The Impact of Hedging on Stock Return and Firm Value: New Evidence from Canadian Oil and Gas Companies

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Abstract

In this paper we analyze the impact of hedging activities of large Canadian oil and gas companies on their stock return and firm value. Differing from the existing literature this research pays particular attention to possible nonlinear payoffs of hedging activities, which may not be fully revealed in the traditional linear framework. By using generalized additive models, we find that the factors that affect stock return and firm value are indeed nonlinear. The large Canadian oil and gas firms are able to hedge against downside risk induced by unfavorable oil and gas price changes. But gas hedging appears to be more effective than oil hedging when downside risk presents. In addition, oil reserves tend to have a positive (negative) impact on stock returns when the oil prices are increasing (decreasing). Finally, hedging, in particular hedging for gas, together with profitability, leverage and reserves, has a significant impact on firm value.

Keywords: hedging, risk management, oil and gas, equity returns, Tobin's Q ratio, generalized additive model, semi-parametric model, nonlinearity

JEL classification: G100, C100

1 Introduction

According to the Modigliani-Miller theorem, in a perfect financial market, hedging would add no value to the firm when there is no asymmetric information, taxes, or transaction costs. However, in the real world, this conclusion may not hold because the assumptions on which the theorem is based are generally violated.

Maximizing shareholder value is one of the aims of the corporate management. Generally, maximizing shareholder value means maintaining and increasing the cash flow of the corporation over time. Hedging can be an effective tool for dealing with the impact of unexpected events on shareholder value. Hedging activities take various forms including managing price risk, protecting mortgage portfolios from interest rate volatility, preventing erosion in the value of cash reserves, deriving better returns on short-term investments, locking in a future interest rate, enhancing the yield of an investment portfolio, designing an effective foreign currency swap program and so on. Theoretically, hedging prevent shareholders from incurring unexpected losses but also decrease the potential for gains. When hedging is implemented properly, it may protect stock return and increase firm value.

But does hedging actually affect firm value? The literature has not yet reached a consensus and evidence is somewhat mixed. Some empirical studies support the hypothesis but some do not. The literature on the effectiveness of hedging has focused primarily on the hedging activities in the financial and commodity risk management. The former includes currency and interest rate hedging. Jorion (1990) illustrates that the foreign currency beta of the U.S. multinational companies is close to zero, meaning hedging on foreign currency does not influence firm value at all. Gagnon et al. (1998) employ constructed currency portfolios to show that dynamic hedging strategies can indeed reduce risk. Allayannis and Weston (2001) use a linear model for the U.S. data and find that hedging enhances firm value. Bartram et al. (2003) examine a large sample of multi-industry companies and find that interest rate hedging, not currency hedging, has a positive impact on firm value. Commodity hedging includes hedging activities on grain, jet fuel, oil and gas, and precious metal such as gold. Sephton (1993) shows that the commodity hedge ratio can be best estimated with the GARCH models. Tufano (1996) studies the hedging activities of North American gold mining firms and finds little evidence to support risk management as a means of maximizing shareholder value. On the other hand, Carter et al. (2003) investigate hedging for jet fuel by firms in the U.S. airline industry and find that jet fuel hedging increases firm value of the airline industry. But in the most recent study of the U.S. oil and gas companies Jin and Jorion (2005) find that hedging oil and gas prices has little impact on firm value.

Although empirical studies have evaluated the impact of hedging activities on firm value, no study has ever examined the role of hedging in Canadian oil and gas companies.[1] Canada is recognized as the 3rd largest producer of natural gas and the 9th largest producer of crude oil in the world. Canada has significant, untapped natural gas reserves, with the largest growth areas expected in the North and on the East Coast.[2] Canada also has huge tar sand reserves, second to the petroleum reserves of Saudi Arabia. Because of Canada's geography, more than 80% of the oil and gas production is exported to the U.S.[3] For Canadian oil and gas producers, oil and gas prices, foreign exchange rates, and interest rates can generate financial and operational uncertainties. It is known that some large Canadian oil and gas companies have been using hedging to reduce the impact of oil and gas price volatility. But there is no systematic study, neither is there any empirical evidence, on the roles that hedging activities have played in the Canadian oil and gas industries.

[1]Haushalter (2000) has studied the reasons for using hedging in the U.S. oil and gas companies while Jin and Jorion (2005) have studied the impact of hedging activities in the U.S. oil and gas companies on firm value.

[2]The data is from Natural Resource Canada (NRC) 2003 annual reports.

[3]The data is 2003 annual reports of Canadian Association of Petroleum Producers (CAPP).

The purpose of this paper is therefore to examine the impact of hedging activities on stock returns and firm value of large Canadian oil and gas companies and to add new evidence on the roles of hedging activities. As pointed out by Jin and Jorion (2005), studying oil and gas industries for hedging has a number of advantages. First, the volatility of oil and gas prices can influence the cash flow of oil and gas companies directly and immediately. Second, the homogeneity of the oil and gas industries renders the study of hedging effects on Tobin's Q ratio based on the oil and gas industries more appropriate than those multi-industry studies where other significant factors may come into play. Third, because oil and gas reserves are main parts of the value of oil and gas companies, hedging may potentially influence profitability and firm value.

