HEC MONTRÉAL

Determinants of joint price hedging and impact on firm value in the oil and gas industry

by

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Master of Science
(Finance)

A thesis submitted for the degree of Master of Science
(M. Sc.)

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January 2021

Résumé

Ce mémoire étudie la propension de 150 entreprises productrices de pétrole et de gaz de faire usage de couverture pour leurs productions. Cet échantillon se focalise sur la période qui s'étale de 1998 à 2010. L'étude vise à comprendre la logique et les déterminants de cette propension, ainsi que son impact sur la valeur de l'entreprise. La théorie suggère qu'en présence d'imperfections et de frictions dans les marchés, utiliser de la couverture devrait avoir un impact positif sur la valeur. Nous vérifions cette théorie de manière innovante en testant son effet sur l'industrie pétrolière et gazière, de façon indépendante dans un premier lieu, et ensuite de façon simultanée. Nous explorons également les déterminants de la couverture pour mieux comprendre ce qui motive les gestionnaires à opter pour un certain niveau de couverture. Conformément à la littérature, l'étude fournit des éléments s'alignant avec la théorie que les entreprises ayant une forte propension à couvrir leur production ont des valeurs de marché plus élevées que celles qui choisissent de moins se couvrir. Nous identifions également plusieurs déterminants de couverture pour les entreprises dans notre échantillon qui sont cohérents avec ceux identifiés dans la littérature.

Mots clés : couverture, gestion de risques, pétrole, gaz, probit, propension de couverture, biprobit

Abstract

This master thesis studies the hedging propensity of 150 oil and gas producing firms from 1998 to 2010. The study aims to understand the rationale and determinants of hedging, as well as their impact on firm value. Theory suggests that, in the presence of imperfections and market frictions, hedging should have a positive impact on the value of a firm. We verify this theory in an innovative way by testing the effects of hedging oil and gas production, both independently and simultaneously. We also explore the determinants of hedging to gain a better understanding of the motivations behind the strategies employed by managers. Consistent with the literature, the study yields evidence of higher market values for firms in the oil and gas industry with a high propensity to cover their production. We also identify several determinants of hedging for the firms in the sample, which are consistent with the literature, thus giving us insight into the economical and managerial motivations behind hedging.

Keywords: hedging, risk management, oil, gas, probit regression, hedging propensity, biprobit regression

Acknowledgements

Completing this thesis would not have been possible without the help of the following people:

I would first like to thank Pr. Georges Dionne for his immense support and guidance in supervising this thesis and providing me with all the help, expertise and time necessary for me to conduct this project. Thank you for always providing me with great insight in a timely manner. You have helped me tremendously to reach this achievement.

I would also like to thank Pr. Mohamed Mnasri for his precious help in writing this thesis. Thank you for sharing your valuable experience and expertise in this topic, and being very supportive throughout this entire process.

Last but not least, I would also like to thank my family for always providing me with a supportive and caring environment, and for encouraging me throughout the writing process. I would not be where I am today without you.

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Introduction

In a perfect, frictionless world, corporate risk management is irrelevant as it does not maximize shareholder wealth (Modigliani and Miller, 1958). This is due to the fact that investors can essentially unwind any hedging measure undertaken by the firm, or create their preferred risk exposure at no cost. However, in the presence of friction in the real world, the theory suggests that hedging may have a positive, value-maximizing impact on companies by reducing cash flow and earnings volatility. Indeed, corporate managers often opt to hedge the risk against different market-specific and industry-specific factors in the hope to limit them, and hopefully enjoy higher valuations. One of the most ubiquitous ways for corporations to hedge is through derivatives, which gained popularity after the financial innovations of the 1970s that yielded an option-pricing model proposed by Black and Scholes (1973).

Evidence in the corporate risk management world suggests that the marginal benefits of hedging the firms' exposures exceeds the marginal costs associated with it. Indeed, a study led by Bartram et al. (2009) spanning 48 countries and over 7000 non-financial firms demonstrated that 54.3% of companies hedge against risks ranging from foreign currency exposure to interest rate uncertainty through the use of derivatives (Bartram et al., 2009). These findings suggest that managers do indeed see value in hedging.

Oil and natural gas producing firms are inherent hedgers because they are subject to the risk of energy commodity prices, which can experience large drawdowns. Oil and natural gas prices fluctuate significantly in response to factors such as geopolitical instability and supply and demand, and sometimes, the most profitable outcome for a firm is to halt production. This has real economic costs as oil and gas producing firms often exercise the option to leave the oil or natural gas in the ground when market conditions are unfavorable. To protect their profitability, many firms opt to hedge their production in the face of future price uncertainty. Hedging, however, comes at a cost, and thus, corporate risk management has the onus of balancing the risks and rewards to achieve the greatest firm value, all things considered.

As such, we observe that producers choose different levels of hedging based on discretionary factors such as risk appetite, economic outlook, forecasted future production and geographical location. The discrepancy in hedging levels raises some important questions: how do hedging decisions affect firm value? Do the benefits of hedging outweigh the costs, empirically? Which of natural gas or oil necessitates the highest level of hedging to maximize firm value? Should producers hedge the value of both commodities at the same time? Shall the company hedge in the short or the long run? Which hedging instruments are the most appropriate?

We explore some of these questions by analyzing the hedging characteristics of 150 firms in the oil and gas industry, with quarterly data spanning from 1998 to 2010. We gauge the hedging decisions of these firms based on their impact on firm profitability, enterprise value, as well as other oil and gas price and demand metrics. This helps us determine if the decision to hedge commodity prices has any real impact on producers. Throughout this body of work, we will contribute to the literature on corporate hedging decisions significantly. Indeed, we are among the first to consider enterprise risk management by analyzing the hedging of two risks simultaneously.

We take a multi-dimensional approach by looking at the hedging question from different angles. We devise an experiment to isolate the decision-making process to hedge either the oil or natural gas production, independently. This is done through univariate probit regressions that help us evaluate the determinants of hedging both commodities, and the differences that exist between the two. Then, we expand this analysis by looking at the joint decision to hedge both the oil and natural gas productions, simultaneously, using a bi-variate probit panel regression. Thus, we can compare and contrast the independent and joint decisions to hedge the oil and gas production.

Finally, we make another contribution to the literature by analyzing the value enhancing property of hedging in an innovative way: we run multivariate regressions against value and profitability metrics for the firms in our sample, and we again look at the problem from a different lens. By categorizing firms based on their hedging strategy for oil and gas, we gain valuable insight into the value enhancing effects of hedging.

Chapter 1
Literature review

1.1 Evidence of enhanced value through hedging

The literature on the topic of corporate hedging reconciles corporate decisions to protect against risks with firm characteristics and other attributes. We first explore the value enhancing features of hedging by looking at different industries and the risks associated with them. We then turn to the theories that explain the rationale for corporate hedging.

1.1.1 Oil Industry

Mackay and Moeller (2006) contributed to the literature by deriving a model to estimate how valuable corporate risk management is for firms that choose to hedge. As such, they took a keen interest in the oil industry by assembling a sample of 34 oil refiners and regressing firm revenues and costs with input and output prices (Mackay & Moeller, 2006). The motivation behind this method was to demonstrate that hedging in the presence of nonlinear revenues and costs relative to prices can create value for the firm. By accepting the tradeoff of incurring convex costs to hedge concave revenues for oil and gas firms (larger ones, specifically), Mackay and Moeller estimate that firms enjoy an increase in firm value of 4%, which the authors demonstrate by regressing hedging levels of the Tobin's Q. The Tobin's Q is the ratio of the market value of a company to the cost of replacing its assets, and it is widely accepted in the literature as a proxy for firm value (Kaldor, 1966).

Dionne and Mnasri (2018), in their paper "Real implications of corporate risk management: Review of main results and new evidence from a different methodology" innovated on the topic of hedging by revisiting the question of whether hedging has a positive effect on firm value. The authors also look at other profitability, risk, and accounting metrics. Using a recent sample of US firms in the oil and gas industry, and a robust econometric methodology, the researchers find evidence of a hedging premium for firms with a higher hedging propensity score. Dionne and Mnasri (2018) also find evidence for a higher marginal risk reduction and higher marginal accounting metrics.

In contrast, some studies offer an opposing view of the value enhancing properties of hedging in the oil and gas industry. For instance, Jin and Jorion attempt to shed light on the question by looking at 119 oil and gas producing firms in the US in a 3 year span (1998-2001) to find support (or lack thereof) of a hedging *premium* in the oil and gas industry. The first step in their analysis consists of testing the stock price sensitivity and commodity prices based on hedging propensity. Their results show a negative relationship between a firm's hedging extent and its beta. Then, using the Tobin's Q, the authors analyze a potential relationship between hedging and market value. They, however, did not find evidence of any value effect of hedging in the oil and gas industry (Jin & Jorion, 2006).

Other studies also corroborate the weak link between hedging and value maximization of a firm: Hentschel and Khothari (2001), with a large sample of 425 US firms, conclude that companies using derivatives as a means to hedge (and even those with large derivatives positions) experience little economically significant value-enhancing effects in the form of reduced stock volatility compared to non-users, thus incurring hedging costs for no discernible benefits.

1.1.2 Hedging foreign currency risk

Allayanis and Weston (2001) analyzed the effect of foreign currency hedging on firm value. Using a sample 720 non-financial firms from 1990 to 1995, the researchers find that using fully convertible debentures (FCDs) to hedge currency risks has a statistically and economically significant positive impact on firm value (proxied using the Tobin's Q). Indeed, the hedging premium equates to 4.87% of market value ($150 million) for the firms sampled. They find that this result stands to scrutiny after controlling for fixed effects and mitigating unquantifiable factors such as managerial skill, while comparing pure play Tobin's Q with raw Tobin's Q. They also determine that the upside of hedging is greater than the downside because the protection received in a period of dollar appreciation strongly and significantly outweighs the windfall received by unhedged firms in favorable conditions (Allayanis & Weston, 2001).

In addition, Allayanis and Weston (2001) address an alternative explanation for the higher Tobin's Q being associated with hedging firms: firms that already have a large Tobin's Q may be more inclined to hedge because they inherently invest in higher growth, more risky investment ventures. By controlling this effect, they reject this alternative explanation through a time-series analysis of changing hedging policy, and thus conclude that higher Q firms do not *choose* to hedge more than lower Q firms. In a study analyzing Swedish companies, Prambourg (2004) arrives at a similar conclusion of adding value when hedging currency risk associated with foreign transactions, while currency translation risk hedging showed no effect.

1.1.3 Hedging fuel costs in the airline industry

A hedging *premium* has also been detected in other industries. Carter, Rogers and Simkins (2003), in their study focused on the airline industry, corroborate Allayanis and Weston's findings that hedging has a significantly positive impact on firm value. In their paper "Does Fuel Hedging Make Economic Sense? The Case of the US Airline Industry," sampling 27 firms, Rogers, Carter and Simkins find that airline companies, with a hedgeable commodity (jet fuel), experience a 12 to 16% premium in firm value, with most of the upside coming from positive market perception of reduction in underinvestment costs. The oil and gas industry shares very similar characteristics with the airline industry in that, in both industries, investment levels, cash flows and costs are correlated with energy prices (Carter et al., 2003).

1.2 Rationales for hedging

1.2.1 Underinvestment and overinvestment

Reducing the cost of underinvestment is often touted as one of the main reasons for enhanced firm value as a result of hedging. Underinvestment spawns from the principal-agent problem between stockholders and debtholders when, in an effort to prevent debtholders from capturing the upside of investments, managers often forgo profitable endeavors and underinvest, which hurts stockholders. Gay and Nam (1998) study the problem of underinvestment using a sample of 325 non-financial firms. By outlining the cost of underinvestment as a core determinant of hedging, the researchers shed light into the three following hypotheses:

> **"Hypothesis I:** Firms with greater investment or growth opportunities will make greater use of derivatives
>
> **Hypothesis II:** firms with enhanced investment opportunities concurrent with low levels of cash stocks will make greater use of derivatives than similar firms with similar cash stocks.
>
> **Hypothesis III:** Firms with greater correlation between cash flows and investment expenses will use derivatives less." (Gay & Nam, 1998)

They found interesting results that support the theory of underinvestment costs being an important determinant of hedging. For instance, the study finds that firms with good investment opportunities tend to use derivatives more when they incidentally have low levels of cash reserves. Also, their study gives support to the claim that a natural hedge is created for firms that experience a high correlation between internally generated funds and investment expenses (Gay & Nam, 1998).

The value enhancing feature of hedging stems from the fact that the market rewards reducing this underinvestment cost. The relationship between hedging and underinvestment costs was cohesively expressed by Bessembinder (1991) where he concludes that, by reducing the cost of underinvestment, equity holders are allowed to enjoy a larger increment of benefits received from newer investments by reducing the volatility of senior claims with additional investments.

