and Lee, 1995; Sadorsky, 2001; Haushalter et al., 2002; Boyer and Filion, 2007; Henriques and Sadorsky, 2008). In addition, this literature focuses on the estimation of oil price exposure at the market or industry level, with minimal empirical research undertaken at the firm level. Our paper redresses this situation by modelling oil price exposures at the firm level, for a sample of North American oil companies over the period 1999 to 2008.[1]

While the extant finance literature gives good service to the potential role of uncertainty around exchange rates or interest rates as additional sources of risk, the more general question of

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[1] The North American market represents the largest proportion of the world's oil companies in terms of both market capitalization and the number of listed firms, with the US and Canada being the third and seventh largest world oil producers, respectively (US Energy Information Administration, 2010a; b).

the theoretical determinants of commodity price exposure has not been totally ignored.[2] Tufano (1998) is the beacon in this regard and his work applies to the gold industry. His modelling predicts that the theoretical drivers of the gold price exposure of gold stocks relate to: (i) market conditions; (ii) exogenous firm characteristics; (iii) a firm's financial policy; and (iv) a firm's risk management policy.[3] Hong and Sarkar (2008) extend the theoretical derivation of the commodity beta to account for the mean-reverting output price process. Despite the importance of the oil industry, to date, the literature is absent a rigorous theoretical framework which models the sensitivity of oil stocks to fluctuations in the output price and the factors driving such oil price exposure. As a consequence there does not exist a robust empirical assessment of the factors driving these "oil betas". We re-redress these limitations in the literature.

Given many similarities in the fundamental characteristics of the gold and oil industries, our strategy for modelling oil commodity betas in the oil industry is to begin with Tufano (1998) theoretical framework. However, this base model requires careful re-interpretation and enhancement. For one thing, oil producing companies have unique operating characteristics which make it difficult to accurately predict the effect of market-wide and firm-based factors on their oil price exposure (Quirin et al., 2000, p. 787). With the impact of these factors being dependent on a number of external influences, the challenge therefore is to build a more reliable model to understand the determinants of stock returns. Accordingly, the contribution of our research lies in the innovation associated with the inclusion of fundamental factors specific to the oil industry in a range of valuation models designed to analytically explain the returns of oil

[2] Prior studies which have sought to estimate the exposure of firms to fluctuations in the commodity price have concentrated on the gold bullion price, most notably; documenting that for gold mining stocks, changes in the gold bullion price (i.e. output price risk) is an important determinant of returns. See, for example, McDonald and Solnik (1977); Tufano (1998); and Faff and Hillier (2004).

[3] Employing a sample of 48 North American gold stocks over the period 1990 to 1994, Tufano (1998) finds that the exposures of gold stocks are negatively related to select exogenous firm characteristics, as well as market conditions and a firm's risk management strategies, while being positively related to the financing policies of gold firms.

stocks. One key element of this relates to accommodating the mean-reverting nature of oil prices in our model.

Our findings can be neatly summarized. We document that there is strong statistical and economic support for market conditions as theoretical determinants of oil price exposure, most notably, oil price (positive role), bond rate (positive), volatility of oil returns (negative) and cost of carry (positive). However, the statistical significance of exogenous firm characteristics and oil firms' financing policy are not convincingly supported by a corresponding level of economic significance. There is also some support for the empirical prediction that financial risk management activities reduce the exposure of oil stocks to fluctuations in the price of crude oil. Finally, extended modelling and tests show that a high degree of mean reversion evidenced in the crude oil price drives systematic cross-sectional differences in stock price sensitivities to oil price returns.

2. Comparison of the Fundamental Characteristics of the Oil and Gold Industries

The basic elements of the underlying valuation models implemented by Tufano (1998) appear common to all mining and extractive industries in general, with particular similarities in the defining characteristics of the oil and gold industries. Publicly traded oil stocks, like gold mining firms, produce a commodity output which is exhaustible and whose price is highly volatile. However, while the gold industry predominantly comprises 'pure play' firms, the oil industry has both upstream (exploration and production) and downstream (refining and processing of crude oil, their distribution and marketing) elements, with firms either fully integrated across all levels of the value-chain or concentrated within a particular sector of specialization (Sadorsky, 2001, p. 18). Despite the differences in the operating structures, the financial composition of these firms does not materially differ, with both industries typically operating with a high degree of financial leverage to support the capital intensity required to purchase, develop and operate mines/oilfields.

The finite nature of gold and oil resources means that firms within these sectors are subject to significant volatility in commodity prices driven by fluctuations in demand and supply conditions. The cyclical nature of the oil industry suggests that uncertainty driven by oil price volatility is a constant concern. Oil is a globally traded commodity with the price determined by global demand and supply conditions, however, an increasing demand for oil coupled with decreasing global supplies has seen a rise in the oil price from historical averages, driving greater volatility in oil price fluctuations. This enhanced volatility has increased risk and uncertainty within the oil market, subsequently negatively impacting stock prices while reducing wealth and investment opportunities (Henriques and Sadorsky, 2008, p. 999).

While the empirical literature evidences the co-movement of commodity prices (e.g. Pindyck and Rotemberg, 1990), another body of research analyses the unique characteristics of these commodities as underlying drivers of fluctuations in the crude oil and gold bullion price. Inflation, changes in the exchange rate of the US dollar and heightened political and economic uncertainty are major factors contributing to gold price movements, with recurring concerns over the inflationary impact of higher oil prices coupled with investor demand and speculative activity also seen to drive increased fluctuation in the gold bullion price (Reserve Bank of Australia, 2007).

The literature also documents that the long-term evolution of the price of an exhaustible commodity should follow a mean reverting price process and gravitate over time toward the mean reverting price level (Hong and Sarkar, 2008). Mean reversion in energy prices is well supported by empirical studies of energy price behavior, as well as basic microeconomic theory (Bessembinder et al., 1995; Longstaff and Schwartz, 1995; Hong and Sarkar, 2008). Basic microeconomic theory suggests that in the long-run the price of a commodity will be tied to its long-term marginal production cost or the long-run profit-maximising price sought by cartel managers in the case of cartelised commodities like oil (Laughton and Jacoby, 1995, p. 188). The speed at which prices revert to their long run level, however, is dependent on a number of factors including the nature, magnitude and direction of the commodity price shock.

Despite these factors, demand and supply pressures and non-constant convenience yields in commodity markets suggest that mean-reversion to long-run equilibrium prices holds. Within commodity-based industries, however, it is difficult to disentangle the structural change in fundamentals of the industry from inherent fluctuations in the mean reverting price process. Estimating the mean reversion parameters of a variety of commodities, Bessembinder et al. (1995) find that there is substantial mean reversion in the crude oil prices but far less reversion in gold bullion prices.[4]

3. Hypothesis Development

3.1. Valuation Models

Tufano (1998) employs three valuation frameworks: fixed-production model; flexible-production model; and a model of fixed-production with hedging.[5] The flexible-production model recognizes that commodity-based firms have real options in their production schedules (see, for example, Brennan and Schwartz, 1985; Paddock et al., 1988; Brennan, 1990; Schwartz and Moon, 2000). The real options model developed by Brennan and Schwartz (1985) for the evaluation of investment projects treats output prices as stochastic, takes explicit account of

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[4] More specifically, Bessembinder et al. (1995) estimate that 55 percent of crude oil price shocks are reversed in the 8 months following the shock, while only 5.7% of gold bullion price shocks are reversed over a similar period.

[5] In the fixed-production model, firms cannot alter their production profiles and do not engage in financial risk management. Under the assumptions of this model, a company owns a fixed quantity of reserves that it is expected to mine/tap at a given production rate which is specified at time zero and remains unaltered over the life of the mine/oilfield. The model is based on the premise of the DCF technique.

managerial control over the output rate (which is assumed to be variable in response to the output price) and incorporates the possibility that a specific project may be closed down or suspended if the output price falls below the firm's marginal cost. Ignoring the optionality embedded in mine operating decisions tends to overstate the mine's sensitivity to price shocks of the underlying commodity (Tufano, 1998, p. 1025). Under the fixed-production model with hedging, firms that sell forward their entire production profile can eliminate their exposure to commodity prices which subsequently drives their commodity beta towards zero. In addition, the price at which gold is sold forward affects the observed beta for those firms that sell forward less than their entire future production.

3.2. Theoretical Determinants of Oil Beta

Starting with Tufano (1998) as our base, there are fourteen candidates as theoretical drivers of oil price exposure broadly relating to four groups. The first group relates to *market conditions* and consists of: (i) crude oil price (PRICE); (ii) crude oil price volatility (VOL); (iii) 10-year Treasury Bond rate (BOND) and (iv) cost of carry (COC). The second group relates to *exogenous firm characteristics* and comprises: (v) quantity of production (PROD); (vi) yearly cash costs (COST); (vii) quantity of crude oil reserves (RES); (viii) market value of the oil firm (MV); and (ix) percent of assets allocated to oil production (%P). Group three relates to the *corporate financing policy*, captured by just one factor (x) leverage ratio (LEV). The final factors can be grouped as relating to *corporate risk management policy* and comprise: (xi) delta-percentage of production (D%P); (xii) delta-percentage of reserves (D%R); (xiii) average-forward-sale-price (W_1); and (xiv) average-delta-contract-price (W_2). Table 1 provides a summary of all of the variables and their definitions.

(Insert Table 1 about here)

Table 2 provides a summary of the empirical predictions provided by the valuation models (first three columns) and empirical literature (fourth column). In the following sub-sections, to conserve space we focus on just two illustrative cases: oil price (PRICE) and quantity of production (PROD), as they present important variations to the modelling setup of Tufano applied to gold. We provide a brief discussion of the other twelve potential drivers of oil beta in the Appendix.

(Insert Table 2 about here)

Oil Price (PRICE)

The fixed-production model is mis-specified for firms within the oil and gold industries as these firms have the option of being able to either temporarily or permanently suspend production when the commodity price falls below a firm's marginal costs. Under the flexible-production model and the parameter estimates of the North American oil industry, the commodity price is predicted to be positively related to the commodity beta.[6] The Brennan and Schwartz (1985) flexible-production model predicts that the change in the commodity beta as a function of the commodity price is given by:

$$\frac{\partial \beta}{\partial P} = \frac{\frac{QB}{k}(\gamma^2+1-2\gamma)P^{\gamma} - \frac{\gamma^2 B(CQ+F)}{r}P^{\gamma-1} - \frac{Q(CQ+F)}{rk}}{\left(BP^{\gamma}+\frac{PQ}{k}-\frac{(CQ+F)}{r}\right)^2} \tag{1}$$

where Q is production quantity; γ is the volatility of oil prices; C is yearly cash costs; F is fixed costs; r is the interest rate; k is the oil cost of carry and B is a complex function of Q, γ, C, F, r and k.

Figure 1 provides a graphical representation of the predicted changes in relevant commodity betas using the flexible-production model for gold and for oil.

[6] The reasoning behind this relationship is explained by option theory. As the commodity price increases, the default trigger is also increased but at a slower rate causing the distance between these measures to increase as default risk falls. A higher output price subsequently reduces the stock price sensitivity, resulting in an inverse relationship.