This study uses a unique data set manually collected from large Canadian oil and gas companies during the period of 2000-2002. In this period, the oil and gas prices were volatile. The data collection procedure used here follows the method of Allayannis and Weston (2001), Carter et al. (2003) and Jin and Jorion (2005). It also considers the unique situations in Canada. In the existing study using the U.S. data, hedging data were typically collected from Item 7A "Quantitative and Qualitative Disclosures about Market Risk" in the 10-K annual reports for the U.S. companies. However, the 10-K reports are not generally available for most Canadian oil and gas companies. Only Imperial Oil and Nexen have filed the 10-K reports but there is no hedge information available in Item 7A for Imperial Oil and no Item 7A for Nexen at all. This research therefore collects the hedging data on futures, options, and swap contracts as well as fixed-price physical delivery contracts and volumetric production payments directly from the annual reports of these companies. This method is more precise than just employing notional amount of derivatives or hedging dummy variables. The accounting data, such as market value and dividend, are retrieved from the Datastream database.[4] After extensive search, thirty-three companies that have hedging and reserves data during

[4]Datasteam is a comprehensive database for global investment research, providing historical international data on broad economic and financial matters, including company accounts, economic indicators, equity, bonds, futures and options, commodities and interest rates, made by Thomson Financial.

the period are identified, resulting the annual data of eighty-eight firm-years. Among them, twenty-eight companies and seventy-six firm-years are identified with the complete hedging, reserves and accounting data. In order to evaluate the impact of the hedging on stock returns, we augment the data by incorporating month stock returns, resulting the monthly data of eight hundred and eighty-one firm-months. To our knowledge, this is perhaps the most comprehensive data for large Canadian oil and gas companies at this time.

The statistical analysis of the data in this paper shows that relationships between hedging activities and payoffs (stock returns and firm value) are generally nonlinear. The linear models traditionally employed in the existing research literature may be too restricted for identifying nonlinear effects. They can be biased and misleading if the true relationships are nonlinear. Therefore, this research proposes the use of the flexible generalized additive models (GAM) [see Hestie (1990), Hestie and Tibshirani (1990), Wood (2000), Venables and Ripley (2002), and Wood (2004)], which is semi-parametric in nature. As shown later in the paper, GAM is statistically superior to the linear model because GAM can accommodate both linear and nonlinear relationships without being restricted to the former.

By using the unique data and GAMs, this research presents new empirical evidence on the roles of hedging activities in the Canadian oil and gas sector. This research finds that the large Canadian oil and gas firms are able to use hedging to protect downside risk against unfavorable oil and gas price changes. But gas hedging appears to be more effective than oil hedging when downside risk presents. In addition, oil reserves tend to have a positive (negative) impact on stock returns when the oil prices are increasing (decreasing). Finally, hedging, in particular gas hedging, together with profitability, leverage and reserves, has a significant impact on firm value.

The remainder of the paper is organized as follows: Section 2 reviews the related literature. Section 3 explains the data collection and sample information. Section 4 reports the findings about the impact of hedging activities on the relationship between oil and gas prices and stock returns. Section 5 discusses the findings of the impact of hedging on firm value. Finally, Section 6 offers concluding remarks.

2 Hedging Literature

2.1 Roles of Hedging

When the financial market is imperfect, hedging activities of a firm can directly affect the volatility of cash flow. When oil/gas price falls, the oil/gas producer will lose revenue if it does not use fixed-price contracts or options to hedge against the risk of price volatility. When the income of a firm surges, tax liability of the firm will increase the context of a convex tax schedule.[5] In this case, hedging can help the firm to smooth its cash flow and to avoid the volatility of the cash flow exacerbated by the tax regime.

In the theoretical literature on hedging, three main motivations for hedging are discussed. First, hedging is used to reduce financial distress and avoid underinvestment. Second, it is used to reduce expected tax costs. Third, hedging can alleviate the manager's personal risk exposure. These are reviewed as follows.

2.1.1 Financial Distress and Underinvestment

When high volatility of cash flow is expected to cause a mismatch between the available liquidity and fixed payment obligations, managers need to consider and implement hedging. Smith and Stulz (1985) analyze the impact of hedging on expected bankruptcy costs and find that hedging can reduce the likelihood of financial distress of the firm, lower its expected bankruptcy costs, and therefore increase its debt capacity and firm

[5] This refers to the schedule where the effective tax rate is greater as the taxable income gets higher.

value. Mayer and Smith (1990) also find that the firm, by reducing cash flow volatility via hedging, can effectively reduce bankruptcy costs, minimize the loss of tax shields, and secure valuable growth options.

From the theoretical perspective, Stulz (1990) and Froot et al. (1993) note that hedging can help companies to maintain adequate internal funds available for good investment opportunities and thus avoid underinvestment. Without risk management, firms sometimes are forced to pursue suboptimal investment opportunities because low cash flow can prevent firms from pursuing optimal investment opportunities or obtaining low-cost financing. Therefore, everything else being equal, the more difficulties firms face in obtaining external financing, the less sufficient cash flow there will be, and the higher hedge premium these firms will pay. By analyzing cash flow in a two-period investment/financing decision model, Froot et al. (1993) find that firms with costly external financed projects would be better off utilizing risk management to reduce the influence of external financing on these projects.

Allayannis and Mozumdar (2000) conduct an empirical study of the S&P 500 non-financial firms and find that firms significantly exposed to the foreign exchange rate risk can use foreign currency derivatives to reduce their dependence on external cash flow for investment. Adam (2002) examines the roles of hedging in 111 North American gold mining companies and finds a positive relationship between the minimum revenue guaranteed by hedging and investment expenditures. The empirical evidence suggests that hedging can increase the likelihood of internal financing for investment and reduce its dependence on external financing.

2.1.2 Expected Tax Costs

Smith and Stulz (1985) discuss the tax-induced explanation for risk management. In the presence of a convex tax schedule, the firm can employ risk management to reduce the volatility of taxable income that would otherwise be exacerbated by the expected tax liabilities. The firm tends to hedge when it has high leverage, shorter debt maturity, lower interest coverage, less liquidity, and high dividend yields because it prefers stable cash flow. Therefore reducing the volatility of taxable income generates greater firm value if the firm faces a convex tax function. Graham and Smith (1999) empirically analyze more than 80,000 COMPUSTAT firm-year cases based on three measures for effective tax functions.[6] They find that, in approximately 50% of the cases, convex tax schedules lead to tax-based incentives to hedge. Graham and Rogers (2002) use the data of 3,232 U.S. companies and an explicit measure for the convex tax schedule and find that hedging does not reduce tax liability when facing a convex tax schedule. However, they suggest that these firms may smooth incomes by other means.