Underinvestment costs also manifest in the following way, as highlighted by Froot et al. (1993) and Bessembinder (1991): due to market frictions, firms with more growth opportunities need to do more hedging because their exposure to market imperfections increases. Therefore, through increased hedging, the propensity and incentive to underinvest decrease. Just like underinvestment, overinvestment can sometimes represent a significant cost to firms, who then display increased levels of hedging propensity as a result.

Overinvestment occurs when managers choose to invest too much, or the majority of the capital at their disposal, which can have the perverse effect of destroying value in the case where managers allocate too much investment capital in negative net present value projects. Morellec and Smith (2007), using a contingent claims model of a firm, provide further insight in the principal-agent problem by incorporating manager-stockholder conflicts to study hedging rationales. The conclusion brought forth by their work shows that firms with a lower market-book ratio (and thus a greater reliance on assets) face higher overinvestment, and they tend to hedge more to control this specific cost. These findings provide further basis for Bartram et al. (2009) research which demonstrates that large firms (with an international scope), who are characterized by lower growth opportunities (lower market-book value), tend to hedge more to reduce the cost of overinvestment.

1.2.2 Distress costs and leverage

Hedging, financing and investing decisions are tightly intertwined. Lin and Smith (2007) investigate this effect and determine that, in the presence of costly financial distress, the more efficient a firm is at leading risky investments, the less likely it is to hedge. On the other hand, the more it invests in riskier investments, the more it tends to hedge. The effect of hedging in relation to firm value dates back to a study by Mayers and Smith (1982) who found evidence in support of the assertion that, in the presence of costly financial distress, lowering the volatility of cash flows and lowering its associated probability of default have positive effects on firm value.

Borrowing costs are also affected by a deterioration in cash flows and cash reserves. This negative effect is further compounded due to the fact that firms that have the most pressing liquidity needs are also the ones that face the highest borrowing costs, thus accelerating the cycle of bankruptcy if the firm is not able to ameliorate its cash flow shortcomings. A 1999 study by Minton and Schrand looked at the impact of cash flow volatility on the costs of equity and debt financing as well as the amount of capital that a firm was willing to invest in discretionary investments such as research and development, advertising and capital expenditure (Minton & Schrand, 1999). The conclusion drawn by this paper is that higher cash flow volatility (and thus risk) lowers discretionary investment costs. This means that firms seeking external capital (whether in the form of debt or equity) forgo discretionary capital investment. They also find a positive relationship between cash flow volatility and borrowing costs, as well as evidence pointing to investments being highly sensitive to volatility in earnings. This implies that cash flow volatility increases both the probability that a firm will seek external financing (given that their investments are underperforming) as well as the costs of financing, thus aggravating its financial distress. These findings were also echoed by the work of Smith and Stulz (1985).

In terms of the relationship between leverage and hedging, the literature yields conflicting results. In one camp, we have a collection of studies that deliver evidence suggesting that increased levels of leverage increase the use of hedging, such as the study by Berkman and Bradbury (1997) that focuses on corporate derivative use of New Zealand corporations. They find that hedging increases with increased leverage. Some other studies corroborate Berkman and Bradbury's findings such as Dolde (1995), Graham and Rogers (2002) or Haushalter (2000).

However, other studies do not find evidence to suggest a positive relationship between leverage and hedging levels. Some of these studies include the work of Nance, Smith and Smithson (1993) who empirically researched the determinants of hedging using a large sample of 169 firms. The proxies used in this study to represent leverage include interest coverage and debt/value. While the signs of the coefficients met the expected theory of increased use of hedging associated with increased levels of leverage, their results were not significant, suggesting that no conclusive inference could be made. Geczy et al (1997), Allayanis and Ofek (2001) also find no evidence in support of the prominent hypothesis.

1.2.3 Unobservable, asymmetric factors

Hedging can serve to reduce other costs due to asymmetry that are not captured by the cost of underinvestment. For instance, in the presence of uncertainty in dividend streams, firms may find value in adopting a hedging policy. In fact, DeMarzo and Duffie (1991) researched this rationale for hedging and found that, due to information asymmetry about dividends streams between principals and agents, hedging (widely supported by shareholders) enhances value for the firm.

1.2.4 Managerial utility

Another rationale for hedging pertains to managerial utility. Tufano (1996), in an empirical examination of risk management practices in the gold mining sector, came to the conclusion that a rationale for hedging is the manager's utility, risk aversion profile, and holding stake in the firm. In fact, Tufano observed that managers, who held stock options, were exposed to a greater convexity in their payoffs and tended to hedge less against the price of gold.

The reason behind this (echoed by Smith and Stulz) lies behind the fact that managers with greater options holdings have an incentive to keep the volatility of earnings high to increase the likelihood for their options to expire in the money. Also, Tufano found the opposite to be valid: managers with more stock holdings, and a greater percentage ownership in the firm, tend to hedge more due to the increased risk aversion experienced by the latter.

1.2.5 Taxes

In the presence of a convex tax function, a firm can benefit from cost-effective hedging. Smith and Stultz (1985) studied this phenomenon and their research brought forth the conclusion that an increased convexity of the tax function faced by the firm incentives managers to increase hedging. This is explained by the fact that hedging reduces the volatility of taxable income, which has the effect of reducing the volatility of pre-tax tax value of the firm. As such, in the presence of a convex tax function, hedging thus reduces the tax liability faced by the firm and reduces its post-tax value.

This theory was further tested empirically by Graham and Smith (1999**)**: they demonstrated that firms that face a convex tax function experienced a 5.4% (up to 40%) reduction in the volatility of expected tax liabilities by applying a hedge to reduce the variability of the firm's taxable income by 5%.

1.2.6 Firm size and focus

Firm size, focus and diversification are also important determinants to consider when looking at the hedging question. Wei, Xu and Zeng (2017) studied the phenomenon in a paper looking at the sustainability and economic viability of hedging in the real estate investment trust (REIT) industry. The authors found that firms with higher concentration on a property type tend to hedge more than diversified firms in terms of property type and size. They found a weaker relationship with geographical diversification, however, suggesting that geographical risk is less of a concern for REITs. This effect was more pronounced for smaller firms than larger firms, which implies a non-linearity in hedging and the size of the firm. They also found that smaller firms tend to have higher hedge ratios than smaller firms (Wei et al., 2017).

The opposing viewpoint is shared by Gezcy, Minton and Schrand, who found evidence of a positive relationship between firm size and derivative use to hedge (Gezcy et al., 1997).

In this paper, the authors find that larger firms, with economies of scale and a high exposure to currency risk tend to hedge their exposure more than other firms. The implication here is that firms with economies of scale have more resources to allocate to a robust risk management plan, and more capital to be able to adopt hedging strategies that may otherwise be cost-prohibitive to smaller firms in relation to their size. In this same paper, the authors also find that firms that have tight financial constraints, yet enjoy high growth opportunities, tend to make greater use of derivative instruments to hedge their currency exposure. The implication here is that firms seek to decrease their cash flow volatility. They do so in order to be able to take advantage of these growth opportunities, since volatile cash flows hinders them. These findings echo the conclusions drawn by Milton and Schrand (1999) that primary motivators to hedge is to take advantage of valuable opportunities that volatile cash flows can threaten.

Chapter 2
Sample and Methodology

2.1 Sample construction

The sample we are using in our study consists of quarterly data for 150 oil and gas producing firms between 1998 and 2010, amounting to a large panel of 6326 observations. The sample was collected by Mohamed Mnasri in the context of his doctoral thesis: "Trois essais sur la gestion des risques financiers : cas de l'industrie pétrolière américaine" (Mnasri, 2014). In order to narrow down the final list of firms to consider for the study, 413 potential firms with a Standard Industrial Certification (SIC) corresponding to 1311 (aggregating the crude petroleum and natural gas sector) were chosen from the Bloomberg database. Then, among the 413 firms, the 150 final firms were filtered by the following criteria: they needed to have a minimum of 5 years of oil and gas reserve data, with 10-K and 10-Q filings available on the EDGAR database, as well as their data available on Compustat to ensure a continuity and uniform methodology throughout.

As for operational and financial data for the firms, COMPUSTAT was used to assemble the quarterly data of financial characteristics of the firms, obtained from the Wharton Research Data Services (WRDS). The Thomson Reuters database was also utilized to obtain managerial data such as manager stock and option holdings, also through the WRDS interface. As for commodity specific data, such as oil and gas reserves and geographical dispersal, Bloomberg's annual dataset was the main source of information, supplemented with a data aggregation from 10-K filings.

Oil and gas industry data is increasingly more valuable in a research setting, especially in the study of risk management and hedging tendencies and strategies. This is due to the fact that its data yields itself to reliable results. First, firms in the industry face similar risks in terms of oil and gas prices (for both pure-play and diversified companies). This means that we can have a fairly high level of confidence with regards to results based on risk management characteristics.

Also, energy commodity (mainly oil and gas) is the most widely traded in the market, as evidenced by the fact that it represents 62% of the S&P GSCI, which is a production weighted index based on the capital allocated to each segment of the commodity market (Gunzberg, 2014). In addition, the derivative market for energy-related contracts is one of the largest and most liquid in the world. In fact, in November of 2019, the daily volume for energy contracts on the Chicago Mercantile Exchange reached 18.2 million, with an average of 10 million contracts per day for the same and an open interest of 131 million contracts (Group CME, 2019).

The advantage of having such a large and liquid derivatives market for energy is that it enables the derivative market to be as complete, transparent, liquid, and with price discovery mechanisms as efficient as possible. This means that it reduces biases about managerial choices to hedge, and allows us to reach a clearer picture of the corporate risk management decision-making.

2.2 Sample description:

2.2.1 Variable definition

The first variable that we construct manually is the hedging propensity score. To construct this binary variable, we assign a value of 0 for firms that rank below the 25th percentile of the sample in terms of hedging extent for oil and gas, respectively (low hedging firms). Similarly, we assign a value of 1 to firms that rank above the 75th percentile of the sample in terms of hedging extent for oil and gas, respectively (high hedging firms).

We also exclude firms that do not have any hedging activity to retain consistency when assigning the low hedging label to firms, which implies some level of hedging, at least. These percentiles were chosen because they are wide and categorical enough to give us the ability to quantifiably distinguish between firms that hedge their oil or gas production to either a low or large extent. This helps us emphasize their defining characteristics. Also, by focusing on these two tranches, we reduce noise by filtering out firms that do not have a definitive stance (low or high) on hedging. Table 1 below summarizes the other variables used.

Table 1. Variable definitions

Variable	Construction	Source
EPS from operations	Quarterly earnings per share from operations	Compustat
Investment Opportunities	Quarterly capital expenditure, with a scale by net property, plant and equipment at the beginning of the quarter	Compustat
Leverage ratio	Ratio of book value of total debts to the total book value of assets	Compustat
Liquidity	Ratio of cash and cash equivalents to the book value of current liabilities	Constructed manually
Dividend Payout	Dividends declared for the quarter (dummy variable)	Constructed manually
Oil reserves	Volume (in millions of barrels) of developed and undeveloped oil reserves (logarithm scale)	10-Ks and Bloomberg
Institutional Ownership	Percentage of shares owned by institutional investors	Thomson Reuters
Geographical diversification of oil production	Constructed using $1-\sum_{i=1}^{N}\left(\frac{q_i}{q}\right)^2$ where q_i represents the daily oil production in the i region (Latin America, North America, Middle East, Africa) while q is the total daily production of oil	Constructed manually
Geographical diversification of gas production	Constructed using $1-\sum_{i=1}^{N}\left(\frac{q_i}{q}\right)^2$ where q_i represents the daily gas production in the i region (Latin America, North America, Middle East, Africa) while q is the total daily production of gas	Constructed manually
Oil price volatility	Historical volatility of oil spot prices measured with the standard deviation	Constructed manually

Oil spot price	Oil spot price proxied by the price of West Texas Intermediate price (monitored inter-quarterly)	Bloomberg
Oil/Gas production risk	Variation coefficient of oil production (daily), calculated on a 12-month rolling window of 12 quarterly observations.	Constructed manually, Bloomberg, 10K reports
Gas price volatility	Historical volatility of gas spot prices measured with the standard deviation	Constructed manually
Gas spot price	Multi-region average of gas indices in the United States (Henry Hub, Gulf Coast, and others)	Bloomberg
Gas reserves	Total volume of developed and undeveloped gas reserves (in cubic feet), with annual disclosure	10K reports and Bloomberg
Gas hedge ratio of future expected gas production	Average of the hedge ratio of future expected natural gas production for the 5 upcoming fiscal years. The estimation method relies on the Fraction of Production Hedged (FPH) which is simply the ratio the notional amount of gas hedged to expected future gas production. The result is then average for the 5 years.	Bloomberg, 10K reports
CEO ownership	Percentage ownership of the firm by its CEO	Thomson Reuters
CEO option holding	Number of options on company stock help by the end of the quarter by the CEO (x 10,000)	Thomson Reuters
Number of analysts	Number of analysts following the firm, and subsequently issues earnings forecast for the quarter	I/B/E/S

2.2.2 Descriptive statistics:

The next step to understand the scope of this study is to gain a better understanding of the firms in our sample using descriptive statistics. Below is a table summarizing the descriptive statistics of the sample.