(Insert Figure 1 about here)

Panel A provides the base parameter values relied upon to predict the impacts the theoretical determinants of commodity price exposure have on the observed exposures of North American oil and gold stocks. The base parameter values are set at representative levels and consistent with Brennan and Schwartz (1985), Tufano (1998) and the parameter values for the North American oil industry as estimated within this study. Panel B shows the predicted effect of the gold bullion price on gold betas, based on parameter values and descriptive statistics provided by Brennan and Schwartz (1985) and Tufano (1998). The figure illustrates that the gold beta is inversely related to the output price, with the exposure of gold stocks decreasing during periods of high gold prices. Note also that the gold betas are predicted to exceed unity for all levels of the gold bullion price which is consistent with the estimations of prior literature including Tufano (1998) and Faff and Hillier (2004).

Based on parameter values consistent with those observed within the North American oil industry, Panel C of Figure 1 shows the predicted effect of changes in the crude oil price on the oil betas of a typical oil stock. Most notably, contrary to the relationship evident within the North American gold industry, the crude oil price is predicted to be positively related to oil betas. Moreover, the oil beta is also predicted to be less than unity which is consistent with empirical research (see, for example, Jin and Jorion, 2006).[7, 8]

[7] As can be seen in Equation (1) which shows the comparative static relation between commodity beta and price, the functional relation is highly non-linear. In particular, the role of commodity price is significantly affected by the complex interactive effects coming from the many other variables in the model. In the gold case, the overall effect of the complex interactions, based on a meaningful set of parameter values (as illustrated in Figure 1) is to produce a declining function for the gold beta. In contrast, when meaningful values are used for the counterpart variables relevant for the oil case (also see Figure 1 for the selected values), they mix in such a way that leads to an increasing function for the oil beta. It seems that the defining characteristic that drives the contrasting predictions is the "location" of the unity (commodity) beta – for gold (oil) the commodity betas are always above (below) unity and graphically we see that the model creates an "asymptote" at the unity value. Put simply, gold (oil) companies approach this asymptote from above (below).

[8] The contrasting relationship between commodity prices and the commodity betas of North American oil and gold stocks is also evidenced under the assumptions of the fixed-production model with hedging (details are available from the authors upon request).

Production Quantity (PROD)

Tufano (1998) predicts that the quantity of gold bullion production is inversely related to the gold beta. Crude oil is a depletable resource so it is expected that the size of the base stock, and specifically flows in and out of the base stock, are likely to impact oil price risk (Sadorsky, 2008, p. 93). From an economic perspective, an increase in the level of production by a firm would increase the oil stock held, which would subsequently increase the exposure of firms to crude oil price variation. On the other hand, an increase in the production of an oil producer is associated with a firm exercising the option of drilling proved oil reserves, such that a firm actually reduces the risk of their assets and their required stock return (Boyer and Filion, 2007).

Figure 2 illustrates the predicted impact of production quantity on the commodity betas of gold and oil firms under the assumptions of the flexible-production model. Panel A confirms the predictions of Tufano (1998), indicating that under the base parameter values assumed by Brennan and Schwartz (1985) and Tufano (1998), the production of gold is inversely related to the gold beta of gold stocks. Based on the parameter values observed within the North American oil industry, however, the production of oil is shown to be positively related to oil betas (Panel B).[9]

(Insert Figure 2 about here)

3.3. Commodity Betas with Mean-reverting Output Prices

The mean reversion literature (Raymar, 1991; Sarkar and Zapatero, 2003) suggests that the speed of the reversion (κ) of output prices provides an additional source of uncertainty beyond that captured by price volatility (VOL). A higher κ indicates that output prices move back to the long-run mean price level at a faster rate, reducing uncertainty and the effect of short-term commodity price fluctuations. Under these conditions, changes in the output price subsequently

[9] Note also, that the oil beta is also predicted to be less than unity across all levels of production which is consistent with the prior literature.

have a smaller effect on equity values which results in a lower commodity beta (Hong and Sarkar, 2008, p. 1290). Both Bessembinder et al. (1995) and Schwartz (1997) document that oil prices are more strongly mean-reverting than the prices of precious metals, which suggests that the value of the oil beta should be smaller than the gold beta. This observation is consistent with prior literature.

Hong and Sarkar (2008) argue that it is necessary to extend the theoretical derivation of the commodity beta to account for the mean-reverting output price process.[10] To address the mean reverting nature of commodity prices, the authors therefore highlight the importance of using a mean-reverting commodity price process which allows the separation of persistent fluctuations in the crude oil price from transitory changes. The parameters of the price process can be estimated from the output price time series using the method developed by Longstaff and Schwartz (1995), reflected in the following regression:

$$\frac{P_{t+1}-P_t}{P_t} = \beta_0 + \beta_1 \frac{1}{P_t} + \varepsilon \qquad (2)$$

where P_t is equal to the daily closing WTI crude oil price over the period 1 January 1999 to 31 December 2008. From Equation (2) we uncover an estimate of the speed of reversion of the crude oil price (KAPPA), as well as the long-term mean level of the oil price process (THETA): the variable KAPPA is given by the negative of the intercept in this regression (i.e. KAPPA = –β_0) and THETA is equal to –(β_1/β_0) (see Hong and Sarkar, 2008).

A higher speed of reversion implies that output prices will revert back to the long-run mean level at a faster rate. This effectively reduces uncertainty and the importance of short-term price fluctuations, meaning changes in output prices have a smaller effect on equity values. As such, given the baseline positive prediction for oil price, KAPPA is predicted to be negatively

[10] Note, however, that when the speed of reversion is large enough, uncertainty is reduced to such a degree that volatility has no effect on equity price sensitivity. Under these circumstances the commodity beta is therefore observed to be independent of price volatility (Hong and Sarkar, 2008, p. 1290).

related to the oil beta. Hong and Sarkar (2008) predict that THETA is inversely related to the gold beta of gold stocks, with an increase in the long-term mean level of the gold process reducing the default risk for a gold stock and the estimated commodity beta as a result of an increase in long-term revenues. Within the oil industry, however, THETA is predicted to be positively related to the exposure of oil stocks to fluctuations in the oil price. The predicted positive relationship is explained by the same factors driving the positive relationship between realised exposures and the average crude oil price (refer to the discussion in Section 3.2), with an increase in the long-term mean oil price process reducing long-run demand for crude oil as consumers seek alternate energy sources.

4. Empirical Framework

4.1. Joint Estimation Regression Model

As our primary form of analysis, we apply a single estimation approach which includes lead and lag terms on both the oil and market returns to accommodate concerns of thin trading (controlling for firm fixed-effects – following Tufano, 1998):[11, 12]

$$R_{i,t} = \alpha_0 + \sum_{k=-1}^{k=1}(\alpha_o + \sum_j \varphi_{o,j} F_{j,i,t})\, R_{o,t+k} + \sum_{k=-1}^{k=1}(\alpha_m + \sum_j \varphi_{m,j} F_{j,i,t})\, R_{m,t+k} + \epsilon_{i,t} \tag{3}$$

where $R_{i,t}$ is the CRSP daily return on stock *i* from *t – 1* to *t*; $R_{o,t+k}$ is the total return of the West Texas Intermediate (WTI) NYMEX crude oil price;[13] $R_{m,t+k}$ is the daily return on the CRSP NYSE/AMEX/Nasdaq value-weighted index; and $F_{j,i,t}$ are the theoretical determinants of oil

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[11] We give prominence to this single estimation approach over a two-stage method because of the econometric efficiency that the former delivers. Nevertheless, as indicated below, the collection of inferences is qualitatively similar between the two alternative approaches.

[12] In a preliminary analysis, unconditional oil betas are estimated across our sample. The mean (median) oil beta for North American oil stocks is estimated to be 0.33 (0.30) over the period 1 January 1999 to 31 December 2008. The magnitude of the estimated oil beta is consistent with the mean (median) monthly unadjusted oil beta of 0.33 (0.28) reported by Jin and Jorion (2006) over the period 1999 to 2002 and the mean monthly oil beta of 0.30 estimated by Sadorsky (2001) for Canadian oil producing firms over the period 1983 to 1999.

[13] Consistent with many prior studies, (e.g. Sadorsky, 2001; Boyer and Filion, 2007; and Sari et al., 2010); the WTI NYMEX closing spot price is used and is obtained from the Thomson Datastream database.

price exposure.[14] Each oil firm is required to have at least 75 percent of daily return observations for each quarter q. As robustness checks, in unreported analysis: (1) this estimation is also conducted using a generalised linear regression (GLR) model with firm fixed-effects; and (2) we also estimate a two-stage estimation approach, again with adjustment for thin trading (as in Tufano) and the results are qualitatively robust to those documented in the text.[15]

4.2. Sample Selection Criteria

The preliminary sample consists of all North American oil and gas firms categorised under SIC code '1311' (e.g. Rajgopal, 1999; Haushalter, 2000; Jin and Jorion, 2006). Given the enhanced disclosure requirements of North American oil firms and the importance of risk management strategies within the industry, the sample period begins 1 January 1999. Each sample firm is required to have data available for the 14 factors outlined in Section 3.2, as well as daily return data over the period 1 January 1999 to 31 December 2008, obtained from the CRSP database. An initial sample of 2,197 firm-quarter observations for 107 North American oil stocks is identified from the Research Insight database.

Table 3 summarizes the filtering process leading to the final sample. As shown in the table, the following omissions are made: (a) 354 firm-quarter observations (involving 19 different firms) with insufficient data to determine the yearly cash costs (COST);[16] (b) 435 firm-quarter observations (involving 17 different firms) with insufficient data to determine the risk management variables; (c) 372 firm-quarter observations (involving 12 different firms) lost as a

[14] We considered applying a logarithmic scaling of some variables in $F_{j,i,t}$ such as size, production and reserves. However, we decided against such transformation since: (a) these variables always enter as interactions and, thus, their individual distributions are not directly important; (b) we deal with distributional issues in a variety of other ways through our full experimental design; (c) such nonlinear transformation will cloud their economic interpretation; and (d) this simpler approach accords with Tufano (1998), thus ensuring comparability from this perspective.

[15] In the first stage of the two-stage approach, we estimate Dimson (1979) market and oil betas, with the Fowler-Rorke (1983) adjustment. Details of these alternative results, suppressed to conserve space, are available from the authors upon request.

[16] Either the information is not disclosed with the annual 10K report or the annual report is not available on EDGAR online.

result of the requirement that firms have 75 percent of the daily observations in the quarter and (d) finally 13 firm-quarter observations with extreme observations are removed. The final sample consists of 59 North American oil firms, producing a total of 1,023 firm quarter observations over the period 1 January 1999 to 31 December 2008.[17]

Table 4 provides two sets of descriptive statistics based at the end of the sample period (i.e. 2008). The aim of this table is to paint a broad picture in terms of the general characteristics of the sampled firms and thereby demonstrate that serious sample biases are absent. Panel A shows the mean values of selected characteristics of the final sample (59 firms) compared to the excluded sample (48 firms), while Panel B shows the mean values of selected characteristics for “high” oil producing companies compared to “low” oil producing companies in the final sample. High (low) oil producing companies are classified as those having a percentage of oil production above (below) the sample median, namely, 23.4%. Each panel reports across five different dimensions for which we could obtain valid data: (a) market capitalization of equity measured in $million (MCap); (b) book to market (B/M); (c) percentage of daily sample observations for which zero returns are observed (i.e. an illiquidity proxy); (d) exploration expense measured in $million; and (e) percentage of oil production (%Oil Production). With regard to %Oil Production, a “conversion rate” is applied to allow comparisons of oil and gas production.[18]

(Insert Tables 3 and 4 about here)

From Panel A we see that the only dimension on which our included sample shows a difference from the excluded companies is their size (MCap): on average, our sample firms are smaller. While this is notable in the sense that it contrasts the typical large firm bias, it does not

[17] Our sample size is consistent with extant empirical examinations of commodity-based industries including Rajgopal (1999), oil and gas, and Tufano (1998), gold, though a little smaller than Haushalter (2000), Jin and Jorion (2006) and Boyer and Filion (2007) whose samples all involve around 100 different firms.