2.1.3 Managerial Risk

According to Stulz (1984) and Smith and Stulz (1985), risk averse managers tend to use hedging if they have a direct interest in the business earnings and if it is costly to hedge for their own accounts. Smith and Stulz (1985) note that managers holding more stocks of their own firms would emphasize risk management more than those holding more options do. This is because stocks provide linear payoffs to the managers whereas options provide convex payoffs. Further, the convexity of option payoffs may provide an incentive for the managers who hold more options to bear more risk. In addition, DeMarzo and Duffie (1995) point out that hedging may serve as a signal of managerial ability to external investors. Among a few empirical studies, Tufano (1996) examines the hedging activities of forty-eight North American gold mining companies and finds that firms whose managers hold more options use less risk management and firms whose managers holding more stocks use more risk management. This finding is consistent with the prediction of Smith and Stulz (1985). The empirical studies that support DeMarzo

[6] The three variables are tax loss carry forwards, investment tax credit, and a binary variable that indicates whether the firm is in the convex region of the tax code based on the firm's historical pretax income.

and Duffie (1995) include the work of Whidbee and Wohar (1999), which studies the information of 175 publicly traded bank holding companies and find that the managerial incentives and external monitoring affect the decision to use derivatives. In addition, Dionne and Triki (2005) find that independence and financial knowledge of the directors of the board would affect hedging decisions based on the data of the thirty-six North American gold mining firms.

2.2 Impact of Hedging on Firm Value

In the existing literature, Rajgopal (1999) analyzes the informational role of the Securities and Exchange Commission (SEC)'s market risk disclosures of thirty-eight U.S. oil and gas companies. He finds that oil and gas reserves have a positive impact on the relationship between stock returns and oil and gas prices. Jin and Jorion (2005) extend the work of Rajgopal (1999) by adding hedging variables and find that hedging can weaken the relationship between stock returns and oil and gas prices while oil and gas reserves can strengthen the relationship.

Allayannis and Weston (2001) directly examine the relationship between foreign currency hedging and firm value measured by Tobin's Q ratio, based on a sample of 720 American non-financial firms with total asset more than USD$500 million. By adding some control variables such as profitability and leverage into the regression model, they find that hedging is positively related to firm value and that firms with hedging have, on average, 4.87% higher firm value than those without. Geczy et al. (1997) analyze foreign currency derivatives of Fortune 500 companies and find that hedging for foreign currency risk is more difficult to evaluate in multinational companies because the net impact of hedging can be distorted by many other factors such as foreign sales, foreign-denominated debts, foreign taxes, etc. Using the framework of Allayannis and Weston (2001), Carter et al. (2003) examine the impact of jet fuel hedging on firm value based on the sample of twenty-seven American airline companies. They find that jet fuel hedging is positively related to airline firm value. The coefficients on the hedging variables in their regression suggest that the hedging premium contributes approximately a 12-16 percent increase in firm value. Jin and Jorion (2005) examine the hedging activities of 119 American oil and gas companies to evaluate the impact of oil and gas hedging on firm value. But they find no evidence to support the view that hedging affects firm value.

It is noted that the existing literature primarily focuses on linear models of hedging and firm value using the American data and that there is only one major study on the U.S. oil and gas industry. This paper attempts to contribute to the literature by studying hedging and firm value for Canadian oil and gas companies based on more flexible semi-parametric nonlinear models.

3 Data and Sample Description

3.1 Sample Description

There are several issues that one must face in the data selection from the universe of the Canadian oil/gas exploration and production companies. First, the Canadian economy has a strong resource and mining sector with many oil and gas exploration and production firms. Many of them, however, are small exploration firms and generally not involved in hedging activities.[7] Hence we need to select relatively large and mature oil and gas exploration and production firms which are involved in hedging activities. Second, some of the large oil and gas companies with hedging activities are integrated oil and gas companies. That is, they are not only involved in the oil and gas exploration but also engaging in refinery and marketing. In order to evaluate the role of hedging activities, it is essential to include these companies. Ignoring them would cause the

[7] The detailed analysis is given below.

loss of valuable information and lead to a rather small sample which is unlikely to give us an accurate picture. Third, some substantial oil and gas players in Canada are partly owned by international corporations and partly owned by investors in Canada (for example, Imperial Oil is partly owned by ExxonMobil in the US, Husky Energy is partly owned by Hutchison Whampoa in Hong Kong, China, and Shell Canada is partly owned by the Royal Dutch Shell in Holland). These oil and gas firms also constitute a large share of the Canadian oil and gas industries and should be duly included. Fourth, Canadian economy is about one-tenth of the size of the US economy. Compare to the similar studies for the US oil and gas industries, the Canadian sample size would be considerably smaller. Therefore, we should use as much as the relevant information as we can while bearing in mind the limited scope of the Canadian oil and gas industries.

In order to find a largest relevant sample of oil and gas companies in Canada, we have selected oil and gas companies with market value more than Cdn$500 million in 2004.[8] Thirty-eight oil/gas exploration and production companies (for example, EnCana, Canadian Natural Resources, Talisman Energy, and Nexen) and eight oil integrated companies (for example, Suncor Energy, Petro-Canada, Imperial Oil, and Husky Energy) meet the criterion. Thirty-three of oil and gas companies of the above list have filed reports with the System for Electronic Document Analysis and Retrieval (SEDAR) during the period of 2000-2002. Thus, we have eighty-eight firm year data, of which seventy-one firm-year data (about 80.7%) are for oil nad gas exploration and production companies and seventeen firm year data (about 19.3%) are for integrated oil companies. The largest five companies in the sample are Encana,[9] Imperial Oil., Shell Canada, Suncor Energy, and Petro-Canada, whose average market value is Cdn$23.8 billion in 2004. The smallest five firms are Gastar Exploration, Crescent Point Energy, Nuvista Energy, Ketch Resource, and Pan-Ocean Energy, whose average market value is about Cdn$522 million in 2004.

[8]The hedging activities and records of these oil and gas firms are more likely to be available and documented systematically. SEDAR is developed in Canada for the Canadian Securities Administrators (CSA).The annual reports from SEDAR are available in www.sedar.com.