Table 2. Descriptive statistics of the sample

	N	Mean	Median	p25	p75	Std. Dev.
EPS from operations	6127	8.18	.09	-.03	.49	284.69
Investment Opportunities	6295	.13	.06	.04	.11	2.33
Leverage ratio	6044	.52	.52	.34	.66	.29
Liquidity	6069	1.56	.28	.08	.85	5.33
Dividend Payout	6326	.27	0	0	1	.44
Oil reserves	6326	276.71	8.01	.95	53.35	1277.73
Institutional Ownership	6326	.34	.22	0	.69	.35
Geographical diversification of oil production	6326	.12	0	0	0	.27
Geographical diversification of gas production	6326	.08	0	0	0	.23
Oil price volatility	6318	3.28	2.37	1.61	3.66	2.83
Oil spot price	6318	49.27	43.45	26.80	69.89	28.04
Oil production risk	6246	.27	.17	.08	.34	.30
Gas hedge ratio	6326	.07	0	0	.07	.15
Gas spot price	6318	5.14	4.83	3.07	6.22	2.62
Gas price volatility	6318	.73	.5	.29	1.11	.56
Gas reserves	6326	1504.19	99.46	13.71	571.70	5888.22
Gas production risk	6222	.27	.18	.09	.36	.28
CEO ownership	6028	.00	0	0	.00	.02
Number of CEO options	6326	174386.22	0	0	120000	681759.97
Number of analysts	6326	5.11	2	0	8	6.914

This table displays the summary statistics for the 150 firms sampled in the study. We can find the number of observations, mean, median, lower quartile, upper quartile and standard deviation of all relevant variables describing the sample.

Table 2 above shows a summary of the descriptive statistics. First, we notice that the Earnings per Share from operations for the 150 firms average at $8.18 with a median of $0.09. This indicates an asymmetric earnings distribution with a notably positive skewness. Use of leverage also seems to be prevalent in our firms of interest. With an average leverage ratio of 51.6%, but also with a wide variability, as evidenced by the associated standard deviation. Another interesting observation that stands out as a result of this statistical analysis is the high level of liquidity on hand that these firms have, which translates to a high ability to honor their short term liabilities, as evidenced by a quick ratio of 1.55, compared to an average quick ratio of 0.3 as of 2019 for the oil and gas industry (CSI Market, 2019). Next, more than a quarter of firms sampled pay a dividend to their shareholders.

This analysis also highlights important details about oil and gas production and reserves. For instance, oil reserves (including developed and undeveloped) amount to 276 million barrels while gas reserves amount to 1504 billion cubic feet per firm. We can also notice a moderately low concentration of oil and gas activities and geographical diversification (on average) with Herfindahl indices of 0.12 and 0.08 for oil and gas, respectively. However, the standard deviation of 0.27 and 0.23 indicates a high dispersion in the data in terms of industry concentration.

Finally, understanding manager characteristics for the firms sampled is important to understand hedging behavior, extent and preferences. On average, managers hold 0.4% of the firms, and their stock option holdings equate to more than 174 000, on average. This study relies on making a distinction between firms that hedge their oil production to a large extent as opposed to firms with low oil production hedging (also applicable to natural gas production). The next step to gain further understanding of the sample is to gain more insight on our sub-samples of choice, namely, the descriptive statistics for low and high hedgers for oil and gas producers.

2.3 Subsample descriptive statistics:

2.3.1 Low hedging propensity of oil production

Firms in the lower quartile in terms of oil hedging propensity (summarized in Table 3) have the following characteristics. First, we can note that the average percentage of oil production that is hedged amounts to around 13%, and interestingly, it appears that firms with low oil hedging also tend to have a low level of hedging of gas production (27%). Also, we note that these firms have a mean earnings per share from operations of 42 cents a share, a mean leverage ratio of 55% and a mean quick ratio quick ratio of 0.49.

Table 3. Descriptive Statistics for low propensity hedgers of oil production

Variable	Obs	Mean	Std. Dev.	Min	Max
EPS from operation	646	.421	1.415	-10.66	7.5
Investment Opportunities	647	.079	.148	-.397	3.213
Leverage ratio	647	.547	.197	0	2.072
Liquidity	647	.486	.841	0	7.089
Dividend Payout	647	.518	.5	0	1
Oil reserves	647	1.783	.884	-.451	3.394
Institutional Ownership	647	.578	.315	0	1.547
Geographical diversification (Oil)	647	.775	.29	.055	1.006
Geographical diversification (gas)	647	.867	.22	.154	1
Oil production risk	647	.197	.202	.009	2.42
Gas reserves	645	2.752	.884	-.537	4.189
Gas production risk	647	.194	.197	.004	1.693
CEO ownership	645	.003	.008	0	.082
Number of CEO options	647	205241.78	731292.36	0	12000000
Number of analysts	647	10.629	8.472	0	33
Oil hedge propensity score	647	.126	.067	.003	.243
Gas hedge propensity score	647	.272	.269	0	1.492

This table summarizes the descriptive statistics for firms that have be identified as low hedgers (belonging to the lower quartile in terms of hedging propensity for oil production)

2.3.2 High hedging propensity of oil production

We can also gather insightful information when looking at the descriptive statistics of the upper 25th percentile of oil hedging firms, as summarized on Table 4. On average, these firms have a high hedging propensity for oil (as expected) of 82% and a fairly high level of gas hedging of 60%. Their dividend payout average 28 cents a share. We can also note that, on average, CEO that manage high hedging firms have more ownership in the firms than low hedgers, and they also hold fewer options than their low hedging counterparts. They also have average earnings per share from operations equivalent to 25 cents a share, a leverage ratio of 65%, and a quick ratio of 0.33, on average.

Table 4. Descriptive Statistics for high propensity hedgers of oil production

Variable	Obs	Mean	Std. Dev.	Min	Max
EPS from operation	632	.254	1.713	-14.71	12.69
Investment Opportunities	635	.099	.164	-.048	1.753
Leverage ratio	633	.655	.247	.033	2.203
Liquidity	637	.334	1.442	0	30.467
Dividend Payout	647	.28	.449	0	1
Oil reserves	647	1.515	.658	-.356	3.088
Institutional Ownership	647	.475	.335	0	1.317
Geographical diversification (Oil)	647	.952	.149	.289	1.044
Geographical diversification (gas)	641	.972	.109	.387	1
Oil production risk	647	.259	.265	.012	1.906
Gas hedge ratio	646	5.535	2.533	1.69	13.48
Gas reserves	647	.267	.236	0	1.475
Oil production risk	632	.007	.041	0	.488
CEO ownership	647	299092.58	1352234.7	0	12000000
Number of CEO options	647	6.6	7.053	0	31
Number of analysts	647	.824	.194	.639	3.362
Oil hedge propensity score	647	.824	.194	.639	3.362
Gas hedge propensity score	647	.598	.362	0	2.19

This table summarizes the descriptive statistics for firms that have be identified as high hedgers of their oil production (belonging to the upper quartile in terms of hedging propensity)

2.3.3 Low hedging propensity of gas production

Next, we focus on low propensity hedgers of gas production (lower quartile), summarized on Table 5. As expected, these firms only hedge 15% of their gas production, on average, and similarly, they also have low propensity to hedge their gas production (19%). As for their financial characteristics, firms that choose to cover their gas production to a lesser extent have, on average, earnings per share equivalent to about 27 cents a share, a leverage ratio of 60% and a quick ratio of 0.41.

Table 5. Descriptive Statistics for low propensity hedgers of gas production

Variable	Obs	Mean	Std. Dev.	Min	Max
EPS from operation	776	.27	4.076	-103.22	13.44
Investment Opportunities	777	.088	.16	-.397	3.213
Leverage ratio	773	.596	.243	0	2.203
Liquidity	776	.414	.766	0	8.059
Dividend Payout	777	.48	.5	0	1
Oil reserves	768	1.702	.906	-1.243	3.394
Institutional Ownership	777	.548	.324	0	1.185
Geographical diversification (Oil)	768	.815	.267	.149	1
Geographical diversification (gas)	777	.89	.201	.189	1
Oil production risk	768	.213	.203	.009	2.42
Gas reserves	774	2.753	.778	.825	3.995
Gas production risk	777	.2	.213	.004	2.228
CEO ownership	774	.005	.011	0	.082
Number of CEO options	777	267207.47	767402.73	0	12000000
Number of analysts	777	9.65	8.094	0	33
Oil hedge propensity score	777	.189	.233	0	1.42
Gas hedge propensity score	777	.151	.076	0	.275

This table summarizes the descriptive statistics for firms that have be identified as low hedgers of their gas production (belonging to the lower quartile in terms of hedging propensity)

2.3.4 High hedging propensity of gas production

Finally, we examine the characteristics of firms that display a high propensity to hedge their gas production (upper quartile), summarized on Table 6. As we can see, these firms cover, on average, 90% of their oil production. In addition, their mean oil production coverage is also fairly high at 45%. In terms of financials, these firms earn on average 6 cents per share from operations, have a leverage ratio of 61%, and have a quick ratio of 0.35.

Table 6. Descriptive Statistics for high propensity hedgers of gas production

Variable	Obs	Mean	Std. Dev.	Min	Max
EPS from operation	760	.063	1.77	-11.84	12.69
Investment Opportunities	775	.106	.32	-.048	7.191
Leverage ratio	764	.607	.213	0	1.775
Liquidity	769	.353	.739	0	7.814
Dividend Payout	777	.295	.456	0	1
Oil reserves	760	1.029	.907	-2.699	3.023
Institutional Ownership	777	.42	.345	0	1.242
Geographical diversification (Oil)	757	.949	.164	.093	1.044
Geographical diversification (gas)	777	.987	.065	.501	1
Oil production risk	759	.295	.288	0	1.78
Gas reserves	777	2.472	.728	-.269	4.091
Gas production risk	777	.263	.244	.005	1.933
CEO ownership	759	.003	.008	0	.061
Number of CEO options	777	152639.51	654734.06	0	12000000
Number of analysts	777	6.651	6.962	0	32
Oil hedge propensity score	777	.455	.367	0	3.362
Gas hedge propensity score	777	.9	.201	.708	2.19

This table summarizes the descriptive statistics for firms that have be identified as high hedgers of their gas production (belonging to the upper quartile in terms of hedging propensity)

Chapter 3

Determinants of hedging (probit regression)

The determinants of hedging are multiple: aggregate demand for oil, financial constraints and characteristics, regional diversification of production, and managerial characteristics all provide valid explanations as to why a firm may have a high or low hedging propensity. In this chapter, through the use of univariate probit regression, we will statistically examine the determinants of hedging brought forth by the sample. First, we need understand the mechanics of the statistical method chosen, and the instrumental variable (change in the Kilian Index).

3.1 Instrumental variable:

3.1.1 Variable description

Measuring global real economic activity takes a crucial role in determining aggregate demand for commodities. Energy commodities (namely oil and gas) are even closely tied to the aggregate demand for the economy due to the increasing globalization of commerce, and the need to ship goods across the world. For our purposes, we chose the change in the Kilian index as our instrumental variable. Kilian (2009) proposed the Kilian Index as a non-lagging variable of real economic activity by examining average shipping costs.

The freighting and shipping industry is widely dictated by supply and demand. Indeed, if aggregate demand experiences a surge, we can also expect that the shipping services will also experience a surge (and vice versa). The supply and demand pressures will also push the prices of shipping upward. However, with advances in shipping technology and capacity, the supply line is driven outward, thus decreasing prices. Since the latter effect was more pronounced than the former in recent year, as outlined by Hamilton (2019), real prices are on a constant decline. Now, taking the growth of GDP, increase in shipping capacity and technology as trending with time, we can analyze the residuals from a time-series regression of the real shipping costs as a proxy for the cyclicality of real economic output.