[18] We convert natural gas from cubic feet to barrels of oil equivalent as per the US Department of Energy, Energy Information Administration (2001) Unit Conversion Factors, accessed from the Society of Petroleum Engineers website: http://www.spe.org/industry/docs/UnitConversion.pdf.

present any obvious major threat to our analysis. Panel B, likewise shows a "size effect" in the high versus low oil producer segments of our sample – high oil producers are, on average, smaller. Since our multivariate modelling has several variables that will capture different dimensions of size, this size differential does not pose a major threat to our analysis. Notably, taking a collective view of Table 4, there appears to be no strong evidence of sample-induced biases in terms of B/M; illiquidity; exploration expense or degree of oil production.

One final piece of commentary is in order at this stage, given that our sample clearly involves many firms that have considerable activity devoted to gas production relative to oil (most simply reflected by our sample median percentage of oil production equal to 23.4%). We offer several considerations that ameliorate any concerns on this score. First, Haushalter (2000) and Jin and Jorion (2006) note that firms within the oil and gas industry often hedge gas prices as opposed to oil prices. The extent to which this "asymmetric" hedging phenomenon occurs will mean that our focus on oil has empirical power. Alternatively, the extent to which this gas focus is a "nuisance" to our analysis, will mean that any findings we can document are more like a "lower bound" of what might be expected in the context of a "pure" experiment. Second, it is noteworthy (not surprisingly) that gas prices and oil prices are historically very highly correlated. For example, the WTI crude oil and Henry Hub gas prices exhibit a correlation of 0.74 over our sample period. As such, the oil price is very likely to be an effective "instrument" in the presence of gas price drivers.

Third, as an additional robustness check, we estimate the conditional oil betas while including a natural gas return factor as an additional explanatory factor in the multi-factor market model. This augmentation does not substantially affect the analysis, with the sample mean oil beta reducing from 0.33 to 0.30. The estimated conditional oil and gas betas are consistent with the extant literature.[19] Finally, any attempt to eliminate heavy gas producers from our sample dramatically reduces the sample and threatens the very viability of our study. Collectively, taking these four considerations into account and weighing up the associated implicit research design trade-offs, we feel that our chosen empirical setup is justified and meaningful.

4.3. Empirical Proxies for the Theoretical Determinants of Oil Price Exposures

4.3.1 Variable Measurement and Data Sources

As indicated above, Table 1 presents an overview of the measurement of all factors hypothesised to affect the oil price exposure of oil stocks. Most of the description in this table is self-explanatory – only a few extra comments are included here for clarification purposes.

In obtaining quantity of oil reserves (RES) for each firm the annual proved reserves, rather than probable reserves are used as a measurement of an entity's oil stock given the greater reliability in proved oil estimates as opposed to probable reserve holdings. The yearly cash costs (COST) for an oil firm refer to the US$/BOE cost of producing both oil and gas (excluding non-cash items such as depreciation, depletion and amortization) collected from annual reports.[20] While, ideally, the COST factor would relate solely to the oil production of a firm, the current disclosure rules within the North American oil and gas industry does not require a specific breakdown of these expenses between the oil and gas sectors.

The extent to which the assets of a firm are allocated to the production of oil (%P) is measured as the proportion of a firm's net property, plant and equipment as a percentage of a

[19] Details are available from the authors upon request.
[20] To obtain BOE (the barrel of oil equivalent), we convert natural gas from cubic feet to barrels of oil equivalent as per the US Department of Energy, Energy Information Administration (2001) Unit Conversion Factors, accessed from the Society of Petroleum Engineers website: http://www.spe.org/industry/docs/UnitConversion.pdf.

firm's total assets.[21] Again, while this factor would ideally measure only the proportion of a firm's assets allocated to crude oil production, the current financial reporting rules for the North American oil and gas industry does not require disclosure of the allocation of assets between the oil and gas sectors.

Following Tufano (1996) and Jin and Jorion (2006), the total delta per firm is calculated from the sum of the delta equivalent of each position reported at the fiscal year-end. For linear hedging instruments, short positions in crude oil (e.g. short futures and forwards, receive-fixed swaps, fixed-price contracts and volumetric production arrangements) are assumed to have a $\Delta = -1$ while long positions are assumed to have a $\Delta = 1$. Following Jin and Jorion (2006), the delta of nonlinear collar contracts adopted by North American oil firms is calculated using the Black (1976) option pricing model.[22, 23]

To understand the economic impact of a firm's financial risk management activities it is necessary to scale the portfolio against its natural exposure. Accordingly, Tufano (1996) and Jin and Jorion (2006) scale the portfolio delta by the forward production for the sample of North American gold and North American oil firms to capture the risk management decision of the firms. Following Jin and Jorion (2006), the delta-percentage of production (D%P) is scaled by next-year oil production.[24]

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[21] This empirical proxy is chosen due to the broad availability of these data across our sample. Alternative potential proxies, such as oil revenues scaled by total revenues or estimated value of proven reserves scales by total assets are infeasible due to a lack of reliable data.
[22] Savickas (2005) shows that the Black-Scholes approach performs equally well from a delta hedging perspective, compared to the Weibull and gamma option pricing models.
[23] In an unpublished appendix available from the authors, we give an overview of the risk management strategies adopted by North American oil companies, as well as an example of the calculation of oil delta for a sample firm.
[24] To calculate this measure, Tufano (1996) scales the delta of the risk management portfolio by the estimated three-year production of the firm provided by an equity analyst in the industry. Given the difficulties associated with accurately estimating forward production for oil and gas firms, Jin and Jorion (2006) scale the delta of the risk management portfolio by the next-year oil production for the sample firms.

4.3.2. Descriptive Statistics of Theoretical Determinants of Oil Price Exposure

The descriptive statistics for the theoretical determinants of oil price exposure are presented in Table 5. Panel A presents the market-condition variables. The PRICE factor has a quarterly average of US$54.47/Bbl over the full sample period, trading within a price range between US$13.13/Bbl to US$123.90/Bbl. The 90-day annualised volatility of WTI crude oil price returns (VOL) is 37.8%, with a maximum volatility of almost 94% over the sample period. The VOL is greater than the mean 13% annualised volatility of the gold bullion price returns reported by Tufano (1998) over the period 1990 to 1994, and above the 25% annualised volatility of crude oil price returns measured by Fusaro (1998). This is not surprising, given the significant volatility of the WTI crude oil price surrounding the spike and subsequent decline of the crude oil price in 2008, with Plourde and Watkins (1998) also noting that the price of crude oil tends to be more volatile than the prices of other major commodities including gold, silver, tin and wheat.

The exogenous firm characteristics presented in Table 5, Panel B display significant skewness and kurtosis driven by extreme values. To address the influence of extreme values on the observed results, Dixon (1960) suggests the winsorization of outliers to improve the efficiencies of these estimators. Consistent with prior literature, data transformation is therefore undertaken with outliers winsorized at the 1% level.

(Insert Table 5 about here)

The mean (median) production (PROD) is 288 (179) MBbls with mean (median) proved developed reserves of 2,974 (1,638) MBbls.[25] This is significantly lower than the quarterly volume of crude oil production and proved reserves reported by Boyer and Filion (2007) in their analysis of the Canadian oil and gas industry, with Boyer and Filion (2007) estimating that the quarterly mean (median) production and proved developed reserves of Canadian oil and gas

[25] MBbl is the standard measurement of crude oil, measured as one million barrels of crude oil.

producers is 4,259 (819) MBbls and 114,160 (23,202) MBbls, respectively, between the first quarter of 1995 and the third quarter of 2002. The measurement of proved reserves for the Canadian oil and gas producers however is a composite measure which includes the proved reserves of crude oil as well as natural gas.

Table 5, Panel D provides the descriptive statistics for the risk management policies. The average North American oil firm hedges 17% of its forward production and 2.3% of same-year proved oil reserves, which is consistent with Rajgopal (1999) who document that the mean North American oil firm hedges 3.86% of its oil reserves between the period 1993 to 1996. The mean hedging undertaken by the sample firms is below the 33% of production and 4% of reserves Jin and Jorion (2006) documents to be hedged by North American oil firms between the period 1998 to 2001. Jin and Jorion (2006), however, focus only on firms with disclosed hedging positions at year-end and did not include those firms without active hedging strategies.[26]

5. Results

5.1 Core Determinants of Oil Price Exposure from the Joint Estimate Analysis

Table 6 presents the results for the joint estimation of the theoretical determinants of conditional oil betas (excluding factors related to mean reversion of oil price), with firm fixed-effects.[27] The joint estimation model provides strong support for market-condition factors as determinants of the crude oil price exposure of North American oil firms. The first thing of note in Table 6 is that the WTI crude oil price (PRICE) is a significant determinant of the oil beta of North American

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[26] While there is no significant correlation identified between the variables relating to market conditions, exogenous firm factors and firm's financial policy, there is significant correlation between the four risk management factors, namely between W_1 and W_2 as well as between D%P and D%R. The significant relationship between these variables poses a potential threat of multicollinearity in the model and the precision of the parameter estimates. When undertaking the multiple regression analysis incorporating these select risk management variables, the regressions are therefore undertaken without the inclusion of both W_1 and W_2 and both D%P and D%R within the same model.

[27] Initially, we exclude the factors relating to oil price mean reversion (KAPPA and THETA) so that clear comparisons can be drawn with Tufano (1998). We assess the complete model specification in Section 5.3.

oil firms (significant at the 1% level). Its positive coefficient suggests that the crude oil price exposure increases as oil prices rise. While this result is consistent with the empirical predictions of the flexible-production model and fixed-production model with hedging, it is counter to the findings of Tufano (1998) and Hong and Sarkar (2008) when examining the North American gold industry. We explore this further, in later analysis.

The estimated role of volatility (VOL) is also consistent with prior literature and the empirical prediction of the flexible-production model which suggests that the volatility of commodity price returns is inversely related to the exposure of oil stocks to crude oil price fluctuations. There is strong support for the interest rate factors (BOND and COC) as drivers of the crude oil price exposure of North American oil firms. While BOND is estimated to have a positive role (at the 1% level of significance), and robust across all model specifications, this is contrary to our predictions. However, this specification is consistent with Hong and Sarkar (2008) and additional regression analysis provided below. The positive association between the cost of carry (COC) and oil price exposure (at the 1% level of significance) is consistent with our empirical predictions.