[9]Encana was established from merging Alberta Energy Company Ltd. and PanCanadian Energy Corporation in 2001.

Because we are interested in the hedging information of the selected firms, we use the financial market and accounting data of these firms for the period of 2000-2002.

When we analyze the impact of hedging on the relationship between oil and gas prices and stock returns, we use the monthly oil and gas prices from the New York Mercantile Exchange (NYMEX) and monthly stock returns of these oil and gas firms from Datastream. The monthly data are then combined with the annual accounting and hedging data, which are discussed in the following part of this paper.

3.2 Hedging Information

All the hedging information of the sample is from the annual reports of selected companies filed at SEDAR or posted at the companies' websites. The existing research such as Allayannis and Weston (2001) and Jin and Jorion (2005) collect the hedging information primarily from the 10-K annual reports. In 1997, the U.S. Securities and Exchange Commission (SEC) declared Financial Reporting Release No.48 (FRR 48), which require disclosure for market risk for all firms for the fiscal year ending after June 15th, 1998.[10] However, there is no such regulation for Canadian companies at the time of this research. Hedging information may be found directly in two parts of an annual report: (a) Risk Management of Management's Discussion and Analysis and (b) Financial Instruments in Notes of Consolidated Financial Statement (see Appendix 1 for an example). In general, the information in Management's Discussion and Analysis highlights the hedging activities in the fiscal year. The information in Financial Instruments in Notes of Consolidated Financial Statement details hedging contracts such as outstanding hedging contract at the end of the fiscal year. The main hedging instruments used by

[10]Under this regulation, U.S. firms are required to report in their annual reports quantitative information on exposures of contract amounts and weighted average spot prices for forwards and futures; weighted average pay and receive rates and/or prices for swaps; contract amounts and weighted average strike prices for options.

Table 1: Delta and Hedging Instruments

Delta	Hedging Instrument
-1	short *linear* contracts, including short futures and forwards, fixed-priced contracts, fixed-received swaps and volumetric production arrangements
value from Black-Scholes option models	*non-linear* contracts, including options, collars and three-way options

Note: The value of each contract is mark to the market.

Canadian oil and gas companies are fixed-price contracts, forwards, received-fixed swaps and options (including collars and three-way options) (see Appendix 2 for details).

Following the method proposed by Jin and Jorion (2005), we calculate individual deltas and sum them up for each firm for each fiscal year. This sum is a measure for the degree of hedging in each firm for that year. This method of calculating each delta is detailed in Table 1. The total delta value of crude oil and natural gas hedging for each firm-year is the sum of the products of deltas and their corresponding notional dollar values of all hedging contracts [The notional output measure of crude oil is expressed in barrel (bbl) and that of natural gas contracts is presented in million of British thermal unit (mmbtu)].

The total delta value is then scaled by the annual production or the commodity reserves, named adjusted delta, such as the adjusted delta of oil production and that of oil reserves. In this study the value of delta is zero or negative and we multiply negative one to the value to reflect the positive role of the adjusted total deltas in the stock return and firm value.

We use gas production and gas reserves as an example to show how the adjusted deltas are defined:

$$Adjusted\ delta\ of\ gas\ production\ (Dgp) = -\left(\frac{Total\ delta\ value\ of\ gas\ hedging}{Value\ of\ next\ year\ gas\ production}\right)$$

$$Adjusted\ delta\ of\ gas\ reserves\ (Dgr) = -\left(\frac{Total\ delta\ value\ of\ gas\ hedging}{Value\ of\ same\ year\ gas\ reserve}\right)$$

That is, the adjusted delta of production, *Dgp*, represents the percentage of next year production that is effectively hedged, while the adjusted delta of reserves, *Dgr*, gives the proportion of current reserves that is effectively hedged. We use *Dop* and *Dor* to denote the adjusted deltas of oil production and oil reserves, respectively.

Table 2 shows the hedging and non-hedging information of the firm-years in the sample. There are 25 non-hedging (in both oil and gas) firm-years (about 28.4% of the sample), 56 firm-years hedging oil prices exposure (about 63.7% of the sample), 50 firm-years hedging gas prices exposure (56.8% of the sample), and 43 firm-year hedging both oil and gas prices exposure (about 48.9% of the sample).

Table 3 illustrates the basic statistics of the adjusted deltas. In terms of the number of the firms that hedge, Canadian oil and gas companies hedge less relative to the oil and gas reserves than the U.S. oil and gas companies do. The average *Dop*, *Dgp*, *Dor* and *Dgr* of the U.S. oil and gas companies are 33%, 41%, 4% and 5% respectively, while those of Canadian oil and gas companies in this study are 14.6%, 8.1%, 1.8% and 1.3%, respectively.[11] These numbers show that the U.S. companies are more likely to employ risk management than their Canadian counterparts are. However, the standard deviations of *Dop* and *Dgp* for the U.S. data are 33% and 40% respectively, higher than those of the Canadian sample — 20.4% and 14.8%.[12] This suggests that the

[11] See Jin and Jorion (2005) for the U.S. numbers.
[12] See Jin and Jorion (2005) for the U.S. numbers.

Table 2: Description of Firm-years: Hedging and Non-hedging

	Gas: Hedging Firm-year Count (%)	Gas: Non-Hedging Firm-year Count (%)	Total Firm-year Count (%)
Oil: Hedging Firm-year Count(%)	43 (48.9)	13 (14.8)	56 (63.7)
Oil: Non-Hedging Firm-year Count(%)	7 (8.0)	25 (28.4)	32 (36.3)
Total Firm-year Count(%)	50 (56.8)	38 (43.2)	88 (100)

Table 3: Basic Statistics of Adjusted Deltas

Adjust Delta	Mean	Standard Deviation	No. of Firm-years
Oil Production (Dop)	14.6%	20.4%	88
Gas Production (Dgp)	8.1%	14.8%	88
Oil Reserves (Dor)	1.8%	2.6%	88
Gas Reserves (Dgr)	1.3%	2.9%	88
Production Average	11.4%		
Reserves Average	1.6%		

large Canadian oil and gas companies are more homogeneous in hedging than their U.S. counterparts.