3.1.2 Variable construction:

As we stated earlier, the premise behind the Kilian index is simply that real economic activity drives shipping costs, which translates into temporarily higher shipping costs when aggregate demand surges. The Kilian index starts with a nominal index for the cost of shipping (denoted as x), and adding to the previous value of x, on a monthly basis, the change in the log of the Baltic Dry Index shipping costs. The Baltic Dry Index is a widely recognized benchmark for the price of moving dry materials across 20 maritime routes (Kilian, 2009).

With this monthly iteration, we can summarize it as follows:

$$x_t = \log(BDI_t) + c$$

Then, we can subtract the log of CPI, and proceed with a regression of the time series:

$$\log(x_t) - \log(CPI_t) = \alpha + \beta t + \varepsilon_t$$

The residuals from the regression above constitute the Kilian index (Hamilton, 2019).

3.2 Probit model

The probit regression, or probit model, is the statistical model we have chosen to conduct our empirical analysis. This regression is used in the presence of binary, dichotomous variables. These dependent variables have a binary outcome, denoted as 0 and 1.

Probit models are used to determine the probability that a specific observation will be classified in a category. In our study, we are also using binary variables for the level of hedging (high or low) that a firm employs to cover its oil or gas production. In addition, we have a vector of regressors, denoted X, which we hypothesize have an effect on the binary level of hedging (denoted Y). As such, the model is specified as:

$$\Pr(Y = 1 \mid X) = \Phi(X^T \beta)$$

Φ in the above equation denotes the Cumulative Normal Distribution Function (CDF), and the β denotes the function's parameters, which can be estimated with the maximum likelihood estimation. To grasp the concept better, let's run through a simple model (Johan & Jo ̈nsson, 2016). Suppose we have the following function with a random variable with Y* being a latent positive variable, and a random variable denoted ε, distributed as $\varepsilon \sim N(0,1)$:

$$Y^* = X^T \beta + \varepsilon$$

Y can be seen as the indicator as to whether the latent variable Y* positive, or Y takes a value of value of 0 otherwise :

$$Y = \begin{cases} 1 & Y^* > 1 \\ 0 & otherwise \end{cases} = \begin{cases} 1 & X^T \beta + \varepsilon > 1 \\ 0 & otherwise \end{cases}$$

The estimation method used is the Maximum Likelihood Estimation method As the name implies, MLE is a statistical method which relies on maximizing the likelihood function to estimate the parameters of a probability distribution function.

MLE can be described as follows:

Given a dataset $\{y_i, x_i\}_{i=1}^{n}$ with the following *n* statistical units, we obtain, for each observation, the following potential conditional states:

$$\Pr(y_i = 1 \mid x_i) = \phi(x_i{}'\beta)$$
$$\Pr(y_i = 0 \mid x_i) = 1 - \phi(x_i{}'\beta)$$

The likelihood of an observation, with x_i being a K*1vector, and being a K*1vector can thus be summarized as:

$$L(\beta_i; y_i, x_i) = \Phi\left(x_i'\beta\right)^{y_i}\left[1 - \Phi\left(x_i'\beta\right)\right]^{(1-y_i)}$$

In order to identify the determinants of hedging for the oil and gas industry, we run two distinct probit regressions, one for oil hedging and the other for gas hedging.

3.3 Oil hedging probit

3.3.1 Oil probit methodology

The goal of the univariate probit for oil hedging is to evaluate the determinants of hedging the oil productions of the firm in our sample. To do so, we regress the binary variable for oil hedging (0 and 1 for low and high hedging propensity, respectively). Low hedging propensity corresponds to the bottom quartile, while high hedging propensity corresponds to the upper quartile of hedging firms in the sample. We regress these binary variables against our instrumental variable, the 1-period change in the Kilian Index, as well as other control variables. We then treat our results for heteroskedasticity by using robust estimators to ensure that are results are unbiased.

3.3.2 Oil probit results

The results for the oil production probit are summarized in Table 7. At first, we can see that the change in the Kilian index (the instrumental variable) is statistically significant with a p-value of 0.013, and its sign is negative. This result suggests that oil producing firms choose to intensify their hedging activities when demand for oil declines. In contrast, we can also note that hedging intensity decreases when demand for oil increases.

In addition, we can notice that other firm-specific variables give us valuable insight on the factors that influence the hedging propensity score for firms that opt to hedge their production. In fact, for the Earnings per Share from operations, an indicator of a firm's profitability has a positive coefficient, significant at the 5% level. This result suggests that firms that display a healthy profitability tend to hedge their oil production more than profitably unhealthy firms. This could be due to the fact that struggling firms need to take more risks (by not hedging their production as much) than profitable firms. Indeed, if we view firm under the lens of the Merton Model, we consider equity as a call option on the firm's assets, firms in distress need to take more risks, and face higher earnings volatility, to increase their chances for their call option to expire in the money. In order to minimize their risk aversion, firms with low profitability will hedge their oil production less (Merton, 1974).

Next, we explore the variable for leverage, and we note that the corresponding coefficient is also positive and significant at the 5% level. We infer from the result that, the more risky a company's corporate structure is, the higher the propensity for this company to hedge its oil production.

As for the coefficient for liquidity, we obtain a negative sign and a p-value of 0.038. This suggests that firms with high reserves of liquidity tend to hedge their oil production to a lesser extent than firms with low reserves of liquidity.

Next, we focus on whether a firm's oil reserves have a bearing on its propensity to hedge its oil production. As it turns out, our results demonstrate that the more reserves of oil a firm possesses, the more aggressively it will hedge against fluctuations in oil prices. This is explained by the fact that, since these companies are highly exposed to oil prices with large oil inventories, they choose to lock in a price to hedge against a steep decline, whereas leaner companies with lower reserves can allow themselves more exposure to oil price volatility.

The next variable we want to focus on is a firm's gas hedging level. The corresponding coefficient in the probit regression is positive and significant at the 1% level. This demonstrates that firms that already have a high propensity to hedge the gas production are also more likely to hedge their oil production. This is also demonstrative of the fact that oil and gas producing firms have similar risk aversion profiles when it comes to hedging against oil and gas price fluctuations. Such a result is not surprising because a firm with a high propensity to hedge against the fluctuations in oil prices faces the same pressures and profitability profiles when it weighs it on the decision to hedge against gas prices fluctuations.

Similarly, the variable which focuses on the effect of gas reserve levels on hedging propensity for oil and gas producing firms is insightful. In fact, with a negative sign significant at the 10% level, the results suggest that the propensity of a firm to hedge its oil production declines as gas reserve levels increase. This makes intuitive sense because a company with large gas reserves is exposed heavily to swings in gas prices, and thus will allocate more resources to hedging its gas production and current inventory than a firm with reserves of gas that have the bandwidth to allocate more resources to oil hedging.

Table 7. Oil hedging univariate probit regression

Oil hedging propensity	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Change in Kilian index	-.006	.002	-2.49	.013	-.01	-.001	**
EPS from operations	.086	.042	2.06	.04	.004	.167	**
Investment opportunities	.849	.557	1.52	.128	-.243	1.941	
Leverage ratio	1.147	.493	2.32	.02	.18	2.114	**
Liquidity ratio	-.186	.09	-2.07	.038	-.361	-.01	**
Dividend payout	-.368	.247	-1.49	.137	-.853	.117	
Oil reserves	.572	.189	3.03	.002	.202	.942	***
Institutional ownership	.106	.342	0.31	.757	-.564	.775	
Oil geographical diversification	-1.267	.537	-2.36	.018	-2.32	-.214	**
Gas geographical diversification	-1.088	.718	-1.52	.13	-2.496	.32	
Oil price volatility	-.032	.021	-1.53	.126	-.073	.009	
Oil spot price	.005	.004	1.44	.149	-.002	.012	
Oil production risk	.058	.408	0.14	.887	-.742	.858	
Gas hedge average	5.543	.814	6.81	0	3.948	7.137	***
Gas spot price	-.018	.026	-0.70	.485	-.069	.033	
Gas price volatility	.013	.064	0.21	.836	-.112	.139	
Gas reserves	-.377	.22	-1.71	.087	-.809	.054	*
Gas production risk	-.227	.456	-0.50	.619	-1.121	.667	
CEO Ownership	8.139	10.587	0.77	.442	-12.612	28.89	
Number of CEO's options	0	0	1.04	.297	0	0	
Number of analysts following firm (quarterly)	-.015	.023	-0.65	.514	-.059	.03	
Constant	-.921	.583	-1.58	.114	-2.065	.222	

Mean dependent var	0.489	SD dependent var	0.500
Pseudo r-squared	0.354	Number of obs	1222.000
Chi-square	189.282	Prob > chi2	0.000
Akaike crit. (AIC)	1138.783	Bayesian crit. (BIC)	1251.164

*** *p*<.01, ** *p*<.05, * *p*<.1

This table shows the results of the univariate probit regression where we regress the instrumental variable (change in Kilian index) and other control variables on the dependent variable (oil hedging propensity). Oil hedging propensity is a binary variable for which 0 represents a low propensity to hedge (bottom 25th percentile in of the firms sampled for hedging propensity), and 1 represents a high propensity to hedge (bottom 25th percentile in of the firms sampled for hedging propensity). We remark that the instrumental variable is negative and significant at the 5% level, which we interpret as firms in the sample hedging their oil production less when the aggregate demand for oil increases, and vice versa.

3.4 Gas hedging probit

3.4.1 Gas probit methodology

The next step in our analysis is conducting a similar probit, with the same instrumental variable (the 1-period change in the Kilian Index). However, this time, our independent variable is the propensity for firms in the sample to hedge their gas production (0 being a low propensity to hedge, and 1 being a high propensity to hedge, as defined earlier). The results for this probit regression are summarized in Table 8. In addition, we will also compare and contrast these results with the probit regression conducted for oil hedging.

3.4.2 Gas probit results

First, the probit regression yields a positive coefficient for the change in the Kilian index. This result suggests that, as opposed to oil production hedging, firms choose to intensify their hedging activities for gas production. This stems from the fact that firms shift their hedging resource allocation from oil to gas when aggregate demand for oil increases, since gas prices tend to fall with rising oil prices, which entails that hedging gas is perceived as more efficient in this scenario.

Our next variable of interest is leverage: as opposed to the probit for oil hedging, we do not obtain a significant result. The next variable that yields a significant regression coefficient is liquidity. Indeed, we obtain a negative sign and a p-value of 0.036. This result suggests that firms with low liquidity reserves to intensify their hedging activities in order to lock in the price of gas and ensure that they can meet their short-term obligations to avoid financial distress. We observed the same result in the first probit analyzing oil hedging.

Next we look at the variable for gas reserves, and we obtain a positive regression of 0.32, which is significant at the 1% threshold. Similar to the oil-focused probit, this result suggests that firms tend hedge more when their gas reserves are high. The next variable is institutional holding: we obtain a negative sign for the coefficient, and significant at the 5% level. This result suggests that, the more institutions hold of a firm, the more that firm is likely to hedge their production of gas.

For the variable explaining the geographical diversification of gas production, we obtain a positive sign that is significant at the 5% level. As opposed to oil hedging, this result suggests that the more geographically diversified a company's gas production is, the more hedging they will operate.

Another interesting observation is regarding the variables describing oil prices and oil price volatility, we obtain in both cases a positive and significant sign at the 1%. These results suggest that the more the price and volatility of oil increase, the higher an oil and gas firm's marginal propensity to hedge gas production will be. Finally, the variable for the spot piece of gas, the probit regression yields a negative and significant at the 5% level. This result suggests that the more the spot price of gas increases, the lower a firm's marginal propensity to hedge its gas production is.