(Insert Table 6 about here)

The joint estimation model provides strong support for the positive association between the size-related firm characteristic factors (production, leverage, and market value) and the oil betas of North American oil stocks. As predicted by the three valuation models, leverage (LEV) is estimated to have a positive association with oil beta. Market value (MV) and the percent of assets in production (%P) are also shown to have a significant positive effect on oil price exposure.

While theory suggests that the risk management policies of firms (as measured by D%P, D%R, W_1 and W_2) should decrease the observed exposures of firms to commodity price fluctuations, the joint estimation model provides no support for this association. This finding is surprising and might be explained by the observations of both Haushalter (2000) and Jin and Jorion (2006) who note that firms within the oil and gas industry often hedge gas prices as opposed to oil prices. In addition, given the significant appreciation of the crude oil price over a substantial part of the sample period, North American oil producers who seek higher crude oil prices in the market may not have found it necessary to limit their upside benefit by entering linear or non-linear hedging positions.[28]

5.2. Discussion

We now present a synthesised discussion of the specifications of the theoretical determinants of crude oil price exposure estimated by both the separate and joint estimation models, with the empirical results compared against extant literature and our predictions. In addition, we provide possible explanation(s) for findings contrary to the empirical predictions and offer insights into the "economic importance" of those factors estimated to be statistically significant. Table 7 provides a summary of the key findings of this study in terms of: predicted impact versus observed impact and an "indicative" analysis of the economic importance of statistically significant findings.[29]

(Insert Table 7 about here)

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[28] It is worthy of note that (in unreported results) applying the alternative two-stage estimation approach, the W_1 and W_2 risk management policy measures have a statistically significant negative relationship with oil betas (significant at the 5% level or better). These results conform to our predictions, indicating that hedging decreases the stock price exposure of North American oil firms.

[29] We choose to classify "economic significance" against a benchmark of a minimum 10% change in the commodity beta, judged against the overall sample mean commodity beta. We acknowledge that this choice of cut-off is arbitrary, but despite this we feel a meaningful dichotomy of economic importance can be identified among the factors examined. Nevertheless, readers are cautioned to have a "healthy scepticism" regarding this indicative analysis.

5.2.1 Market Conditions

As summarized in Panel A of Table 7, the models provide strong support for market conditions related factors as theoretical determinants of the exposure of North American oil stocks to fluctuations in the price of crude oil. Regarding the four such factors examined: crude oil price (PRICE), volatility (VOL), 10-year Treasury bond rate (BOND) and the cost of carry (COC), each exhibit statistical significance (at the 1% level of significance), with only the 10-year Treasury bond rate producing an association contrary to expectations.

Both the separate and joint estimation models estimate a positive association between the crude oil price (PRICE) and oil price exposure, with an increase in the quarterly average oil price by one standard deviation or US$27.60/Bbl predicted to increase the estimated oil beta by about 0.14. While this finding is consistent with our empirical predictions, it is inconsistent with the estimations within the North American gold industry where prior literature has evidenced a negative association between the exposure of gold stocks to changes in the gold bullion price (Tufano, 1998; Hong and Sarkar, 2008). Notably, fluctuations in the crude oil price are estimated (under the joint estimation model) to have a greater effect on the commodity beta than that observed within the gold market, with a one standard deviation increase in the quarterly average crude oil price increasing the mean oil beta by approximately 39% as opposed to the around 15% change in the gold beta estimated by Tufano (1998) following a one standard deviation increase in the quarterly average gold bullion price.

The observed difference in the effects of commodity prices on the exposure of North American oil and gold industries might partly be attributed to differences in the fundamental characteristics of the two industries. The production of crude oil by North American oil firms is heavily influenced by OPEC. Unlike the North American gold industry, the restrictions imposed by OPEC on crude oil supply effectively inhibit the ability of North American oil producers to increase output to capitalise on periods of higher crude oil prices. While this restricts the potential upside benefit, oil producers have the ability to reduce their downside risk by diversifying their supply operations into gas production during periods of low crude oil prices. Under these conditions, the risk imposed on a North American oil firm within a higher crude oil price environment may outweigh the risk from sustained declines in output prices, thus explaining the positive association between exposure and the level of the crude oil price. In comparison, the operations of North American gold stocks are predominantly "pure play", with a significant risk posed to these firms during sustained periods of decreasing gold bullion prices, further justifying the negative association between gold price exposure and the gold bullion price.

Consistent with prior literature and our empirical predictions, the joint estimation model shows that an increase in the volatility of WTI crude oil price returns reduces the sensitivity of North American oil stocks to fluctuations in the crude oil price. Option theory explains that a higher volatility of output prices will move the default boundary further, which subsequently reduces default risk and the sensitivity of equity prices. From a valuation perspective, as the volatility of crude oil price returns does not affect firm value under the fixed-production models, the significance of this factor indicates that the market takes real optionality into account when valuing oil firms. The economic significance of volatility is observed to be similar within the North American gold and oil industries, with the mean gold beta decreasing approximately 15% compared to 10% in the mean oil beta following an increase in quarterly volatility of the relevant commodity prices by one standard deviation.[30]

Under the assumptions of the fixed-production models, interest rate factors (BOND and COC) do not directly affect the oil beta but rather proportionally affect the market value of the

[30] These estimations are based on the specifications provided by the joint estimation models.

firm (Tufano, 1998, p. 1041). Within the specifications of the flexible-production model the oil beta is a direct function of interest rate factors. The joint estimation models show a significant positive association between BOND and the oil beta, with (model (i) of) the joint estimation model indicating that a decrease in BOND by one standard deviation will reduce the oil beta by 16.35%. This finding is consistent with Hong and Sarkar (2008) who explain that a higher interest rate decreases the asset value of a firm through increasing the discount rate, which brings a firm closer to their default trigger and subsequently increases the sensitivity of equity values.

The gold lease rate is a common risk factor among North American gold stocks, reflecting the cost of borrowing gold as determined by the supply and demand for metal in the lending market (Tufano, 1998; International Monetary Fund, 2004). While a similar lease rate is not observed within the oil industry, a counterpart measure at the firm level is the cost of carry (COC). While both the separate and joint estimation models indicate that the COC is a statistically significant factor driving the commodity exposure of oil stocks, its economic importance appears minor (particularly in comparison to the other market characteristics).

5.2.2. *Exogenous Firm Characteristics*

As summarized in Panel B of Table 7, our results provide partial support for exogenous firm characteristics (PROD, MV, COST and %P) as determinants of the crude oil price exposure of North American oil stocks. However, the statistical significance of the size-related factors is not convincingly supported by a corresponding level of economic significance.

The models indicate production (PROD) has a positive association with oil beta as predicted. In terms of economic significance, an increase in quantity of production by one standard deviation (268.824 MBbls) increases the oil beta by 0.03 or approximately 8 percent of the mean oil beta (based on model (iv) in Table 6). This contrasts the findings of Tufano (1998) within the North American gold industry where production was statistically insignificant.

There is only partial support for COST as a factor driving oil price exposure, with only the (unreported) separate estimation model indicating its statistical significance. The results of the separate estimation model are also contrary to our empirical predictions and prior literature, indicating that the oil price exposure of North American oil firms decrease following an increase in the yearly cash costs of a firm. This result might be a reflection however of the noise associated with the measurement of this variable, with the cash costs attributed to both the oil and gas production of a firm rather than focussed specifically on crude oil production. Across all models, there is no significant association estimated between the proved reserves (RES) of a North American oil firm and oil price exposures. But, as Tufano (1998) notes, there is considerable noise in the measurement of proven reserves with it being subject to engineering estimates of the amount of recoverable resources controlled by a firm.

The joint estimation model suggests that %P is a significant factor affecting oil price exposure. For example, an increase in the %P by one standard deviation or 17.9% will increase the oil beta by 0.02 or around 6% of the mean oil beta. The effect of %P is substantially less than that documented by Tufano (1998) when examining North American gold stocks, which documents that a one standard deviation increase in %P increases the gold beta by 0.44 or approximately 20% of the estimated gold beta.

5.2.3. Corporate Financial Policy

The joint estimation model provides strong support for a firm's financial policy as a theoretical determinant of crude oil price exposure, with the significantly positive relationship between the leverage ratio and the oil beta indicating that firms are able to reduce their exposure through using less debt (Hong and Sarkar, 2008, p. 1290). This suggests that leverage policy can be used as a substitute for hedging, which was previously noted by Peterson and Thiagarajan (1996) in their analysis of a case study of North American gold producers. As shown in Panel C of Table 7, the economic significance of leverage within the North American oil and gold industries is comparably weak, with a one standard deviation increase in the factor estimated to increase the oil and gold betas by round 5-6 %.

5.2.4. Corporate Risk Management Policy

There is some support for the empirical predictions that financial risk management activities reduce the exposure of North American oil stocks to fluctuations in the price of crude oil, with the predictions only supported in the (unreported) separate estimation model. In economic terms the affect is reasonably important in some cases, with an increase in W_1 by one standard deviation or US$22.46 reducing the oil beta by approximately 17%. Interestingly, D%P and D%R are positively associated with the oil price exposure of oil stocks which is contrary to both the extant literature and our predictions. The positive association is suggestive that, if anything, these firms tend to engage in speculation rather than hedging practices.

The weak role of risk management policies is consistent with the underlying premise of the Modigliani and Miller perfect capital market context where risk management should be irrelevant. The finding is also supported by limited extant literature including Peterson and Thiagarajan (1996) who document that hedging has no effect on the equity price exposures of two North American gold mining firms.[31]

[31] The findings of Jin and Jorion (2006) provide further insight into the insignificance of the effect of risk management on oil price exposure. Specifically, they note that given commodity risk exposure is both easy to identify and easy to hedge, hedging by the firm does not confer a special advantage as institutional investors are able to adopt risk management strategies based on the commodity price risk of firms.

5.3. Commodity Betas with Mean Reverting Output Prices

Table 8 provides the results of the joint estimation of the oil betas for North American oil stocks when accounting for the speed of mean reversion in the crude oil price and the long-term mean level of the oil price process. It is evident that the KAPPA and COC are significantly correlated which introduces potential mis-estimation and difficulties in the interpretation of the co-linear variables. The joint estimation of oil betas in the context of oil price mean reversion is therefore undertaken after removing COC from the regression and maintaining the interchange of the combination of hedging variables.

Consistent with both prior literature (Hong and Sarkar, 2008) and our empirical predictions, we find KAPPA is inversely related to oil beta (at the 1% level of significance). This specification indicates that short-term price fluctuations in the crude oil price are less important within the North American oil industry with the market apparently understanding that output prices will revert back to their long-run mean level, effectively reducing uncertainty and the sensitivity of equity values to crude oil price changes. The significance of the mean reverting process of the crude oil price also provides additional support to the estimation of the mean oil beta at 0.33, which is considerably below the sample mean gold beta at around 2 (Tufano, 1998).

The long-term mean level of the oil price process (THETA) is estimated to have a significant positive relationship with the oil beta (at the 1% level of significance). While these specifications are contrary to the estimation of Hong and Sarkar (2008) within the North American gold industry, it is consistent with our empirical predictions, indicating that oil price risk increases following an increase in the long-term mean price level. The magnitude of THETA is documented to be greater than that observed by Hong and Sarkar (2008) within the gold industry, with model (iii) predicting that the oil beta will increase by 0.4104 with a US$1 increase in the long-term level of the oil price process. This finding is economically significant in the context of a sample mean oil beta of 0.33 within the North American oil industry, and the insignificance of the THETA estimate documented by Hong and Sarkar (2008) for gold.