3.3 Tobin's Q Ratio

Tobin suggested that the combined market value of all the companies on the stock market should be equal to their replacement costs [Tobin (1969) and Hayashi (1982)]. The Q ratio is theoretically defined as the market value of a firm's assets divided by the replacement value of the firm's assets. Then, when the assets are priced properly in the capital market, the Q ratio should be equal to one. The change of the Q ratio is an direct measure of the change of the firm value in the capital market.

In this paper, we use the following equation for the theoretical Q ratio:

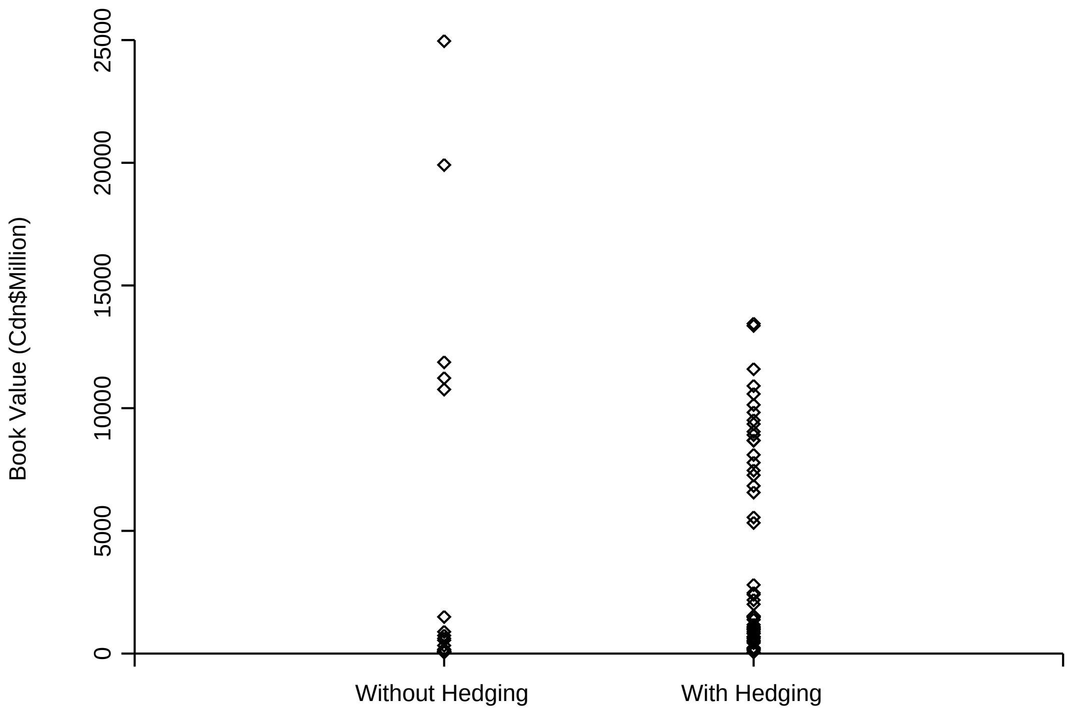
$$Q = \frac{Book\ value\ of\ liability + Market\ value\ of common\ stock}{Book\ value\ of\ total\ asset}.$$

The market value of common equity can be found in the Datastream database. The book value of liability and total assets are from the annual reports. However, several companies do not have necessary market information such as market value and stock prices during the period of 2000-2002 in the Datastream database due to mergers and corporation reconstruction. Only twenty-eight companies and seventy-six firm-years are therefore used.

Panel A in Table 4 shows the summary statistics of total asset (in millions of Canadian dollars), market value of equity (in millions of Canadian dollars), and the corresponding Q ratios. The average Q ratio is 1.56, which is similar to that of the U.S.[13] The standard deviations of the Canadian oil and gas companies' total asset and market value of equity are huge. Panels B and C of Table 4 illustrate the basic statistics of the firms with hedging activities for oil and gas prices, respectively. On average, these firms hedge about 23.0% of their next year oil production, which amounts to about 3.0% of their oil reserves, and about 148.0% of their next year gas production, which represents about 2.0% of their gas reserves. All the ratios are less than those of the U.S. oil and gas companies. The Canadian oil and gas companies do not hedge as much as their U.S. competitors do.[14] The average Q ratio for oil hedging firms is 1.35, while that of gas hedging firms is 1.31. Panel D of Table 4 shows the basic statistics of the firms without any hedging activities. The large standard deviations of total asset and market value of equity in non-hedging companies show that non-hedging occurs at both large and small

[13]See Jin and Jorion (2005).
[14]See Jin and Jorion (2005).

Figure 1: Book Value of Total Asset with or without Hedging



firms and it is not dependent on the firm size. The average Q ratio for non-hedging firms is 2.00.

Figure 1 plots the book values of total asset of the oil and gas firms with or without hedging. It shows that non-hedging companies vary substantially in size (both very small and very large) while the hedging companies are concentrated in a particular range in terms of the values of total asset. This may reflect the fact that very large firms tend to be integrated oil companies which can diversify their operations in both up- and down-streams of the exploration, production, and distribution processes.