Table 8: Gas hedging univariate probit regression

Gas hedging propensity	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Change in Kilian index	.005	.002	2.63	.009	.001	.008	***
EPS from operations	.003	.012	0.27	.788	-.02	.026	
Investment opportunities	-.031	.136	-0.23	.822	-.298	.236	
Leverage ratio	-.21	.474	-0.44	.658	-1.139	.719	
Liquidity ratio	-.16	.076	-2.09	.036	-.309	-.01	**
Dividend payout	-.328	.251	-1.31	.191	-.82	.164	
Oil reserves	-.799	.178	-4.49	0	-1.149	-.45	***
Institutional ownership	-.602	.322	-1.87	.061	-1.232	.029	*
Oil geographical diversification	.176	.611	0.29	.773	-1.022	1.375	
Gas geographical diversification	2.117	.841	2.52	.012	.468	3.766	**
Oil price volatility	.065	.018	3.59	0	.029	.1	***
Oil spot price	.014	.003	4.30	0	.008	.02	***
Oil production risk	-.091	.361	-0.25	.801	-.799	.617	
Gas spot price	-.073	.03	-2.45	.014	-.132	-.015	**
Gas price volatility	-.061	.071	-0.86	.392	-.2	.078	
Gas reserves	.621	.187	3.31	.001	.254	.988	***
Gas production risk	-.018	.359	-0.05	.961	-.721	.686	
CEO Ownership	-12.789	8.503	-1.50	.133	-29.454	3.877	
Number of CEO's options	0	0	-1.15	.25	0	0	
Number of analysts following firm (quarterly)	-.005	.019	-0.24	.811	-.042	.033	
Constant	-3.14	.787	-3.99	0	-4.682	-1.598	***

Mean dependent var	0.495	SD dependent var	0.500
Pseudo r-squared	0.289	Number of obs	1458.000
Chi-square	222.391	Prob > chi2	0.000
Akaike crit. (AIC)	1480.313	Bayesian crit. (BIC)	1596.579

**** p<.01, ** p<.05, * p<.1*

This table shows the results of the univariate probit regression where we regress the instrumental variable (change in Kilian index) and other control variables on the dependent variable (gas hedging propensity). Gas hedging propensity is a binary variable for which 0 represents a low propensity to hedge (bottom quartile in of the firms sampled for hedging propensity), and 1 represents a high propensity to hedge (upper quartile in of the firms sampled for hedging propensity). We remark that the instrumental variable is positive and significant at the 5% level, which we interpret as firms in the sample hedging their gas production more when the aggregate demand for oil increases, and vice versa.

3.5 Oil and gas probit discussion

3.5.1 Interplay between oil and gas production and hedging

An interesting insight that we can extract from the probit regression is regarding the relationship between hedging propensity and commodity prices. Indeed, for the instrumental variable, the change in the Kilian index, we observed that the oil probit resulted in a negative and significant regression coefficient while the gas probit resulted in a positive and significant coefficient. These results demonstrate an interplay in the decision-making process to hedge these two commodities: increased aggregate demand for oil results in less hedging of the oil production and more hedging of the gas production. In addition, we noted that, for the gas probit, the regression coefficient corresponding to the spot price of oil was positive and significant, suggesting that an increase in the price of oil triggers increased hedging activity for gas production.

In order to gain a better understanding of this interplay, we need to look at the mechanisms that regulate these connected resources.

3.5.2 Associated gas production and cointegration:

Oil production ramps up with increased oil prices: since these firms have a real option on the extraction of oil and gas, it allows them to react to macroeconomic trends of prices by adjusting their production. As a result of increased oil production, gas production can also increase in this case because the two resources are extracted from the same source in the ground. Thus as oil production is increased, naturally the gas produced and extracted also increases as a by-product. To cement this concept, we also explore the cointegration of oil and gas prices which has been discussed at large in the literature. In fact, in a study focused on the switching relationship between oil and gas prices (Brigida, 2014), the author reinforced the idea of price cointegration between oil and natural gas.

In summation, we can synthesize both mechanisms as follows: higher demand for oil, which results in higher oil prices, also increases the production of natural gas due to the associated gas production effect. Then, due to the cointegration of both prices, oil being higher on a long time frame means that gas prices also move higher, in tandem. Therefore, these mechanisms can help explain why the hedging propensity for gas production decreases with an increased aggregate demand of oil. As oil prices soar, it drives the production of oil, which also increases the production of gas. Then, the increase in gas price levels due to the cointegration between oil and gas prices decreases the propensity to hedge gas production (Independent Statistics & Analysis, 2020).

Chapter 4.
Joint decision-making to hedge oil and gas productions (biprobit regression)

Firms producing both oil and natural gas are faced with the added challenge of needing to consider their hedging strategy for two commodities, simultaneously. Indeed, firms only have a limited amount of resources to allocate to hedge their production of oil and gas, and thus need to consider several factor before choosing to hedge. Some of these include the risk factors producers face.

By testing both hedging oil and gas, simultaneously, we will gain a better understanding of the determinants for this hedging allocation. Thus, in this chapter, we will take the analysis further by studying this unique feature of oil and gas companies (as opposed to single-commodity, pure play firms). To aid our analysis, we will be using the seemingly unrelated bivariate probit regression. But before we delve into the results of our analysis, we first need to get a better understanding of this statistical method.

4.1 Bivariate probit methodology

4.1.1 Model description

In the first part of the study, we used univariate probit regressions, which model the dichotomous variables (0 and 1 for low and high hedging propensity, respectively). Then, the probit uses the inverse of the normal distribution specified for the dichotomous variables' probabilities, and the predictors are linearly modeled as a function, accordingly. A bi-probit uses the same basic tenants in its construction, but the difference, as the name implies, is that in the regression models we have two dependent variables (Y_1 and Y_2) that are simultaneously and jointly function of regressors.

Thus, due to the binary nature of the dependent variables, and the joint regression function, we have 4 different outcomes to analyze:

- Firms with a low propensity to hedge for both oil (Y_1) and gas(Y_1):
  ($Y_1 = 0$ and $Y_2 = 0$)
- Firms with a high propensity to hedge for both oil and gas:
  ($Y_1 = 1$ and $Y_2 = 1$)
- Firms with a high propensity to hedge for oil and a low propensity to hedge for gas:
  ($Y_1 = 1$ and $Y_2 = 0$)
- Firms with a low propensity to hedge for oil and a high propensity to hedge for gas:
  ($Y_1 = 0$ and $Y_2 = 1$)

Finally, a seemingly unrelated biprobit regression expands the biproit regression by using the outcomes above in a function that does not model any relationship between the covariates. Then, any potential, unobserved heterogeneity in the model is tested by analysis of the correlation between residual terms.

Therefore, the seemingly unrelated biprobit regression is the appropriate method in this instance because it will allow us to model the explanatory variables on the decision to hedge both oil and gas production, jointly and concurrently.

Also, this model will help address any potential endogeneity between the decision to hedge oil and gas since this regression accounts for correlations and relationships of unobserved terms and residuals. Below is a representation of this econometric model, proposed by Arnold Zellner in 1962:

$$Y_1^* = X_1\,\alpha_1 + \gamma Y_2 + \;u_1,\quad Y_1 = \begin{cases} 1 & \text{if } Y_1^* > 0 \\ 0 & \text{if } Y_1^* \le 0 \end{cases},$$

4.1.2 Latent variables

Latent variables, which are incompletely observed variables, are first specified as Y^*_1 and Y^*_2 which represent a propensity score for oil and gas hedging, respectively (0 which corresponds to firms hedging their production in the lower quartile for hedging, and 1 which corresponds to firms hedging their production in the high quartile).

For the incompletely observed latent variables Y^*_1 and Y^*_2 we specify the following equations:

$$Y_1^* = X_1\beta_1 + \varepsilon_1$$
$$Y_2^* = X_2\beta_2 + \varepsilon_2$$

The random disturbances ε_1 and ε_2 are jointly normal, with null variances, and correlation denoted as ρ:

$$\begin{Bmatrix} \varepsilon_1 \mid X \\ \varepsilon_2 \mid X \end{Bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}\begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}\right)$$

Thus, our observed dichotomous variables, denoted as Y_1 and Y_2, are specified using the latent variables, as follows:

$$Y_1 = \begin{Bmatrix} 1 & for\, Y_1^* > 0 \\ 0 & otherwise \end{Bmatrix}$$
$$Y_2 = \begin{Bmatrix} 1 & for\, Y_2^* > 0 \\ 0 & otherwise \end{Bmatrix}$$

Finally, we can summarize the bivariate probit model with these specifications (Seyoum, 2018).

$$P(y_1 = i, y_2 = j) = \Phi(X_1^{'}\beta_1, X_2^{'}\beta_2, \rho)$$

4.1.3 Estimation method for coefficients

In order to estimate the biprobit coefficients, the maximum-likelihood estimation method is used, by which of this statistical method, we maximize the likelihood replicating the observation in the dataset using the model parameters.

Using the latent variables described earlier, and our postulated equations, we can arrange the likelihood model as:

$$L = \prod \begin{Bmatrix} P(\varepsilon_1 > -X_1\beta_1, \varepsilon_2 > -X_2\beta_2) + P(\varepsilon_1 < -X_1\beta_1, \varepsilon_2 > -X_2\beta_2) \\ +P(\varepsilon_1 > -X_1\beta_1, \varepsilon_2 < -X_2\beta_2) + P(\varepsilon_1 < -X_1\beta_1, \varepsilon_2 < -X_2\beta_2) \end{Bmatrix}$$

We then maximize the log likelihood function below to find the estimators for our biprobit regression coefficients.

$$\ln L = \prod \begin{Bmatrix} \ln \Phi(X_1'\beta_1, X_2'\beta_2, \rho) + \ln \Phi(-X_1'\beta_1, X_2'\beta_2, -\rho) \\ +\ln \Phi(X_1'\beta_1, -X_2'\beta_2, -\rho) + \ln \Phi(-X_1'\beta_1, -X_2'\beta_2, \rho) \end{Bmatrix}$$

4.2 Bivariate probit regression results

4.2.1 Model fit

The results of the seemingly unrelated biprobit are summarized in Table 9. First, we take a look at the fit of the overall model, which is tested using the Wald's test.
The Wald test yields a X_2 value of 35.75, which corresponds to a p-value of 0.0000, which demonstrates that the model is significant.

Next, we look at our correlation between our oil hedging variable and our gas hedging variable. With a significant rho of 0.756, we note a correlation between the hedging propensity score of oil and gas. This correlation is quite high, and this could be addressed in future iterations by changing the specification of the model.

4.2.2 Statistically significant coefficients

The results of the bivariate probit give us valuable insights into the joint decision that firms make to hedge both their production of oil and gas. First, we start by analyzing the result for the instrumental variable, the delta Kilian Index. We obtain a negative and strongly significant regression coefficient for both equations. This result suggests that the joint decision to hedge both oil and gas production is influenced by the aggregate demand for oil. In fact, when aggregate demand for oil increases, the propensity for firms to hedge both oil and gas production decreases.

The conclusion drawn from this bivariate probit is interesting when compared with the results of the univariate probit models for oil and gas, discussed earlier, which studied the independent decision to hedge the oil or gas production. Indeed, while the univariate probit for oil also yielded a negative coefficient for the delta Kilian Index, the univariate probit for gas yielded a positive sign in contrast to the negative sign we obtained in the bivariate probit, suggesting that the firms' hedging propensity is in part determined by whether the decision is independently or jointly made.

Liquidity is the next variable of interest, and it has a negative and significant coefficient. This result suggests that firms' propensity to hedge their oil and gas production tends to increase when liquidity reserves decrease, thus solidifying the earlier findings using the univariate probits that firms with liquidity constraint prefer to hedge more because they are more exposed to a potential risk event, which elevates their distress costs and prompts then to intensify their hedging activities.

Our next variables of interest are the rate of geographical diversification for oil and gas. As we can see in Table 9, the variables for oil and gas geographical diversification are negative and significant at the 5% and 1% threshold, respectively. This result suggests that geographical diversification is a determinant factor of consideration for energy firms when making the joint decision to hedge their oil and gas production, respectively. In fact, firms' propensity to hedge decreases as their production for both oil and gas is broadly diversified geographically. An interpretation for this tendency is that a firm's overall hedging strategy relies on how geographically diversified their production is because this diversification reduces the risk of firms and are thus less sensitive to shocks whereas firms with geographically concentrated productions, which is inherently more risky, tend to hedge more to reduce their risk profile.

The next variable of focus is CEO stock ownership in the firms they manage. As we can see, we obtain a negative sign in both instances of the probit, with a p-value of 0.21 in the case of oil and a p-value of 0.012 for in the case of gas. This result suggests that the higher a manager's personal stake is in the firm, measured by stock ownership, the lower the firm's propensity to hedge is.

This finding is thought-provoking as it is contrary to the literature: indeed, Tufano (1996) came to the conclusion that there exists a positive relationship between manager ownership of the firm and hedging in the gold industry while our result suggests that managers tend to take on more risk (by hedging less) the more of the firm they own.