(Insert Table 8 about here)

6. Conclusion

The primary objective of this paper is to model the potential economic drivers of the exposure of oil stocks to fluctuations in the oil price (i.e. model the drivers of their oil price beta) and empirically test this model using a representative sample of North American oil stocks, over the period 1999-2008. We document strong statistical and economic support for market conditions-type variables as the drivers of oil betas: oil price (positive), bond rate (positive), volatility of oil price returns (negative) and the cost of carry (positive). For example, and most notably, the crude oil price is positively associated with oil beta, with a change in oil price by one standard deviation (US$27.70/Bbl) changing the oil beta by approximately 39 per cent in the same direction. While we also find a statistically significant role for various firm characteristics, financial policy and financial risk management, few of these cases are convincingly supported by a corresponding level of economic significance. For example, the role of production and market value are significant and positive but are shown to be economically weak.

Our paper also accounts for additional explanatory factors of oil price exposure, relating to commodity price mean reversion (Hong and Sarkar, 2008). Consistent with extant literature and our empirical predictions, we document an inverse relation between the speed of mean reversion and oil beta, while the long-term mean price level is estimated to be positively associated with oil beta. We argue that this latter result reflects the mean-reverting nature of the crude oil price, such that persistent fluctuations away from the long-term mean are not expected by the market.

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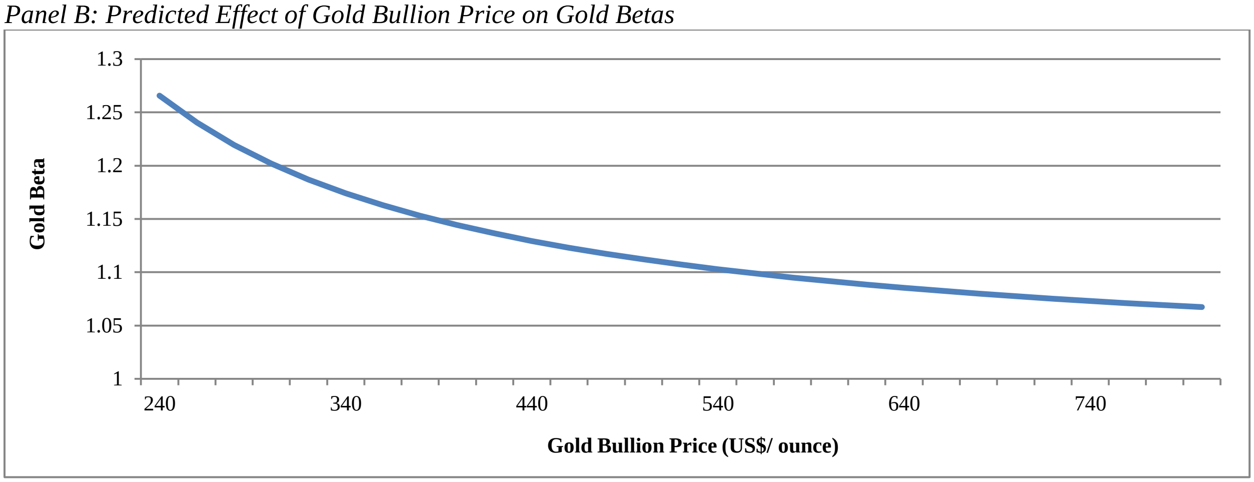
Figure 1: Impact of Commodity Prices on Commodity Betas

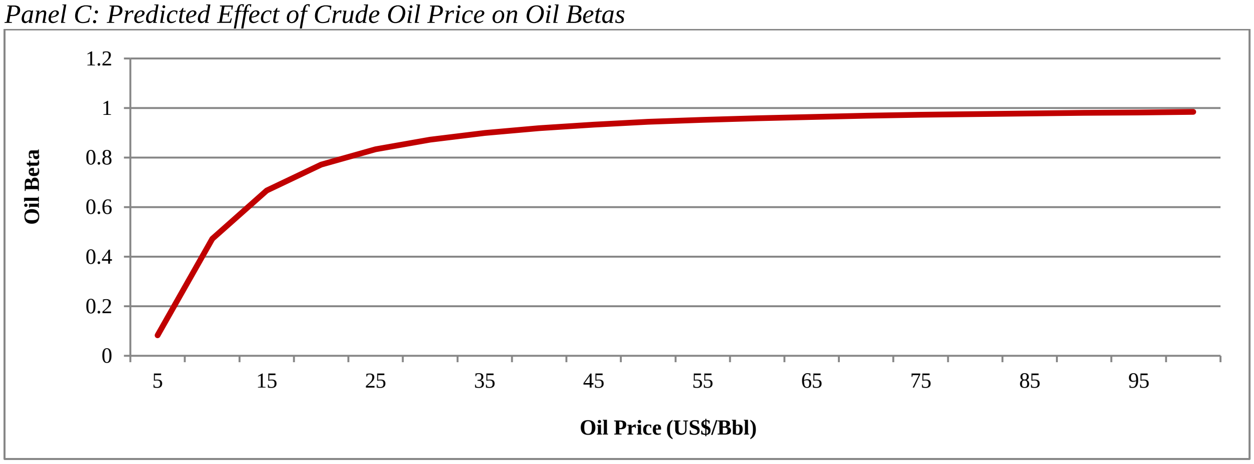
Panel A: Base Parameter Values for Valuation Models

Variable		Gold	Oil
Interest Rate	r	10.00%	4.50%
Gold Lease Rate/ Oil Cost of Carry	k	2.00%	1.00%
Volatility	δ	10.00%	37.80%
Production Quantity	Q	100,000.00	287,679.00
Yearly Cash Costs	C	250.00	10.00
Fixed Costs	F	200,000.00	180,000.00
Fraction Hedged	α	0.27	0.25
Forward Price	W	400	80
Opening Costs	K_1	200,000.00	1,000,000.00
Closing Costs	K_2	200,000.00	1,000,000.00
Price Mine/Oil Field Would Open	P_1	100.00	4.00
Price Mine/Oil Field Would Close	P_2	250.00	10.00

Panel B: Predicted Effect of Gold Bullion Price on Gold Betas



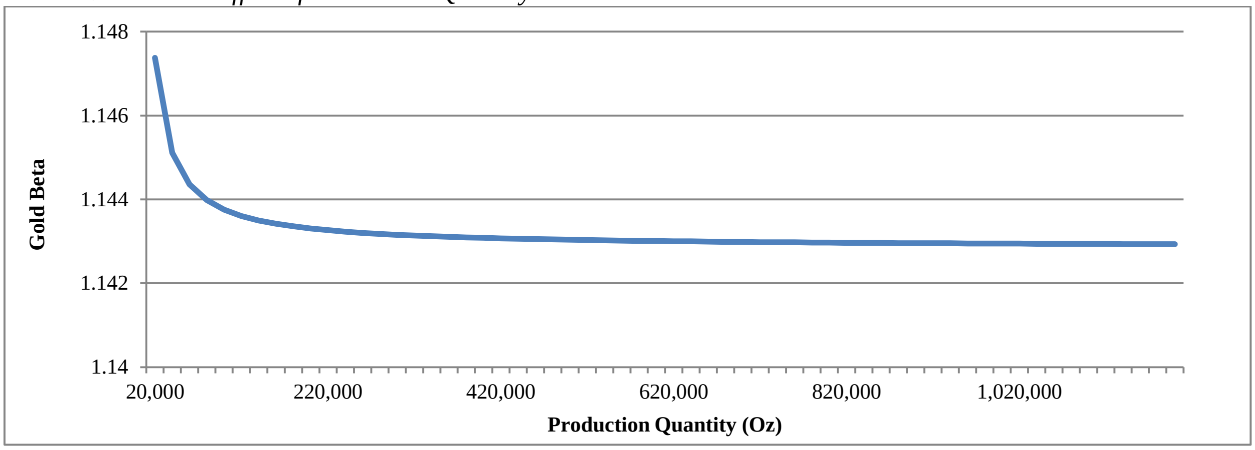
Panel C: Predicted Effect of Crude Oil Price on Oil Betas



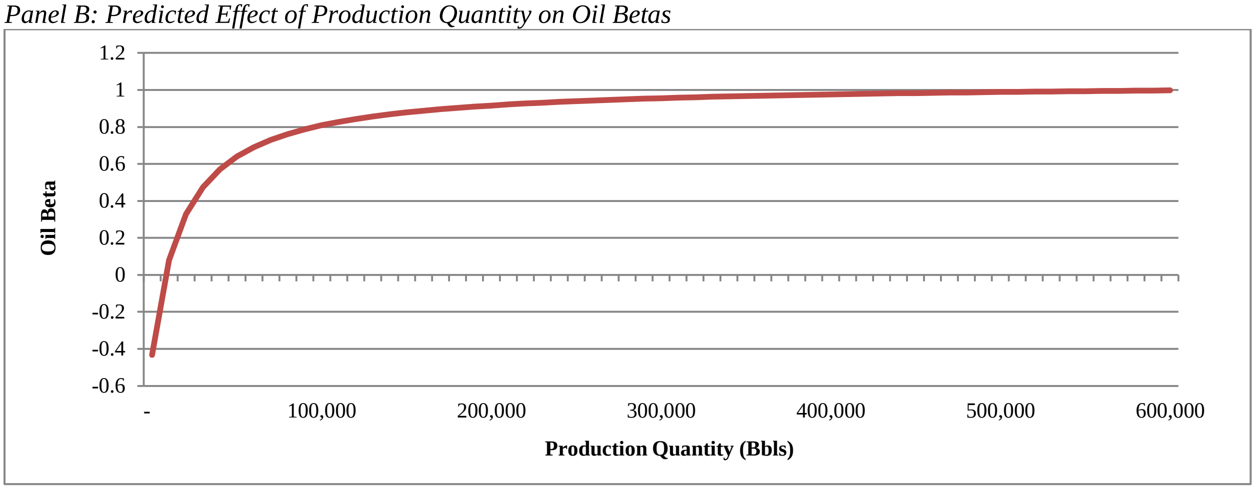
This figure shows the predicted effect of changes in the underlying commodity prices have on the commodity betas within the gold and oil industry under the assumptions of the flexible-production model. Panel A provides the base parameter values relied upon to predict the impacts the theoretical determinants of commodity price exposure have on the observed exposures of North American oil and gold stocks. The base parameter values are set at representative levels and consistent with Brennan and Schwartz (1985), Tufano (1998) and the parameter values for the North American oil industry as estimated within this study. Panel B shows the predicted effect of fluctuations in the gold bullion price on the gold betas of North American gold stocks. Panel C shows the predicted effect of fluctuations in the crude oil price on the oil betas of North American oil stocks.