Table 4: Basic Statistics of Adjusted Deltas

Panel A: All Firm-years				
	No. of Obs.	Mean	Std. Dev.	Median
Total Asset (Cnd$M)	76	4019.22	5195.44	1135.98
MVE (Cnd$M)	76	3574.25	4857.15	838.46
Q ratio	76	1.56	0.93	1.34
Panel B: Firm-years with Hedging Activities for Oil				
	No. of Obs.	Mean	Std. Dev.	Median
Total Asset (Cnd$M)	46	4356.03	4302.58	1857.33
MVE (Cnd$M)	46	3740.24	4083.39	1406.85
Dgp	46	0.23	0.22	0.18
Dgr	46	0.03	0.03	0.02
Q ratio	46	1.35	0.49	1.26
Panel C: Firm-years with Hedging Activities for Gas				
	No. of Obs.	Mean	Std. Dev.	Median
Total Asset (Cnd$M)	41	4318.25	4323.21	2001.12
MVE (Cnd$M)	41	3180.61	3350.00	1263.33
Dgp	41	0.18	0.21	0.06
Dgr	41	0.02	0.03	0.01
Q ratio	41	1.31	0.40	1.24
Panel D: Firm-years without Hedging Activities				
	No. of Obs.	Mean	Std. Dev.	Median
Total Asset (Cnd$M)	23	3670.47	7059.76	167.30
MVE (Cnd$M)	23	3663.59	6628.01	260.50
Q ratio	23	2.00	1.47	1.81

Note: Total Asset represents the book value of asset. MVE represents the market value of equity. Total asset and MVE are in million Canadian dollars (Cdn$M). *Dop* and *Dor* denote the adjusted deltas of oil production and reserves, respectively. *Dgp* and *Dgr* denote the adjusted deltas of gas production and reserves, respectively. Panel A shows the statistics for the all firm-years. The statistics for subsamples of firm-years with hedging activities for oil and gas are reported, respectively, in Panels B and C. Panel D illustrates the statistics of firm-years without any hedging activities.

4 Impact of Hedging on the Relationship between Stock Returns and Oil and Gas Prices

In this section, we examine the impact of hedging on the relationship between stock returns and oil and gas prices using both linear and nonlinear models. We first study the relationship between stock returns and oil and gas prices directly based on the monthly data. Then we extend our models to study the roles of hedging and reserves in determining stock returns.

As shown in Figure 2, monthly stock returns of hedging firms appear to have slightly lower volatility than those of non-hedging firms during the period of 2001-2002. But it is still unclear as what roles that hedging may play. Therefore, we need to study this in depth using the multi-factor models.

4.1 Relationship between Oil and Gas Prices and Stock Returns

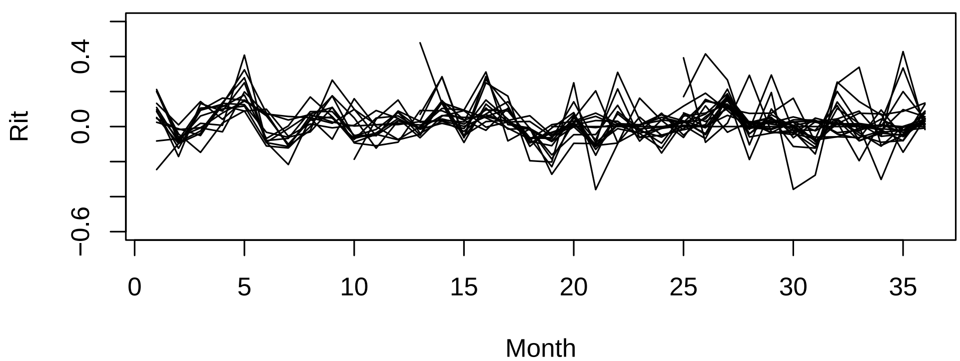
To examine the relationship between stock returns and oil and gas price changes, we first adopt the following model of Jin and Jorion (2005):

$$R_{it} = \alpha + \beta_m R_{mt} + \beta_o R_{ot} + \beta_g R_{gt} + \varepsilon_{it} \tag{1}$$

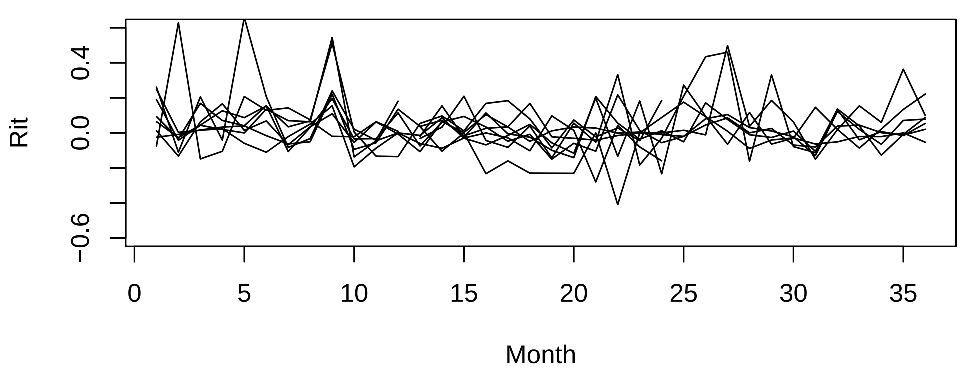
where R_{it} is the stock return for Canadian oil and/or gas company i at time t; R_{mt} denotes the market-index return or the S&P/TSX 60 index return at time t;[15] R_{ot} is the percentage change in the price of NYMEX near futures contracts for oil ("oil price change" hereafter) at time t; R_{gt} is the percentage change in the price of NYMEX near

[15] The S&P/TSX 60 index consists of 60 largest (measured by market capitalization) and most liquid (heavily traded) stocks listed on the Toronto Stock Exchange (TSX). They are usually domestic or multinational industry leaders in Canada.

Figure 2: Monthly Stock Returns with or without Hedging



Stock Returns vs. Time with Hedging



Stock Returns vs. Time without hedging

futures contracts for natural gas ("gas price change" hereafter) at time t; and ε_{it} is the error term for company i at time t in this model. The advantage of this model is that betas associated with oil and gas price changes may illustrate the role of hedging indirectly. If these betas are close to zero, this indicates that stock returns are not sensitive to these price changes.