Table 9: Seemingly unrelated bivariate probit

Oil hedging propensity	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Change in Kilian index	-.006	.002	-3.14	.002	-.01	-.002	***
EPS from operations	.044	.035	1.28	.202	-.024	.112	
Investment opportunities	1.034	.557	1.86	.063	-.058	2.126	*
Leverage ratio	.262	.461	0.57	.57	-.642	1.167	
Liquidity ratio	-.55	.226	-2.43	.015	-.994	-.106	**
Dividend payout	-.188	.256	-0.73	.463	-.69	.314	
Oil reserves	.106	.171	0.62	.535	-.229	.44	
Institutional ownership	-.268	.348	-0.77	.442	-.951	.415	
Oil geographical diversification	-1.165	.509	-2.29	.022	-2.162	-.168	**
Oil production risk	.135	.311	0.44	.664	-.475	.746	
CEO ownership	-13.671	10.916	-1.25	.21	-35.067	7.724	
Number of CEO's options	0	0	1.08	.282	0	0	
Number of analysts following firm (quarterly	-.035	.019	-1.79	.074	-.072	.003	*
Constant	.41	.449	0.91	.361	-.47	1.289	
Gas hedging propensity							
Change in Kilian index	-.006	.002	-2.91	.004	-.01	-.002	***
EPS from operations	-.044	.033	-1.34	.181	-.109	.021	
Investment opportunities	.588	.46	1.28	.201	-.313	1.489	
Leverage ratio	-.375	.49	-0.76	.444	-1.334	.585	
Liquidity ratio	-.373	.146	-2.55	.011	-.659	-.087	**
Dividend payout	-.16	.266	-0.60	.547	-.681	.361	
Institutional ownership	-.203	.381	-0.53	.593	-.95	.543	
Gas geographical diversification	-2.521	.78	-3.23	.001	-4.049	-.993	***
Gas production risk	.238	.365	0.65	.514	-.477	.953	
CEO ownership	-34.626	13.794	-2.51	.012	-61.662	-7.591	**
Number of CEO's options	0	0	1.43	.151	0	0	
Number of analysts following firm (quarterly)	-.026	.017	-1.48	.139	-.059	.008	
Constant	1.062	.442	2.40	.016	.194	1.929	**
Athrho	1.032	.178	5.80	0	.683	1.381	***

Mean dependent var	0.550	SD dependent var	0.498
Number of obs	653.000	Chi-square	132.085
Prob > chi2	0.000	Akaike crit. (AIC)	1345.359
Rho	0.7748		

**** p<.01, ** p<.05, * p<.1*

This table shows the results of the seemingly unrelated bitprobit regression, which test the firms' *joint* decision to hedge both their oil and gas production. The regression coefficient for the Kilian index is significant and negative, which implies that, in the case of jointly hedging their oil and gas production, firms repond to a increase in global demand for oil (as indicated by the change in the Kilian index, by reducing their hedging activities, and vice versa.

4.3 Biprobit results discussion

To conclude, the seemingly unrelated biprobit regression conducted in this chapter is an interesting way to tackle the hedging question under a different lens. Indeed, the joint decision to hedge oil and gas yields slightly different results from the univariate approach and demonstrates specifically that the decision to hedge in the oil and gas industry is in large part driven by the demand for oil. More specifically, these results allude to the fact that by the significant and negative regression coefficient for the instrumental variable, the change in the Kilian Index.

This echoes the idea that there exists an interrelationship and cointegration between oil and gas prices that prompts energy producers to increase their hedging activities for their oil and gas production in anticipation of price and demand shocks for oil and gas.

The year 2020 presents a unique case study to explore these concepts explored in this thesis. Indeed, following the COVID-19 global pandemic that jeopardized the global economy, the oil and gas industry was hit specifically hard as countries around the globe entered in states of lockdown and air travel was essentially halted. In fact, passenger air transport was down a staggering 90% in April. This had a direct implication on energy prices as global demand for oil was down 30% in comparison to a year prior, with levels comparable to the energy demand in 1995. Oil and gas firms reacted promptly by hedging their 2021 production in anticipation for further depressed demand and prices for energy prices (OECD, 2020).

Energy producing companies have exhibited comparable hedging decision making when compared to the results of this thesis. Indeed, in response to a lower demand for oil in the upcoming year, oil and gas companies have decided to hedge 41% of their forecasted 2021 oil production (setting a price floor of $42 per barrel) and 45% of their forecasted natural gas production (with an average price floor set at $2.58 MMBtu) (Bloomberg NEF, 2020). As we can see, a demand shock prompts the hedging of both oil and gas production, which corroborates the finding that lower demand for oil (as proxied by the change in the Kilian index in the bi-probit) prompts oil and gas firms in our sample to jointly increase the hedging of oil and gas output.

Chapter 5
Hedging and firm value

The core aim to hedge oil and gas output by energy producing firms should be to first and foremost to maximize shareholders' wealth, which entails adding value to the firm. The theory suggests that, in a financial and economic environment with friction, hedging enhances the value of a firm by reducing the volatility and variable of cash flows and earnings, thus reducing costs associated with financial distress, among others. However, the value enhancement can only work if the marginal benefit of hedging exceeds its marginal cost: derivative instruments can be quite costly for firms, and they can also cause them to miss out on large gains if the price of oil or gas moves against their predictions.

Take, for example, Cenovus, an integrated oil and gas Canadian company: In 2017, the company, following a large acquisition, decided to take the safe route and make a large hedging decision to lock in a price for oil in anticipation of a major decline. The company then announced $469 million of realized hedging losses, which represents the loss due to price appreciation that it didn't benefit from due to the hedge (Cenovus, 2018).

Several studies have explored this concept with mixed conclusions. First, Allayannis and Weston (2001) found evidence of a 5% "hedging premium," or Carter et al (2006) that found a hedging premium even greater than 5% in the airline industry. Other studies have found contradictory evidence for the value maximizing feature of hedging. One such study is Jin and Jorion (2006) that also focused on the oil and gas industry, in which they found no evidence for the value enhancement as a result of hedging. In our study, we want to test this feature by running several regressions to gain a multifaceted view of this issue.

5.1 Hedging value methodology

To best answer the question of whether hedging enhances firm value, we first have to specify the method through which we will answer this question. First, we need to identify the regression parameters that we will use, then we need to describe the variables chosen for our regressions.

5.1.1 Regression parameters

To estimate the effect of hedging on the value of the firms in our sample, we chose linear regressions in which we regress various values and profitability metrics (dependent variables) on different combination of probabilistic outcomes in hedging propensity for oil and gas. For instance, we can estimate the effect on the firm value of firms that have a high propensity to hedge their oil production while at the same time having a low propensity to hedge their gas production. The value and profitability of these firms are proxied using different variables, which we will outline below.

5.1.2 Variables

The dependent variables that we have chosen to conduct our regressions allow us to gauge the effect of hedging on firm value, profitability and risk profile.

Firm's Tobin's Q (in log):
Also known as the Q Ratio, the Tobin's Q is a widely utilized proxy for firm value in the literature. As its name suggests, this variable was first defined by James Tobin and was first used in the literature by Nicholas Kaldor, who published an economic focused paper detailing the variable (Kaldor, 1966). The Tobin's Q is the ratio of the sum of the company's market value of equity, book value of debt, and book value of preferred shares to the book value of its assets, in log. Equilibrium is thus reached when market value is equivalent to replacements costs.

Thus, this ratio allows us to reconcile the intrinsic value with the market value of a firm. A low Tobin's Q (between 0 and 1) would imply that a firm is undervalued because its market value is less than it would cost to replace its assets. A high Tobin's Q would imply that a firm is overvalued because its market value is greater than it would cost to replace its assets.

Return on Equity:

Return on equity is a very popular metric in the financial literature. It measures a firm's financial performance and profitability by taking the ratio of its net income with its shareholder equity. This metric is also considered as the return on net assets of a firm since the equity of shareholders can also be expressed as the difference between a company's assets and its liabilities.

Idiosyncratic risk:

Idiosyncratic risk, as opposed to systematic risk, refers to the sum of factors that can negatively impact the individual firms in the sample. Based on daily returns on 1-month crude oil futures contracts and 1-month natural gas futures contracts (Dionne & Mnasri, 2018), this variable is estimated using the Fama French model (1993) as well as the Fama-French- Carhart 4-factor residual methodology.

Market Beta (Systematic risk)

This variable measures the extent to which the value of a firm moves and covaries with the broad market. The beta is estimated by taking the ratio of the covariance of the firm's security and the market to the variance of the market.

Our independent variables consist of conditional probabilities which represent the simultaneous outcomes of hedging oil and/or gas. These variables were generated using the PREDICT function in STATA which is used to calculate predictions based on previous estimations.

p00:

This is our first simultaneous probabilistic explanatory variable. This variable simply determines the probability that a firm in the sample has both a low propensity to hedge its oil production *and* low propensity to hedge its natural gas production. We can also denote this variable as follows:

$$\Pr(y_{1j} = 0, y_{2j} = 0)$$

p11:

This is our second simultaneous probabilistic explanatory variable. This variable simply determines the probability that a firm in the sample has both a high propensity to hedge its oil production *and* high propensity to hedge its natural gas production. We can also denote this variable as follows:

$$\Pr(y_{1j} = 1, y_{2j} = 1)$$

p10:

This is our third simultaneous probabilistic explanatory variable. This variable simply determines the probability that a firm in the sample has a high propensity to hedge its oil production *while having a* low propensity to hedge its natural gas production. We can also denote this variable as follows:

$$\Pr\ (y_{1j} = 1, y_{2j} = 0)$$

p01:

This is our fourth simultaneous probabilistic explanatory variable. This variable simply determines the probability that a firm in the sample has a low propensity to hedge its oil production *while having a* high propensity to hedge its natural gas production. We can also denote this variable as follows:

$$\Pr\ (y_{1j} = 0, y_{2j} = 1)$$

We also include control variables in our model.

5.2 Hedging value regressions results

In this section, we run a variety of regressions. We regress the dependent variables based on firm metrics on the variables p11, p10, p00 and p01, detailed above. With these regressions, we want to estimate the effect of hedging decisions by firms on several metrics, namely: market valuation, profitability and risk. We then highlight the results that yield a significant regression coefficient for the dependent variable, accordingly. In terms of fit, the coefficients of determination range from 0.108 to 0.488. The results are summarized in Tables 14 to 16.

5.2.1 Tobin's Q vs p11: (High oil and gas hedging)

Table 10 summarizes the results of the first regression, in which we regress the sample firms' Tobin's Q values on the explanatory variable p11 and other control variables. P11 denotes the high, simultaneous propensity to hedge oil and gas.

As we can see on this table, we obtain a positive and significant regression coefficient with a value of 0.835 and a p-value of 0.043. This result implies that there is evidence to suggest that firms with a high propensity to hedge both their oil and natural gas production tend to have a high Tobin's Q, which means that hedgers tend to have a relatively higher market valuation. Other interesting insights from these tables are the following significant variables:

Liquidity (-): this relationship indicates that firms have marginal increases in hedging propensity when their liquidity reserves decrease. Oil reserves (-): the negative relationship indicates that firms with a higher propensity to hedge both of their oil and gas productions tend to have smaller reserves of oil. Other notable significant relationships that we identified through the regression are the following: institutional ownership (+), oil volatility (-), gas spot price (+), number of options held by CEOs (-)

Table 10: p11 vs Tobin's Q linear regression

Tobin's Q	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
p11	.835	.406	2.06	.043	.028	1.642	**
EPS from operations	.001	.008	0.07	.946	-.015	.016	
Investment opportunities	.157	.159	0.99	.326	-.16	.474	
Leverage ratio	.337	.235	1.43	.156	-.131	.804	
Liquidity ratio	-.158	.048	3.28	.002	.062	.253	***
Dividend payout	.135	.085	1.59	.116	-.034	.304	
Oil reserves	-.214	.095	-2.26	.026	-.402	-.026	**
Institutional ownership	.273	.128	2.14	.035	.019	.527	**
Oil geographical diversification	.043	.156	0.27	.785	-.267	.352	
Gas geographical diversification	.377	.275	1.37	.173	-.169	.924	
Oil price volatility	-.051	.009	-5.67	0	-.069	-.033	***
Oil spot price	.002	.002	0.98	.33	-.002	.005	
Oil production risk	-.002	.159	-0.01	.992	-.317	.314	
Gas hedge ratio	-.166	.109	-1.52	.132	-.382	.051	
Gas spot price	.047	.013	3.56	.001	.021	.074	***
Gas price volatility	-.02	.027	-0.73	.468	-.073	.034	
Gas reserves	-.134	.091	-1.47	.145	-.315	.047	
Gas production risk	.039	.213	0.18	.856	-.384	.462	
CEO ownership	8.953	7.247	1.24	.22	-5.465	23.37	
Number of CEO's options	0	0	-2.53	.013	0	0	**
Number of analysts following firm (quarterly)	.036	.01	3.47	.001	.015	.056	***
Constant	.912	.237	3.85	0	.441	1.382	***

Mean dependent var	1.498	SD dependent var	0.506
R-squared	0.283	Number of obs	649.000
F-test	8.391	Prob > F	0.000
Akaike crit. (AIC)	783.727	Bayesian crit. (BIC)	882.186

*** *p*<.01, ** *p*<.05, * *p*<.1

This table displays the results when regressing the variable p11, which corresponds to high hedging propensity for both oil and gas production, and other control variables on the Tobin's Q. The positive and significant result for the variable p11 suggests that firms that have a high hedging propensity for oil and gas tend to enjoy a higher Tobin's Q, and thus a higher market valuation.