Figure 2: Impact of Production Quantity on Commodity Betas

Panel A: Predicted Effect of Production Quantity on Gold Betas



Panel B: Predicted Effect of Production Quantity on Oil Betas



This figure shows the predicted effect of changes in annual production have on the commodity betas within the North American gold and oil industry under the assumptions of the flexible-production model. Panel A shows the predicted effect of changes in the quantity of gold production on the gold betas of North American gold stocks. Panel B shows the predicted effect of changes in the quantity of oil production on the oil betas of North American oil stocks. Refer to Panel A of Figure 1 for parameter values relied upon to determine these figures. The base parameter values are set at representative levels and consistent with Brennan and Schwartz (1985), Tufano (1998) and the parameter values for the North American oil industry as estimated within this study.

Table 1: Summary of Variables, Definitions and Data Sources

Factor	Notation	Observed Variable	Definition	Data Source
Panel A: Market Conditions				
Crude Oil Price	PRICE	Average crude oil price over quarter	Average of daily NYMEX WTI spot closing prices, measured in US$ per barrel	Thomson Datastream
Volatility	VOL	90-day annualized oil return volatility	90-day annualized volatility of oil returns	n.a.
Interest Rates	COC	Cost of carry	Quarterly average of the difference between the daily 6 month NYMEX WTI futures price and the daily NYMEX WTI spot closing price, divided by the daily NYMEX WTI spot closing price	Thomson Datastream
	BOND	10-year Treasury bond rate	Quarterly average of daily 10-year Treasury bond rates	Thomson Datastream
Panel B: Exogenous Firm Characteristics				
Size-Related Factors	PROD	Production in Mbls	Annual production in Mbls	Research Insight
	MV	Firm market value	Quarter-end market value of firm in US$millions	Research Insight
	COST	Yearly cash costs	Yearly cash costs in $US/BOE	Annual Report
	RES	Proven oil reserves	Year-end proven reserves in Mbls	Research Insight
Percent in Production	%P	Percent of firm's assets allocated to oil production	Quarterly Net Property, Plant and Equipment/ Quarterly Total Assets	Research Insight
Panel C: Corporate Financial Policy				
Financial Leverage	LEV	Debt-to-equity ratio	(Quarterly long-term debt + quarterly current portion) / Quarter-end market value of firm in US$millions	Research Insight
Panel D: Corporate Risk Management Policy				
Percent Hedged	D%P	Delta-percentage of production	Delta of risk management portfolio/ Next-year production	Annual Report
	D%R	Delta-percentage of reserves	Delta of risk management portfolio/ year-end total reserves	Annual Report
Forward Prices	W1	Average-forward contract-price	(Sum of quarterly forward price x quarterly hedged amount) / Sum of hedged amount	Annual Report
	W2	Average-delta contract-price	Average contract price, measured by Mbls, where options included at delta-equivalent at spot	Annual Report

This table provides a summary of the factors included in Equation (3) to estimate the association between the theoretical drivers of the oil price exposure and the oil betas of North American oil firms across the period 1 January 1999 to 31 December 2008. The table includes an overview of the measurement of each of the theoretical determinants of oil price exposure as well as the data sources used. BOE refers to the barrel of oil equivalent, equating 1 barrel (Bbl) of crude oil to approximately 6000 cubic feet of natural gas. MBbl is the standard measurement of crude oil, measured as one million barrels of crude oil.

Table 2: Predicted Impact of Determinants of Oil Price Exposure

	Fixed-Production Model	Flexible-Production Model	Fixed-Production Model with Hedging	Tufano (1998) Findings for Gold Betas	Predicted Impact for Oil Betas
Panel A: Market Conditions					
PRICE	-	+	+	–	+
VOL	n.a.	–	n.a.	–	–
BOND	n.a.	–	n.a.	–	–
COC (CY)	n.a.	+	n.a.	–	+
Panel B: Exogenous Firm Characteristics					
PROD	-	+	–	n.a.	+
COST	+	+	+	n.a.	+
RES	n.a.	n.a.	n.a.	+	+ / –
MV	n.a.	n.a.	n.a.	–	+
%P	n.a.	n.a.	n.a.	+	+
Panel C: Corporate Financial Policy					
LEV	+	+	+	+	+
Panel D: Corporate Risk Management Policy					
D%P	n.a.	n.a.	–	–	–
D%R	n.a.	n.a.	–	n.a.	–
W_1	n.a.	n.a.	–	–	–
W_2	n.a.	n.a.	–	–	–

This table provides a summary of the predicted impact of the determinants of oil price exposure of oil firms for three alternative valuation models: '+' indicates a predicted positive sign and '–' indicates a predicted negative sign. The fixed-production model, flexible-production model and fixed-production model with hedging relate to the valuation models elucidated by Tufano (1998) to determine the relationship between the theoretical determinants of gold price exposure and gold betas of 48 North American gold stocks over the period 1990 to 1994. The fixed-production model is based on the assumption that firms cannot alter their production profiles and do not engage in risk management activities. The flexible-production model incorporates the real options available to firms through treating output prices as stochastic and taking explicit account of managerial control over the output rate. The fixed-production model with hedging is based on the premises of the fixed-production model but takes specific account of the risk management activities adopted by a firm. The column headed "Tufano Findings" summarizes the observed results of Tufano (1998) within the North American gold industry. The final column summarizes the predicted impact of each variable on oil price beta investigated in the current study. Variable definitions: PRICE is the relevant commodity price. VOL is the relevant commodity price return volatility. BOND is long-term Treasury Bond rate. COC (CY) is the cost of carry relating to crude oil (convenience yield relating to gold bullion). PROD is the annual production for each firm (oil or gold). COST is the annual cash costs of operating the mine/oil field. RES is the reserves for each firm. MV is the market value of the firm. %P is the % of assets allocated to mining/oil. LEV is the debt-equity ratio. D%P is the delta % of production. D%R is the delta % of proven reserves. W_1 is the average forward contract price. W_2 is the average delta contract price.

Table 3: Sample Filtering

Data/Variable(s) Collected	Source	Quarterly Observations	No. of Firms
PROD, RES, MV, %M, LEV	ResearchInsight	2,197	107
Data Filters (observations lost due to lack of valid data)			
COST	Annual Reports	(354)	(19)
W_1, W_2, D%R, D%P	Annual Reports	(435)	(17)
PRICE, VOL, BOND, COC	Thomson DataStream	-	-
Daily stock returns	CRSP	(372)	(12)
Extreme observations	na	(13)	-
		1,023	59

This table outlines the range of filters used to achieve our final sample of North American oil stocks. PRICE is equal to the quarterly average of daily NYMEX West Texas Intermediate closing prices, in US$/BBL. VOL is equal to the 90-day annualised oil price return volatility. COC is the quarterly average of the cost of carry of WTI crude oil, measured as the difference between the WTI NYMEX 6-month crude oil futures price and WTI NYMEX crude oil spot price. BOND is quarterly average of daily 10-year US Treasury Bond rates. PROD is equal to the annual production for each firm in MBbls. LEV is equal to debt-equity ratio, calculated by the sum of quarterly long-term and one-year debt divided by the quarterly market value of the firm. COST is equal to the yearly cash costs per BOE, where BOE refers to the barrel of oil equivalent, equating 1 barrel (Bbl) of crude oil to approximately 6000 cubic feet of natural gas. RES is equal to the annual reserves for each firm measured in MBbls. MV is the quarterly market value of the firm in US$million. D%P is equal to the delta of the risk management portfolio divided by one-year ahead production. D%R is equal to the delta of the risk management portfolio divided by annual proven reserves in MBbls. W_1 is equal to the sum of the quarterly forward price multiplied by the hedged amount, divided by the sum of the hedged amount. W_2 is equal to the average contract price, weighted by Bbls, where options are included at delta-equivalent at spot. %M is equal to the yearly percent of assets of mining, calculated by the proportion of Net Property, Plant and Equipment divided by Total Assets.

Table 4: General Descriptive Statistics

Panel A: Mean Characteristics of Final Sample versus Excluded Firms			
	Final Sample	Excluded Companies	Test of Mean Difference (t-stat)
MCap	$453.664m	$3,056.05m	–2.57**
B/M	1.330	1.238	0.18
Illiquidity	2.5%	7.0%	–1.62
Exploration Expense	$6.522m	$18.529m	–1.57
%Oil Production	34.1%	40.5%	–1.05
Panel B: Mean Characteristics of above Median versus Below Median %Oil Production			
	High Oil Producers (> Median %Oil Prod)	Low Oil Producers (< Median %Oil Prod)	Test of Mean Difference (t-stat)
MCap	$175.968m	$731.361m	–2.57**
B/M	0.9221	1.737	–0.99
Illiquidity	2.6%	2.3%	0.37
Exploration Expense	$4.977m	$8.067m	–0.58
%Oil Production	60.6%	7.7%	10.61***

This table reports two sets of descriptive statistics based at the end of the sample period (i.e. 2008). Panel A shows mean selected characteristics of the final sample (59 firms) compared to the excluded sample (48 firms), while Panel B shows mean selected characteristics of "high" oil producing companies compared to "low" oil producing companies in the final sample. High (low) oil producing companies are classified as those having a per cent of oil production above (below) the sample median, 23.4%. Each panel reports across five different dimensions for which we could obtain valid data: (a) market capitalization of equity measured in $million (MCap); (b) book to market (B/M); (c) percentage of daily sample observations for which zero returns are observed (illiquidity); (d) exploration expense measured in $million; and (e) percentage of oil production (%Oil Production). With regard to %Oil Production, a "conversion rate" is needed to allow comparisons of oil and gas production. We convert natural gas from cubic feet to barrels of oil equivalent as per the US Department of Energy, Energy Information Administration (2001) Unit Conversion Factors, accessed from the Society of Petroleum Engineers website: http://www.spe.org/industry/docs/UnitConversion.pdf.

Table 5: Descriptive Statistics for Key Test Variables

	Mean	Median	Min	Max	Std. Dev.	Skewness	Kurtosis
Panel A: Market Conditions							
PRICE	54.467	53.096	13.125	123.895	27.601	0.866	3.170
VOL	0.378	0.338	0.232	0.938	0.142	2.380	9.487
COC	-0.001	-0.006	-0.103	0.089	0.044	-0.097	2.505
BOND	0.045	0.046	0.032	0.065	0.007	0.594	3.604
Panel B: Exogenous Firm Characteristics							
PROD	287.679	179.365	0.000	943.005	268.624	0.909	2.599
COST	10.720	7.440	0.720	49.000	9.275	1.842	6.689
RES	2974.253	1638.000	0.000	15180.000	3550.094	1.753	5.486
MV	330.045	131.840	2.690	3142.680	540.078	3.146	14.023
%P	0.784	0.849	0.128	0.985	0.179	-1.620	5.222
Panel C: Corporate Financial Policy							
LEV	0.472	0.184	0.000	5.740	0.894	3.933	20.529
Panel D: Corporate Risk Management Policy							
D%P	0.170	0.000	0.000	15.656	1.010	14.205	216.649
D%R	0.023	0.000	0.000	1.907	0.122	14.306	219.553
W1	9.913	0.000	0.000	99.133	22.460	2.332	7.432
W2	11.552	0.000	0.000	142.067	25.708	2.517	9.169

This table provides the descriptive statistics for all variables hypothesised to affect the oil price exposure of our sample of 59 North American oil stocks over the sample period January 1999 to December 2008. PANEL A provides the descriptive statistics for the market condition variables. PRICE is equal to the quarterly average of daily NYMEX West Texas Intermediate closing prices, in US$/Bbl. VOL is equal to the 90-day annualised oil price return volatility. COC is the quarterly average of the cost of carry of WTI crude oil, measured as the difference between the WTI NYMEX 6-month crude oil futures price and WTI NYMEX crude oil spot price. BOND is the quarterly average of daily 10-year US Treasury Bond rates. PANEL B provides the descriptive statistics for the exogenous firm characteristics. PROD is equal to the annual production for each firm in MBbls. COST is equal to the yearly cash costs per BOE, where BOE refers to the barrel of oil equivalent, equating 1 barrel (Bbl) of crude oil to approximately 6000 cubic feet of natural gas. RES is equal to the reserves for each firm measured in MBbls (sampled annually). MV is the quarterly market value of the firm in US$millions. %P is equal to the yearly percent of assets of oil production, calculated by the proportion of Net Property, Plant and Equipment divided by Total Assets. PANEL C provides the descriptive statistics for variable relating to a firm's financial policy. LEV is equal to the debt-equity ratio, calculated by the sum of long-term and one-year debt divided by the market value of the firm. PANEL D provides the descriptive statistics for a firm's risk management policies. D%P is equal to the delta of the risk management portfolio divided by one-year ahead production. D%R is equal to the delta of the risk management portfolio divided by annual proven reserves in MBbls. W_1 is equal to the sum of the quarterly forward price multiplied by the hedged amount, divided by the sum of the hedged amount. W_2 is equal to the average contract price, weighted by Bbls, where options are included at delta-equivalent at spot.