The time dummy and firm dummies are also tested in the model but they are not statistically significant. Hence, we pool the cross-sectional and time series data to estimate this model. Furthermore, because of their resulting extreme Cook's distance in the stock return estimates, some data points (Gastar Exploration in February 2002 and Peyto Exploration and Development in October 2001) are excluded from the sample.[16]

Table 5 shows the estimation results for the pooled monthly data during the period of 2000-2002. Panel A of Table 5 shows that stock returns have linear relationships with oil and gas price changes. These relationships are mostly positive and statistically significant. On average, a 1% change in oil price leads to a 0.26% change in stock returns. This Canadian result is similar to that found by Rajgopal (1999) and Jin and Jorion (2005). But a 1% change in gas price only leads to a 0.10% change in stock returns, which is much lower than that of Rajgopal (1999) (0.41%) or Jin and Jorion (2005) (0.29%). The stock returns of these Canadian companies do not respond to gas price changes as much as they do to oil price changes. However, we note that the value of the beta associated with the market-index return is small and statistically insignificant. At this point, we do not know if stock returns and the market-index return could relate to each other nonlinearly.

To explore any nonlinear relationships, we extend our analysis by using the generalized additive model (GAM),[17] which can be viewed as an extension of the generalized

[16]Cook's distance is a metric for measuring the influential data points. A large Cook's distance for a data point indicates that the data point is influential in the linear regression [see Chambers and Hastie (1992), p. 230].

[17]See Hestie (1990), Hestie and Tibshirani (1990), Wood (2000), Venables and Ripley (2002), and Wood (2004).

linear model (GLM).[18] The advantage of GAM over GLM is that GAM is a more flexible model for identifying nonlinear effects. Let the sample counterparts of random variables

$$Y, X_1, X_2, \ldots, X_p$$

be

$$y, x_1, x_2, \ldots, x_p.$$

The GAM takes the following functional form:

$$g[\mu(x_1, x_2, \ldots, x_p)] = \alpha + s_1(x_1) + \cdots + s_p(x_p), \tag{2}$$

where $\mu(x_1, x_2, \ldots, x_p) = E(Y|X_1, X_2, \ldots, X_p)$, g is the link function, α is a constant, and s is a continuous and twice differentiable function. When Y is a real valued variable and the error is assumed to be Gaussian, and the link function g is the identity function, the GAM is reduced to the additive model as follows

$$E(Y|X_1, \cdots, X_p) = \alpha + s_1(x_1) + \cdots + s_p(x_p). \tag{3}$$

The above structure regression can be deemed as the first order analysis of variance (ANOVA) decomposition of $E(Y|X_1, \cdots, X_p) = s(x_1, \ldots, x_p)$ in a p-dimensional real space R^p.

The nonlinear functions $s_j(x_j)(j = 1, \ldots, p)$ are estimated jointly by the backfitting algorithm. This algorithm minimizes a penalized residual sum of squares

$$PRSS(\alpha, s_{1,\cdots,}s_p) = \sum_{i=1}^{N} \left(y_i - \alpha - \sum_{j=1}^{p} s_j(x_j) \right)^2 + \sum_{j=1}^{p} \lambda_j \int s_j^{''}(t_j)^2 dt_j \tag{4}$$

[18] See McCullagh and Nelder (1989).

by iteratively fitting nonlinear functions $s_j(x_j)(j = 1, \cdots, p)$ using a one dimensional natural spline with its smoothness controlled by the penalty term

$$\lambda_j \int s_j''(t_j)^2 dt_j.$$

The tuning parameter λ_j can be either pre-specified or automatically searched in each step by minimizing the generalized cross-validation (GCV) score. Sometimes we write $s_j(x_j)$ as $s(x_j, d_j)$ where d_j is the degree of smoothness. d_j may be non-integer. A more recent version of GAM fitting implemented in the `mgcv` package in R by Wood (2000, 2004) selects the multiple smoothing parameters more efficiently through minimization of the GCV score. This package employs a Bayesian approach to estimate the variance so that it makes the confidence interval calculation for $s(x_j, d_j)(j = 1, \ldots, p)$ easier.[19]

Figure 3 and Panel B of Table 5 show that the nonlinear effects of changes in oil and gas prices on stock returns are very significant. In GAM, the χ^2 test is performed to test the nonlinearity of each s function. It turns out that all three explanatory variables have nonlinear relationships with stock returns. The GAM fits the data better and R^2-adj reaches 0.194, a substantial increase from that of the linear model.

Figure 3 shows the estimated nonlinear effects of the explanatory variables on stock returns. First, we note that $s(R_{mt}, 8.51)$ is quite flat when $R_{mt} > 0$. But $s(R_{mt}, 8.51)$ becomes negative at $R_{mt} = -0.10$ and becomes positive at $R_{mt} = -0.05$. In other words, stock returns of oil and gas companies do not have a linear sensitivity to the market-index return. Clearly, this nonlinear relationship could not be identified in the linear model. Second, we find that $s(R_{ot}, 6.19)$ has a slightly positive slope. $s(R_{ot}, 6.19)$ becomes negative when $R_{ot} = -0.05$ and becomes positive when $R_{ot} > 0.10$. If the oil price falls more than 5%, stock returns go down but do not fall as fast as the oil price does. If the oil price rises more than 10%, stock returns rise but do not rise as fast as the oil price does. This could result from some form of hedging. Third, we note

[19]See Wood (2000) for details.

that $s(R_{gt}, 4.71)$ has a slight negative slope. $s(R_{gt}, 4.71)$ become sensitive to R_{gt} when $R_{gt} < -0.20$ or > 0.20. It implies that stock returns rise when the gas price falls by 20%. However, stock returns fall when the gas price rises more than 20%. This is an indirect evidence of some form of hedging of gas prices.

4.2 Impact of Hedging on Stock Returns

In this section, we extend the previous model to a more general setting in order to examine explicitly whether oil and gas hedging can moderate the impact of oil and gas price changes on stock returns. We use the following extended model for this purpose:

$$R_{it} = \alpha + \beta_m R_{mt} + [\gamma_1 + \gamma_2 Dop_{it} + \gamma_3 (OR_{it}/MVE_{it})] R_{ot} \qquad (5)$$

$$+[\gamma_4 + \gamma_5 Dgp_{it} + \gamma_6 (GR_{it}/MVE_{it})] R_{gt} + \epsilon_{it}$$

where Dop_{it} (Dgp_{it}) is the adjusted delta of oil (gas) production for firm i at time t; OR_{it} (GR_{it}) is the oil (gas) reserves of firm i at time t; and MVE_{it} is the market value of equity for firm i at time t. γ's are parameters and ε_{it} is the error term for firm i at time t. This extended model maintains the key explanatory variables and adds the variables for oil/gas hedging and oil/gas reserves.