5.2.2 Return on Equity vs p00: (Low oil and gas hedging):

On table 11, we can find the results after regressing the sample firms' return of equity values on the explanatory variable p00, which denotes the low, simultaneous propensity to hedge oil and gas and other control variables.

As we can see in this table, we obtain a negative and significant value for the explanatory variable p00, with a regression coefficient of -0.863 and a p-value of 0.015.

This results suggests that firms with a low propensity to simultaneously hedge their oil natural gas production tend to have a low return on equity. This seems to fall in line with the earlier regression, and provides further evidence that there exists a value enhancing property of hedging. Indeed, with this significantly negative coefficient, the firms in our sample that do not hedge either of their productions have their profitability and returns on equity eroded, thus eroding shareholder wealth.

Table 11: p00 vs ROE linear regression

ROE	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
p00	-.863	.349	-2.48	.015	-1.556	-.17	**
EPS from operations	.118	.022	5.30	0	.073	.162	***
Investment opportunities	-.028	.06	-0.46	.645	-.147	.091	
Leverage ratio	-.226	.156	-1.45	.149	-.536	.083	
Liquidity ratio	.124	.055	2.27	.026	.015	.233	**
Dividend payout	.035	.044	0.79	.432	-.053	.122	
Oil reserves	.017	.045	0.37	.71	-.072	.105	
Institutional ownership	.088	.073	1.22	.227	-.056	.233	
Oil geographical diversification	.038	.062	0.61	.546	-.086	.161	
Gas geographical diversification	.359	.215	1.67	.098	-.068	.787	*
Oil price volatility	-.019	.01	-1.92	.058	-.039	.001	*
Oil spot price	-.002	.001	-1.36	.179	-.004	.001	
Oil production risk	-.138	.094	-1.46	.148	-.325	.05	
Gas hedge ratio	.017	.097	0.18	.86	-.176	.21	
Gas spot price	-.026	.019	-1.36	.177	-.064	.012	
Gas price volatility	.024	.045	0.53	.597	-.066	.115	
Gas reserves	-.062	.053	-1.16	.248	-.168	.044	
Gas production risk	-.037	.096	-0.39	.7	-.229	.154	
CEO ownership	3.169	2.586	1.23	.224	-1.975	8.314	
Number of CEO's options	0	0	-1.33	.188	0	0	
Number of analysts following firm (quarterly)	.012	.008	1.65	.102	-.003	.027	
Constant	.613	.243	2.52	.014	.13	1.096	**

Mean dependent var	-0.015	SD dependent var	0.523
R-squared	0.219	Number of obs	644.000
F-test	3.456	Prob > F	0.000
Akaike crit. (AIC)	875.915	Bayesian crit. (BIC)	974.204

**** p<.01, ** p<.05, * p<.1*

This table displays the results when regressing the variable p00, which corresponds to low hedging propensity for both oil and gas production, and other control variables on the Tobin's Q. The positive and significant result for the variable p11 suggests that firms that have a high hedging propensity for oil and gas tend to enjoy a higher Tobin's Q, and thus a higher market valuation

5.2.3 Idiosyncratic risk vs p00 (Low oil and gas hedging)

The next variable of interest that yields a significant result is the bivariate probabilistic variable (p00 in this case) is risk. As we can see on Table 12, we obtain a positive regression coefficient (0.03195), significant at the 5% level. The result above suggests that companies that have displayed a low propensity to hedge both their oil and gas productions have experienced more risk. More risk, which can be reflected by more volatile earnings and a more volatile share price, can erode shareholder value because it increases the uncertainty of cash flows and can cause the firm to incur costs associated with financial distress as a consequence.

Some other control variables also yield significant results such as EPS from operations (-) significant at 10%, leverage (+) significant at 1%, dividend payout (-) significant at 1%, oil reserves (-) significant at 5%, institutional ownership (-) significant at 1%, oil diversification (+) significant at 1%, gas diversification (-) significant at 1%, and oil price volatility and spot price (+) significant at 1% and 5%,

Table 12: p00 vs Idiosyncratic risk linear regression

idrisk_std_v2	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
p00	.032	.016	2.00	.048	0	.064	**
EPS from operations	-.001	0	-1.69	.095	-.001	0	*
Investment opportunities	.001	.004	0.35	.726	-.006	.009	
Leverage ratio	.021	.008	2.74	.008	.006	.036	***
Liquidity ratio	-.003	.002	-1.19	.239	-.007	.002	
Dividend payout	-.009	.002	-3.87	0	-.013	-.004	***
Oil reserves	-.004	.002	-2.42	.018	-.008	-.001	**
Institutional ownership	-.012	.003	-3.56	.001	-.019	-.005	***
Oil geographical diversification	.009	.004	2.48	.015	.002	.016	**
Gas geographical diversification	-.023	.008	-2.77	.007	-.039	-.006	***
Oil price volatility	.002	0	8.20	0	.002	.003	***
Oil spot price	0	0	-1.93	.057	0	0	*
Oil production risk	-.003	.004	-0.75	.454	-.012	.005	
Gas hedge ratio	0	.004	0.01	.992	-.008	.008	
Gas spot price	-.001	0	-1.50	.138	-.001	0	
Gas price volatility	-.001	.001	-1.33	.188	-.003	.001	
Gas reserves	-.004	.003	-1.32	.192	-.011	.002	
Gas production risk	.001	.004	0.35	.729	-.007	.01	
CEO ownership	-.197	.207	-0.95	.345	-.609	.216	
Number of CEO's options	0	0	0.69	.494	0	0	
Number of analysts following firm (quarterly)	0	0	-1.29	.202	-.001	0	
Constant	.035	.012	3.01	.003	.012	.059	***

Mean dependent var	0.025	SD dependent var	0.019
R-squared	0.492	Number of obs	629.000
F-test	20.643	Prob > F	0.000
Akaike crit. (AIC)	-3590.248	Bayesian crit. (BIC)	-3492.477

**** p<.01, ** p<.05, * p<.1*

5.3 Results and future works

The summarized results converge to the conclusion that hedging in the oil and gas industry has a positive impact on the value of the firm. Starting with the Tobin's Q regression, the positive result associated with high hedgers of oil and gas suggests that these firms have experienced higher market valuations as a result.

In contrast, in the return on equity regression, the negative coefficient associated with low hedgers of oil and gas suggests that the profitability of these firms was lower as a result. This is also echoed by Table 14 in the Appendix where we regress the Tobin's Q against p00 (low hedgers of oil and gas). In that table, although we do not arrive at a significant result for the coefficient, its negative sign hints at the fact that low-hedging firms tend to experience low market valuations.

Finally, the last variable we explored in this chapter is risk, and the positive coefficient shows that low hedgers experience more risk compared to firms that hedge more intensely.

We can also note that we do not find significant evidence to suggest that hedging one energy commodity more than the other yields a higher valuation, better accounting metrics and lower risk. Thus, we cannot make a categorical claim as to which of oil or gas is preferable to hedge for firms that extract both.

Given these results, we find probing evidence that hedging has a positive impact of the value of the firms sampled in this study. This result contradicts some findings in the literature that also focused on the oil and gas industry. One such study was conducted by Lookman (2004). Lookman finds that, in the case where oil and gas exploration and production companies are undiversified and hedge their primary risk exposure, which is a commodity price, hedging results in a lower firm value.

However, in the case where an oil and gas firm is diversified, and their hedge protects against a secondary risk exposure, hedging actually results in a higher firm value. While we did not categorize the firms in our sample by segment diversification, the evidence points to the fact that, on an aggregate basis, we find that more intense hedging results in a higher firm value.

An opportunity for a future expansion of this paper would be to add a binary variable to the mix that would discriminate between segment diversification between firms. By considering whether a firm face a primary or secondary risk correlated with oil and gas prices, we could learn more about the optimal hedging strategy that firms should adopt, and we could unlock some more insight on the hedging mechanism and its influence on firm value.

This study leads the way to a lot of future works that can add to this study is to explore the relationship between hedging propensity and other variables. For instance, another variable that we could add in the dependent variables of our multivariate regressions is cash flow volatility. With this addition, we could empirically test the impact of hedging on the cash flow question, which would then allow us to introduce other variables like borrowing costs, and discretionary investments like research and development. This would help us to evaluate the findings of Minton and Schrand (1999), who found evidence that higher levels of cash flow volatility are associated with lower levels of discretionary investments, and that higher cash flow volatility is associated with higher borrowing costs. In addition, we could also narrow the focus by looking at the tax effect on hedging. We could achieve this by finding an appropriate proxy for tax convexity to regress our probabilistic variables, and we could expand the question by looking at tax incentives associated with hedging such as tax loss carryforwards.

Another interesting area to explore for future works is the hedging strategy itself as well as the effect of characteristics of the derivative instruments chosen by firm in the oil. For instance, we could introduce proxy variables of linearity that hedgers in the oil and gas industry use and evaluate how that affects the value of the firms in the sample.

Finally, another potential expansion would be to regress proxies for firms' enterprise risk management quality and infrastructure as well as qualitative proxy variables for key assets like the Chief Risk Officer's qualifications. Moreover, we could use proxies for corporate governance to evaluate whether or not management quality and governance measures has a measurable, tangible impact on firm value as well the characteristics of the overall hedging strategy that a firm chooses to undertake.

Conclusion

The existence of a "hedging premium" is a controversial, yet very important concept. Indeed, hedging decision-making can have crucial repercussions on a firm's enterprise risk management strategy, and its costs are substantial. Modigliani and Miller (1958) proposed the concept of irrelevance with regards to hedging in the sense that, in a frictionless market environment, the value of a hedged firm should be identical to the value of an un-hedged firm. The value of a firm is theoretically all predicated on the amount of cash flow the firm can generate given its assets. Intuitively, the firm can exchange a high-risk cash flow stream for a low-risk cash flow stream, which embodies the idea of hedging. However, in doing so, the firm also forgoes the high return that is associated with a high risk cash flow stream, and therefore, on a risk-adjusted basis, both of these cash flows' values are equal, which translates in the value of the firms being unaffected by their hedging activities. However, the key assumption is that markets are frictionless. Since that is not the case due to factors like transaction costs, distress and bankruptcy costs, to name a few, the question remains as to whether or not hedging is justified and cost-effective as a means of increasing firm value.

The literature is divided in providing a definitive conclusion on the subject, however, industry spending on hedging activities demonstrates that managers believe that it provides a benefit to the firm. In fact, companies in the oil and gas industry spend billions of dollars in capital, year in, year out, in hedging instruments; this makes the question economically significant. The oil and gas industry is also a great testing ground for this claim because these firms face the primary risk of oil and gas risk price fluctuations, which are subject to many factors such as global demand, geopolitical factors, demographic trends, and more. These factors therefore affect the bottom line, as well as earnings and cash flow volatility, prompting managers and risk management departments to attempt to smooth their earnings by hedging their production by locking in prices, thus weathering uncertainty.

In this paper, we attempt to answer questions that offer a multi-faceted understanding of the hedging quandary. First, we asked ourselves the following: what are the determinants of hedging? We proceeded by testing the hedging determinants for either oil or gas production, independently, and we then supplemented this with an analysis based on the firms' decisions to hedge both oil and natural gas simultaneously.

Interestingly, we found that oil and gas firms adjust their hedging activities based on the global demand for oil, which we proxied using the change in the Kilian index, a proxy of global economic activity based on a short term view of real shipping costs. What we find in our analysis, is that, jointly, hedging propensity for oil and natural gas decreases when global demand for oil increases, which raises some interesting implications on the timing of hedging and the response mangers have to changing economic conditions. We also learn what other firm characteristics play a role in the decision-making process for intense hedging, or lack thereof. When viewed independently, the decision to hedge the oil and gas at a different level in response to changes in the global demand for oil raises interesting questions. For instance, we tackle how the cointegration of oil and gas prices, and the way oil and gas are related in the way they are produced, affects the hedging propensity of firms depending on market conditions and global demand for oil.

Then, we tested for a "hedging premium" by analyzing whether or not firms' value was enhanced as a result of hedging. We regressed value, accounting performance and risk measures on different combinations of hedging behavior. We found evidence for a "hedging premium" as indicated by the following: we found a positive relationship between firms with a high propensity to hedge and their Tobin's Q. This implied that firms with a tendency to hedge more than their counterparts enjoy higher market valuations, which is in line with the idea of a hedging "premium".