Table 6: Estimating the Determinants of Conditional Oil Betas

	Pred Sign	(i)	(ii)	(iii)	(iv)
Intercept		-0.0406	-0.0794	-0.0421	-0.0807
		(0.03)	(0.05)	(0.03)	(0.05)
Panel A: Market Conditions					
PRICE	+	0.0046***	0.0046***	0.0046***	0.0046***
		(16.29)	(16.32)	(16.31)	(16.34)
VOLATILITY	–	-0.2369***	-0.2376***	-0.2369***	-0.2371***
		(6.13)	(6.14)	(6.13)	(6.13)
BOND	–	2.9314***	2.9299***	2.9232***	2.9203***
		(3.22)	(3.22)	(3.21)	(3.21)
COC	+	1.1226***	1.1214***	1.1237***	1.1226***
		(6.74)	(6.73)	(6.75)	(6.74)
Panel B: Exogenous Firm Characteristics					
PROD	+	0.0997***	0.0985***	0.0991***	0.0977***
		(3.10)	(3.07)	(3.07)	(3.04)
COST	+	0.0176	0.1207	0.0251	0.1292
		(0.02)	(0.14)	(0.03)	(0.15)
RES	+ / –	-0.0036	-0.0033	-0.0034	-0.0031
		(1.42)	(1.29)	(1.36)	(1.22)
MV	+	0.0454***	0.0455***	0.0451***	0.0452***
		(2.67)	(2.68)	(2.66)	(2.66)
%P	+	0.1095***	0.1099***	0.1101***	0.1106***
		(2.70)	(2.71)	(2.71)	(2.72)
Panel C: Corporate Financial Policy					
LEV	+	0.0194***	0.0191***	0.0195***	0.0192***
		(2.70)	(2.66)	(2.71)	(2.68)
Panel D: Corporate Risk Management Policy					
D%P	–	0.0112	0.0136		
		(1.17)	(1.37)		
D%R	–			0.0883	0.1063
				(1.12)	(1.31)
W_1	–	-0.4992		-0.5049	
		(1.55)		(1.56)	
W_2	–		-0.4928		-0.4974
			(1.60)		(1.61)

This table report the estimation of Equation (3) when controlling for firm fixed-effects: $R_{i,t} = \alpha_0 + \sum_{k=-1}^{k=1}(\alpha_o + \sum_j \varphi_{o,j} F_{j,i,t})\, R_{o,t+k} + \sum_{k=-1}^{k=1}(\alpha_m + \sum_j \varphi_{m,j} F_{j,i,t})\, R_{m,t+k} + \epsilon_{i,t}$ where $R_{i,t}$ is the daily stock return of firm *i*, $F_{j,i,t}$ are the factors predicted to affect oil price exposure of North American oil firms, $R_{o,t+k}$ is the daily return of the WTI crude oil price and $R_{m,t+k}$ is the daily return on the CRSP NYSE/ AMEX/ Nasdaq value-weighted index. Broadly, the factors relate to: market conditions; exogenous firm characteristics; a firm's financial policy; and a firm's risk management policy. PRICE is equal to the quarterly average of daily NYMEX West Texas Intermediate closing prices, in US$/Bbl. VOL is equal to the 90-day annualised oil price return volatility. BOND is quarterly average of daily 10-year US Treasury Bond rates. COC is the quarterly average of the cost of carry of WTI crude oil, measured as the difference between the WTI NYMEX 6-month crude oil futures price and WTI NYMEX crude oil spot price. PROD is equal to the annual production for each firm in MBbls. LEV is equal to the debt-equity ratio, calculated by the sum of long-term and one-year debt divided by the market value of the firm. COST is equal to the yearly cash costs per BOE, where BOE refers to the barrel of oil equivalent, equating 1 barrel (Bbl) of crude oil to approximately 6000 cubic feet of natural gas. RES is equal to the reserves for each firm measured in MBbls (sampled annually). MV is the market value of the firm in US$millions. D%P is equal to the delta of the risk management portfolio divided by one-year ahead production. D%R is equal to the delta of the risk management portfolio divided by proven reserves in MBbls. W_1 is equal to the sum of the forward price multiplied by the hedged amount, divided by the sum of the hedged amount. W_2 is equal to the average contract price, weighted by Bbls, where options are included at delta-equivalent at spot. %P is equal to the yearly percent of assets of oil production, calculated by the proportion of Net Property, Plant and Equipment divided by Total Assets. To address the potential for multicollinearity between factors, models (i) to (iv) incorporate the risk management variables (D%P, D%R, W_1 and W_2) individually. Coefficient estimates on the Intercept, PROD, COSTS, RES, MV, W_1 and W_2 are scaled by 1000. In parentheses below each coefficient is the associated *t*-statistic. The sample comprises 64,234 observations. ***, ** and * denotes significance levels at 1%, 5% and 10% respectively.

Table 7: Indicative Economic Impact of the Determinants of Conditional Oil Betas

	Predicted Impact	Observed Impact	Δ Oil Beta for 1 St. Dev Δ in Variable	% Δ in Oil Beta	% Δ in Gold Beta	Economically Significant?
Panel A: Market Conditions						
PRICE	+	+	0.127	38.47%	-6.52%	Yes
VOL	–	–	-0.034	-10.19%	-14.70%	Yes
BOND	–	+	0.054	16.35%	-0.65%	Yes
COC	+	+	0.021	6.22%	-0.07%	No
Panel B: Exogenous Firm Characteristics						
PROD	+	+	0.026	7.95%	n.a.	No
COST	+	–	-0.032	-9.84%	n.a.	No
RES	+ / –	n.a.	n.a	n.a	10.22%	No
MV	+	+	0.025	7.43%	-4.41%	No
%P	+	+	0.020	5.93%	19.91%	No
Panel C: Corporate Financial Policy						
LEV	+	+	0.017	5.26%	6.51%	No
Panel D: Corporate Risk Management Policy						
D%P	–	+	0.033	9.98%	-9.65%	No
D%R	–	+	0.031	9.35%	n.a.	No
W_1	–	–	-0.056	-17.02%	-1.33%	Yes
W_2	–	–	-0.080	-24.15%	-0.00%	Yes

This table provides a comparison of the impact that determinants of conditional oil betas have on the oil price exposures of our sample of North American oil firms over the period 1 January 1999 to 31 December 2008. Given the econometric efficiency of the joint estimation model, the observed impact reflects the direction of the statistically significant cases. In cases where the joint estimation model does not produce a statistically significant relationship, the observed impact reflects the relationship estimated by the (unreported) separate estimation model (if significant). 'Δ Oil Beta for 1 St. Dev Δ in Variable' refers to the estimated change in the oil beta based on the estimates of the separate and joint estimation models. '% Δ in Oil Beta' refers to the percentage change in the oil beta based on parameter values in our study. '% Δ in Gold Beta' refers to the percentage change in the gold beta based on parameter values estimated by Tufano (1998) – provided for comparative purposes. 'Economically Significant?' classifies as economically significant ('Yes') those cases in which the observed change in the oil beta exceeds 10% (otherwise: 'No'). Variable definitions: PRICE is the crude oil price. VOL is volatility of crude oil price return. BOND is long-term Treasury Bond rate. COC is the cost of carry relating to crude oil. PROD is the annual oil production for each firm. COST is equal to the yearly cash costs per BOE, where BOE refers to the barrel of oil equivalent, equating 1 barrel (Bbl) of crude oil to approximately 6000 cubic feet of natural gas. RES is the oil reserves for each firm. MV is the market value of the firm. %P is the % of assets allocated to oil. LEV is the debt-equity ratio. D%P is the delta % of production. D%R is the delta % of proven oil reserves. W_1 is the average forward contract price. W_2 is the average delta contract price.

Table 8: Estimating the Determinants of Conditional Oil Betas with Mean Reverting Output Prices

	Pred Sign	(i)	(ii)	(iii)	(iv)
Intercept		0.0006***	0.0006***	0.0006***	0.0006***
		(3.18)	(3.18)	(3.18)	(3.18)
Panel A: Market Conditions					
PRICE	+	0.0063***	0.0063***	0.0063***	0.0063***
		(9.80)	(9.80)	(9.83)	(9.84)
VOL	–	-0.2058***	-0.2053***	-0.2057***	-0.2063***
		(-4.59)	(-4.58)	(-4.59)	(-4.61)
BOND	–	1.3450	1.3513	1.3408	1.3327
		(1.48)	(1.49)	(1.48)	(1.47)
Panel B: Exogenous Firm Characteristics					
PROD	+	0.0007	0.0006	0.0006	0.0007
		(0.80)	(0.70)	(0.71)	(0.81)
COST	+	0.0208***	0.0210***	0.0211***	0.0209***
		(2.89)	(2.91)	(2.93)	(2.91)
RES	+ / –	-0.0039	-0.0042*	-0.0040	-0.0037
		(-1.54)	(-1.66)	(-1.60)	(-1.46)
MV	+	0.0001***	0.0001***	0.0001***	0.0001***
		(3.55)	(3.55)	(3.53)	(3.54)
%P	+	0.0983**	0.0979**	0.0986**	0.0991**
		(2.42)	(2.41)	(2.42)	(2.43)
Panel C: Corporate Financial Policy					
LEV	+	0.0001***	0.0001***	0.0001***	0.0001***
		(0.00)	(0.00)	(0.00)	(0.00)
Panel D: Corporate Risk Management Policy					
D%P	–	0.0145	0.0124		
		(1.46)	(1.29)		
D%R	–			0.0994	0.1158
				(1.26)	(1.42)
W_1	–		-0.0004	-0.0004	
			(-1.34)	(-1.36)	
W_2	–	-0.0004			-0.0004
		(-1.42)			(-1.44)
Panel E: Oil Price Mean Reversion					
KAPPA	–	-0.0018***	-0.0018***	-0.0018***	-0.0018***
		(-3.18)	(-3.18)	(-3.20)	(-3.21)
THETA	+	0.4090***	0.4096***	0.4104***	0.4099***
		(2.69)	(2.69)	(2.70)	(2.70)
Adj. R^2		0.1222	0.1223	0.1222	0.1223

This table reports the joint estimation of conditional oil betas with mean reverting output prices estimated using Equation (3): $R_{i,t} = \alpha_0 + \sum_{k=-1}^{k=1}(\alpha_o + \sum_j \varphi_{o,j} F_{j,i,t})\, R_{o,t+k} + \sum_{k=-1}^{k=1}(\alpha_m + \sum_j \varphi_{m,j} F_{j,i,t})\, R_{m,t+k} + \epsilon_{i,t}$; where $R_{i,t}$ is the daily stock return of firm i, $F_{j,i,t}$ are the factors predicted to affect oil price exposure of North American oil firms, $R_{o,t+k}$ is the daily return of the WTI crude oil price and $R_{m,t+k}$ is the daily return on the CRSP NYSE/AMEX/Nasdaq value-weighted index. The factors determined to affect the oil price exposure of North American oil firms relate to: market conditions; exogenous firm factors; a firm's financial policy; and a firm's risk management policy. Refer to Table 7 for definitions of all theoretical determinants of oil price exposure (except KAPPA and THETA). KAPPA refers to the speed of reversion of the crude oil price derived from estimating Equation (2): $\frac{P_{t+1}-P_t}{P_t} = \beta_0 + \beta_1 \frac{1}{P_t} + \varepsilon$: where P_t is equal to the daily closing WTI crude oil price over the period 1 January 1999 to 31 December 2008. The variable KAPPA is given by the negative of the intercept in this regression ($-\beta_0$). THETA refers to the long-term mean level of the oil price process, also derived from estimating Equation (2), equal to $-(\beta_1/\beta_0)$. To address the potential for multicollinearity between factors, models (i) to (iv) incorporate the risk management variables (D%P, D%R, W_1 and W_2) individually. In parentheses below each coefficient is the associated t-statistic. The sample comprises 64,234 observations. ***, ** and * denotes significance levels at 1%, 5% and 10% respectively.

Appendix A: Discussion of the Role of the Potential Determinants of Conditional Oil Beta

A.1 Volatility (VOL)

At the firm level, the volatility of crude oil prices is an important common risk factor for all North American oil firms, with fluctuations in the price of crude oil directly affecting investment decisions and cash flows (Boyer and Filion, 2007, p. 433). While the fixed-production and fixed-production with hedging models do not provide any sign prediction for volatility, the flexible-production model estimates that the commodity beta is a decreasing function of the volatility of commodity prices.[32] The intuition underpinning this observation is explained by basic option theory which suggests that a higher level of volatility will move the default boundary further which subsequently reduces equity sensitivity as represented by a decreased commodity beta (Hong and Sarkar, 2008, p. 1290).[33] The volatility of the returns of crude oil prices is therefore predicted to be inversely related to the exposure of North American oil stocks to fluctuations in the crude oil price.

A.2 10-Year Treasury Bond Rate (BOND)

Interest rate variations are a significant common risk factor among North American oil firms. The scale of investment required in the extraction of oil means significant capital outlay is necessary to purchase, develop and operate both onshore and offshore oil wells. This investment coupled with the significant expenditure required to renew and locate additional reserves means a high degree of financial leverage is necessary within the industry to meet both ongoing growth and cash flow objectives. Within the Canadian oil industry, Sadorsky (2001) observes that interest rates have a large and statistically significant negative effect upon the returns of

[32] The fixed-production and fixed-production with hedging models do not provide a prediction for volatility as they do not rely on the assumption of stochastic output prices as seen in the flexible-production model.

[33] Hong and Sarkar (2008) note that since the payoff to equity holders is zero at default, the sensitivity of equity value is higher when the default trigger is closer (i.e. default risk is higher). Accordingly, anything that increases (decreases) default risk or moves the default trigger closer (further) will result in a higher (lower) sensitivity of equity prices.

Canadian oil firms. The author explains that movements in interest rates alter the relationship between competing financial assets as well as affect the price investors are willing to pay for equities through influencing the level of corporate profits.

The flexible-production model uses the standard corporate risk-free rate to discount the expenses of firms within the natural resources industry. Under these specifications, an increase in the interest rate results in an associated increase in the discount rate, which subsequently decreases firm expenses and increases asset values. The increase in the value of a firm's asset base moves the default trigger further, thus reducing the sensitivity of equity values, as measured by the commodity beta. Accordingly, we predict that the 10-year Treasury bond rate has an inverse relationship with the commodity beta of oil stocks.

A.3 Cost of Carry (COC)

In developing the real options valuation model, Brennan and Schwartz (1985) include the convenience yield on a commodity as a proxy for the value derived from firms being able to profit from temporary local shortages of commodities through ownership of a physical commodity. As the convenience yield is not readily observed within the gold industry, Tufano (1998) adopts the gold lease rate as an alternate proxy. Based on the predictions of the flexible-production model, Tufano (1998) predicts that the gold lease rate has a positive relationship with the gold beta of gold producers. The reasoning underpinning this prediction is that an increase in the gold lease rate increases the rate of interest paid on both gold loans, as well as transactions in financial derivatives or margin payments on forward contracts by gold investors within the market. This subsequently reduces demand for gold bullion in the market, which increases the commodity sales risk faced by gold producers. Within other commodity-based industries, the cost of carry provides the counterpart concept, referring to the no arbitrage carrying costs of holding an underlying asset until maturity, including incidental expenses and financial costs.

Based on the assumptions of the flexible-production model and empirical findings of Tufano (1998), the cost of carry is predicted to be positively related to the estimated oil betas of North American oil stocks.

A.4 Yearly Cash Costs (COST)

Firms with higher per-unit production costs face a higher probability of financial distress and are subsequently more susceptible to commodity price fluctuations (Tufano, 1996; Haushalter, 2000). Following the theory underpinning the predicted association between financial leverage and oil price risk, as well as the assumptions of the three valuation models, the yearly cash costs of a firm are predicted to be positively associated with commodity betas.

A.5 Reserves (RES)

From an economic perspective, increases in oil reserves are expected to increase the oil supply available within the market which subsequently lowers oil price risk. This is supported by Sadorsky (2008) who documents a statistically significant negative relationship between these factors. From a valuation perspective however, the reserves of a firm are predicted to be inversely related to oil price exposure with the returns of oil stocks increasing when the marked-to-market value of oil reserves increases. Rajgopal (1999) supports this theory, determining that oil reserves have a positive impact on the relationship between stock returns and crude oil prices. The three valuation models are unable to provide further insight into the predicted impact of reserves on oil betas.

A.6 Market Value (MV)

There is potential noise in the measurement of yearly cash costs, production quantities and reserves, bringing the potential disadvantage of biased regression estimators. The market value of a firm provides an indirect proxy of the size-related factors (production, reserves and yearly cash costs). When assessing the size-related factors it is predicted that larger firms have higher levels of yearly cash costs, production and leverage, with the market value of firm therefore predicted to have a positive effect on the oil price exposure of North American oil firms.

A.7 Percent in Production (%P)

The three valuation models assume that a firms' assets are allocated only to the production of crude oil, however, theory would suggest that the stock price of an oil firm with operations outside the oil sector should be less closely associated with fluctuations in the underlying spot price of crude oil. This diversification is evident within the North American oil industry where a number of firms are observed to also produce natural gas in addition to their production of crude oil. In accordance with the predictions provided by Tufano (1998), a lower the level of diversification of a firm's operations (i.e. higher *%P*) is expected to have positive effect on the oil price exposure of oil stocks.

A.8 Financial Leverage (LEV)

Firms within the natural resources sector expend significant capital outlays to purchase, develop and operate resource rich land holdings which, coupled with normal business and equipment maintenance costs, makes external financing essential. While the use of debt as a source of financing is therefore pervasive, the degree of financial leverage often varies between industries within the sector. Prior literature notes that the North American oil and gold industries are among the most highly levered industries within the natural resources sector, such that a significant fixed cost is borne by these firms in the form of a fixed financial charge imposed by borrowing (Tufano, 1998; Boyer and Filion, 2007; Hong and Sarkar, 2008).

The three valuation models predict that the commodity beta is directly related to the fixed costs of a firm. These predictions are explained by the option theory underpinning the flexible-production model, with Hong and Sarkar (2008) noting that a higher leverage ratio increases the default risk of a firm through bringing the default trigger closer. The positive association between the leverage ratio and the commodity beta indicates that firms are able to reduce their stock price exposure by using less debt thus allowing leverage policy to be adopted as a substitute for hedging (Peterson and Thiagarajan, 1996; Hong and Sarkar, 2008). Based on the predictions of all three valuation models, the oil beta of oil stocks is predicted to be positively related to financial leverage.

A.9 Delta-Percentage of Production (D%P)

Energy companies are among the most active and sophisticated users of derivatives, adopting both linear and non-linear contracts as a means of reducing exposures to market risk (Hull, 2009, p. 583). The fixed-production model with hedging indicates that by selling forward its entire production profile, a firm is able to effectively eliminate their exposure to fluctuations in the underlying commodity price and drive their commodity beta towards zero. The delta-percentage of production (D%P) provides a summary measurement of the portfolio of risk management activities scaled against its natural exposure (i.e. production) in order to understand its economic impact. Based on the assumptions of the fixed-production model with hedging, the D%P is predicted to be inversely related to the oil beta of oil stocks.

A.10 Delta-Percentage of Reserves (D%R)

The percentage of a firms' total production profile or its reserves are an alternative measure of the extent to which an entity has moderated its output price exposure from the perspective of an investor. Following the empirical prediction of D%P, the delta-percentage of reserves (D%R) is also predicted to be inversely related to the oil price exposure of oil stocks.

A.11 Average-forward-contract-price (W_1)

Where firms use forward contracts to hedge, Tufano (1998) develops a measure of the average forward sale price (W_1) given by the average forward price at which a firm sold gold. Consistent with prior research, the measure predicts that a firm which has sold their oil production forward will reduce their exposure to fluctuations in the crude oil price (Tufano, 1998; Haushalter, 2000; Jin and Jorion, 2006). Accordingly, W_1 is predicted to be inversely related to the oil price exposure of North American oil stocks.

A.12 Average-delta-contract-price (W_2)

The W_1 measure ignores the effect of non-linear option contracts employed by firms. Haushalter (2000) shows that in 1994 approximately 10.5% of the sample North American oil and gas firms use option contracts as means of hedging. Thus, given the relative importance of option contracts as a risk management strategy, it is important to explicitly account for options through the use of an alternative measure of hedging contract prices. Consistent with prior literature and the empirical predictions of this study, the average-delta-contract-price is predicted to be inversely related to the commodity beta with firms who have adopted appropriate risk management strategies effectively able to reduce their exposure to fluctuations in commodity prices (Tufano, 1998; Haushalter, 2000; Jin and Jorion, 2006).