In addition, we found a negative relationship between firms with a low hedging propensity for their oil and natural gas productions and their return on equity. This cements the previous claim that hedging has a net positive impact on a firm because firms with a low propensity for hedging underperform their counterparts with a higher propensity to hedge their production. Finally, we found evidence to suggest that firms with a low propensity to hedge face significantly more risk, which translates into higher financial distress costs and more volatile earnings. Hedging is a costly proposition, one which is still heavily debated in the literature, however, our paper offers validity to the claim that the benefits of hedging outweigh its costs, and serves to increase firm value.

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Appendix

Table 13. p11 panel regression results

	(1) Tobin's Q	(2) ROE	(3) Oil Beta	(4) Idiosyncratic Risk	(5) Market Beta
p11	.835**	.151	-.166	-.018	-.141
	(.406)	(.342)	(.174)	(.014)	(.345)
EPS from operations	.001	.117***	.008**	-.001	-.01
	(.008)	(.022)	(.003)	(0)	(.016)
Investment opportunities	.157	.05	.036	.001	.053
	(.159)	(.088)	(.077)	(.005)	(.106)
Leverage ratio	.337	-.216	-.083	.021***	-.159
	(.235)	(.16)	(.061)	(.008)	(.236)
Liquidity ratio	.158***	.035	-.032	-.001	-.027
	(.048)	(.049)	(.022)	(.002)	(.061)
Dividend payout	.135	-.028	-.093***	-.007***	-.297***
	(.085)	(.045)	(.024)	(.002)	(.079)
Oil reserves	-.214**	.034	.043**	-.005**	-.016
	(.095)	(.047)	(.019)	(.002)	(.066)
Institutional ownership	.273**	-.001	-.038	-.01***	.092
	(.128)	(.056)	(.035)	(.003)	(.12)
Oil geographical diversification	.043	-.034	.031	.009*	-.002
	(.156)	(.108)	(.055)	(.005)	(.141)
Gas geographical diversification	.377	-.057	-.143*	-.012*	-.119
	(.275)	(.159)	(.078)	(.007)	(.22)
Oil price volatility	-.051***	-.014	-.004	.002***	.051***
	(.009)	(.01)	(.003)	(0)	(.008)
Oil spot price	.002	-.001	.002***	0**	-.001
	(.002)	(.001)	(0)	(0)	(.001)
Oil production risk	-.002	-.125	-.033	-.004	-.165
	(.159)	(.091)	(.056)	(.004)	(.152)
Gas hedge ratio	-.166	.01	-.059	.001	-.436***
	(.109)	(.098)	(.041)	(.004)	(.118)
Gas spot price	.047***	-.018	-.01*	-.001**	.018
	(.013)	(.018)	(.005)	(0)	(.015)
Gas price volatility	-.02	.024	.037**	-.001	.064
	(.027)	(.045)	(.016)	(.001)	(.059)
Gas reserves	-.134	-.026	-.018	-.005	.248**
	(.091)	(.053)	(.026)	(.003)	(.097)
Gas production risk	.039	-.05	-.009	.002	-.286
	(.213)	(.097)	(.047)	(.004)	(.193)
CEO ownership	8.953	-1.303	-3.173*	-.088	-3.073
	(7.247)	(2.555)	(1.673)	(.135)	(6.14)
Number of CEO's options	0**	0	0**	0	0
	(0)	(0)	(0)	(0)	(0)
Number of analysts following firm (quarterly)	.036***	.002	-.001	0	-.014*
	(.01)	(.007)	(.003)	(0)	(.008)
Constant	.912***	.24**	.309***	.054***	.635**
	(.237)	(.118)	(.089)	(.009)	(.296)
Observations	649	644	629	629	629
R-squared	.283	.212	.109	.488	.132

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

Table 14. p00 panel regression results

	(1) Tobin's Q	(2) ROE	(3) Oil Beta	(4) Idiosyncratic Risk	(5) Market Beta
p00	-.465	-.863**	-.169	.032**	.199
	(.452)	(.349)	(.183)	(.016)	(.422)
EPS from operations	.004	.118***	.008**	-.001*	-.01
	(.008)	(.022)	(.003)	(0)	(.016)
Investment opportunities	.279*	-.028	-.021	.001	.048
	(.157)	(.06)	(.057)	(.004)	(.101)
Leverage ratio	.341	-.226	-.088	.021***	-.159
	(.24)	(.156)	(.061)	(.008)	(.236)
Liquidity ratio	.108	.124**	.011	-.003	-.034
	(.071)	(.055)	(.028)	(.002)	(.071)
Dividend payout	.111	.035	-.065***	-.009***	-.304***
	(.085)	(.044)	(.025)	(.002)	(.086)
Oil reserves	-.198**	.017	.032*	-.004**	-.016
	(.095)	(.045)	(.019)	(.002)	(.065)
Institutional ownership	.208	.088	.009	-.012***	.088
	(.129)	(.073)	(.037)	(.003)	(.139)
Oil geographical diversification	-.082	.038	.087***	.009**	.005
	(.172)	(.062)	(.032)	(.004)	(.133)
Gas geographical diversification	.32	.359*	.012	-.023***	-.175
	(.386)	(.215)	(.133)	(.008)	(.308)
Oil price volatility	-.051***	-.019*	-.006*	.002***	.052***
	(.009)	(.01)	(.003)	(0)	(.008)
Oil spot price	.003*	-.002	.002***	0*	-.001
	(.001)	(.001)	(0)	(0)	(.001)
Oil production risk	-.011	-.138	-.035	-.003	-.161
	(.159)	(.094)	(.057)	(.004)	(.152)
Gas hedge ratio	-.144	.017	-.062	0	-.44***
	(.108)	(.097)	(.041)	(.004)	(.117)
Gas spot price	.051***	-.026	-.013**	-.001	.019
	(.014)	(.019)	(.006)	(0)	(.016)
Gas price volatility	-.028	.024	.04**	-.001	.065
	(.027)	(.045)	(.016)	(.001)	(.059)
Gas reserves	-.118	-.062	-.034	-.004	.253**
	(.091)	(.053)	(.024)	(.003)	(.101)
Gas production risk	.067	-.037	-.011	.001	-.292
	(.218)	(.096)	(.048)	(.004)	(.195)
CEO ownership	7.827	3.169	-1.368	-.197	-3.608
	(6.987)	(2.586)	(1.919)	(.207)	(7.658)
Number of CEO's options	0**	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Number of analysts following firm (quarterly)	.03***	.012	.004	0	-.015*
	(.01)	(.008)	(.003)	(0)	(.009)
Constant	1.398***	.613**	.308***	.035***	.507*
	(.305)	(.243)	(.096)	(.012)	(.288)
Observations	649	644	629	629	629
R-squared	.274	.219	.108	.492	.132

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

Table 15: p10 panel regression results

	(1) Tobin's Q	(2) ROE	(3) Oil Beta	(4) Idiosyncratic Risk	(5) Market Beta
p10	-.836	.939**	.242	-.022	.177
	(.583)	(.431)	(.234)	(.019)	(.53)
EPS from operations	.011	.11***	.006	0	-.012
	(.01)	(.023)	(.004)	(0)	(.016)
Investment opportunities	.323**	.1*	.005	-.003	.026
	(.151)	(.053)	(.063)	(.004)	(.084)
Leverage ratio	.393	-.266	-.099*	.022***	-.171
	(.238)	(.161)	(.059)	(.008)	(.241)
Liquidity ratio	.033	.033	-.006	.001	-.005
	(.047)	(.026)	(.015)	(.001)	(.04)
Dividend payout	.071	-.039	-.08***	-.006***	-.286***
	(.076)	(.032)	(.02)	(.002)	(.075)
Oil reserves	-.162*	.013	.03	-.005**	-.026
	(.094)	(.043)	(.021)	(.002)	(.064)
Institutional ownership	.14	-.015	-.01	-.008***	.115
	(.112)	(.064)	(.03)	(.003)	(.127)
Oil geographical diversification	-.241	.05	.097***	.01**	.05
	(.178)	(.073)	(.031)	(.004)	(.154)
Gas geographical diversification	.343	-.426**	-.161**	.002	-.125
	(.3)	(.172)	(.071)	(.008)	(.25)
Oil price volatility	-.048***	-.014	-.005*	.002***	.051***
	(.008)	(.01)	(.003)	(0)	(.008)
Oil spot price	.004***	-.002	.002***	0*	-.001
	(.002)	(.001)	(.001)	(0)	(.001)
Oil production risk	.004	-.135	-.035	-.003	-.166
	(.161)	(.092)	(.056)	(.004)	(.152)
Gas hedge ratio	-.151	.02	-.061	0	-.438***
	(.109)	(.098)	(.041)	(.004)	(.118)
Gas spot price	.05***	-.01	-.01*	-.001***	.018
	(.015)	(.015)	(.006)	(0)	(.014)
Gas price volatility	-.027	.02	.038**	-.001	.065
	(.027)	(.045)	(.016)	(.001)	(.059)
Gas reserves	-.132	.022	-.014	-.007*	.25***
	(.088)	(.047)	(.028)	(.004)	(.094)
Gas production risk	.022	0	-.001	.001	-.281
	(.216)	(.097)	(.048)	(.004)	(.192)
CEO ownership	8.101	-5.439	-3.267**	.077	-3.05
	(7.615)	(3.647)	(1.579)	(.121)	(5.007)
Number of CEO's options	0*	0	0*	0	0
	(0)	(0)	(0)	(0)	(0)
Number of analysts following firm (quarterly)	.023***	.001	.002	0	-.012*
	(.007)	(.004)	(.001)	(0)	(.006)
Constant	1.297***	.219	.226***	.049***	.566**
	(.253)	(.137)	(.081)	(.011)	(.255)
Observations	649	644	629	629	629
R-squared	.276	.216	.108	.486	.132

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

Table 16: p01 panel regression results

	(1) Tobin's Q	(2) ROE	(3) Oil Beta	(4) Idiosyncratic Risk	(5) Market Beta
p01	-.403	.163	.35*	.008	-.106
	(.601)	(.383)	(.177)	(.018)	(.522)
EPS from operations	-.001	.12***	.012***	-.001	-.012
	(.01)	(.021)	(.004)	(0)	(.017)
Investment opportunities	.31**	.094	.025	-.002	.015
	(.149)	(.059)	(.065)	(.004)	(.094)
Leverage ratio	.325	-.204	-.065	.021***	-.168
	(.238)	(.158)	(.06)	(.008)	(.234)
Liquidity ratio	.058	.012	-.018*	.001	-.006
	(.041)	(.021)	(.01)	(.001)	(.041)
Dividend payout	.067	-.038	-.076***	-.006***	-.288***
	(.076)	(.031)	(.019)	(.002)	(.075)
Oil reserves	-.2**	.045	.05**	-.005**	-.025
	(.096)	(.048)	(.02)	(.002)	(.068)
Institutional ownership	.159	-.028	-.023	-.008***	.116
	(.112)	(.056)	(.029)	(.003)	(.124)
Oil geographical diversification	-.049	-.102	-.011	.011**	.052
	(.189)	(.113)	(.059)	(.006)	(.18)
Gas geographical diversification	-.139	-.031	.097	-.001	-.12
	(.374)	(.23)	(.124)	(.009)	(.333)
Oil price volatility	-.047***	-.013	-.005**	.002***	.051***
	(.008)	(.01)	(.003)	(0)	(.008)
Oil spot price	.002	0	.003***	0**	-.001
	(.002)	(.001)	(.001)	(0)	(.002)
Oil production risk	-.002	-.127	-.035	-.004	-.163
	(.16)	(.089)	(.057)	(.004)	(.152)
Gas hedge ratio	-.154	.017	-.055	0	-.442***
	(.109)	(.097)	(.041)	(.004)	(.118)
Gas spot price	.06***	-.018	-.014**	-.001***	.017
	(.016)	(.018)	(.006)	(0)	(.014)
Gas price volatility	-.027	.022	.037**	-.001	.066
	(.026)	(.046)	(.016)	(.001)	(.059)
Gas reserves	-.076	-.027	-.044*	-.006**	.248**
	(.079)	(.041)	(.023)	(.003)	(.101)
Gas production risk	.066	-.046	-.017	.002	-.289
	(.22)	(.095)	(.049)	(.004)	(.197)
CEO ownership	3.047	-1.205	-.654	.035	-2.932
	(7.828)	(3.05)	(1.653)	(.18)	(6.832)
Number of CEO's options	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Number of analysts following firm (quarterly)	.024***	0	.002	0	-.012*
	(.007)	(.004)	(.002)	(0)	(.006)
Constant	1.298***	.268	.188**	.046***	.598**
	(.293)	(.183)	(.079)	(.011)	(.273)
Observations	649	644	629	629	629
R-squared	.273	.211	.112	.485	.132

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*