The above model is used in the finance literature for the following hypotheses. The first hypothesis is that hedging by a firm can reduce the impact of oil and gas prices on its stock return; or γ_2 and γ_5 are expected to be negative. The second hypothesis is that a firm owning more oil and/or gas reserves has greater risk exposure to changes in oil and gas prices; or γ_3 and γ_6 should be positive. However, as noted that these linear relationships can be quite restricted if the partial responses to some explanatory variables are nonlinear. In this research, we allow these relationships to be nonlinear.

Table 5: Statistical Analysis of Stock Price Exposure

Panel A: Linear Three-factor Model for Stock Returns (R_{it})				
Explanatory Variables	Coefficient	Std. dev.	t-ratio	p-value
Intercept	0.020	0.004	5.044	0.000
R_{mt}	0.017	0.061	0.284	0.777
R_{ot}	0.263	0.050	5.318	0.000
R_{gt}	0.095	0.025	3.810	0.000
No. of obs.	881			
R^2-adj	0.055			

Panel B: Nonlinear Three-factor Model for Stock Returns (R_{it})				
Terms in GAM	Coefficient	Std. dev.	t-ratio χ^2 test for nonlinearity	p-value
Intercept	0.024	0.003	6.967	0.000
$s(R_{mt}, 8.51)$	—	—	62.862	0.000
$s(R_{ot}, 6.19)$	—	—	95.146	0.000
$s(R_{gt}, 4.71)$	—	—	20.009	0.019
No. of obs.	881			
R^2-adj	0.194			

Note: This table illustrates the estimation results of the linear coefficients and nonlinear functions in three-factor model. Panel A represents the estimation results of the linear model:

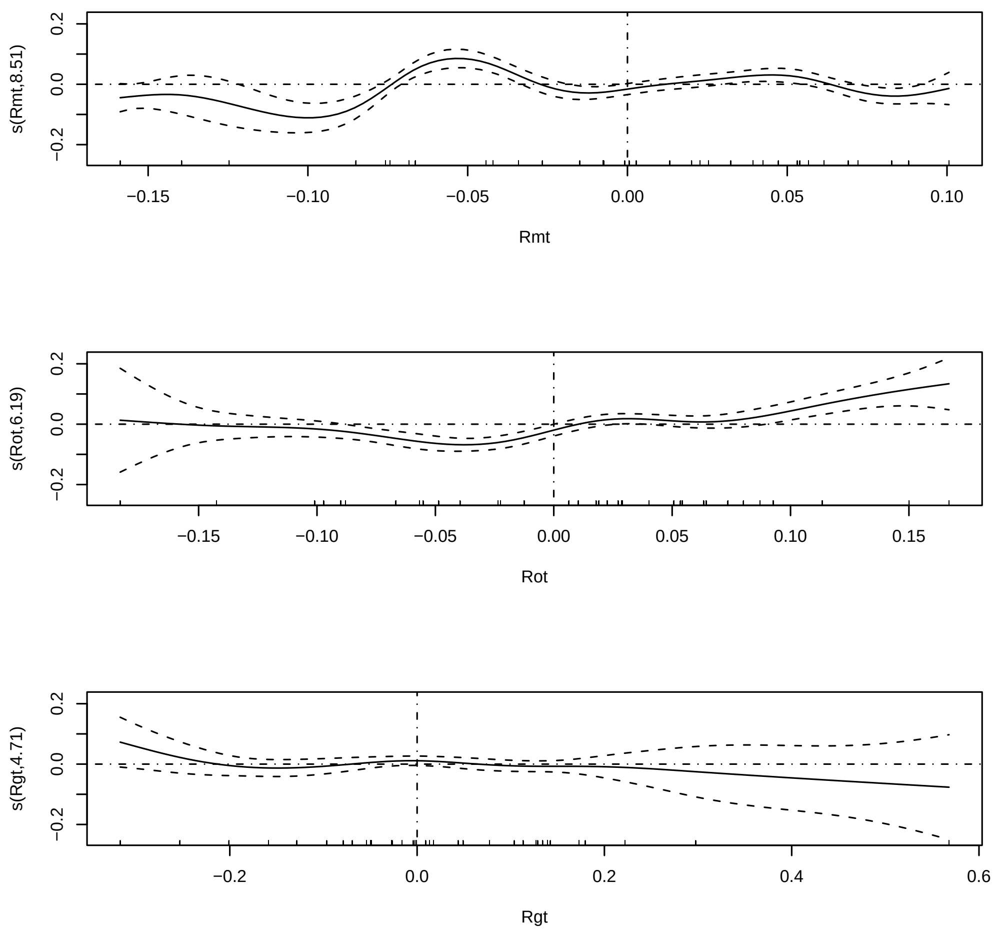
$$R_{it} = \alpha + \beta_m R_{mt} + \beta_o R_{ot} + \beta_g R_{gt} + \varepsilon_{it}.$$

Panel B shows the estimation of the generalized additive model.

$$R_{it} = \alpha + s(R_{mt}) + s(R_{ot}) + s(R_{gt}) + \varepsilon_{it}.$$

Here R_{it}, R_{mt}, R_{ot}, and R_{gt} denote the stock return of company i at time t , the market-index return at time t, the percentage change in the NYMEX crude oil futures price at time t , and the percentage change in the NYMEX gas future price at time t, respectively. ε_{it} is the error term. The sample includes the pooled monthly data during the period of 2000-2002. $s(x, d)$ denotes the estimated nonlinear function of variable x with d degrees of smoothness.

Figure 3: Nonlinear Variables in The Three-factor Model



Note: This figure shows the estimated nonlinear curves of the variables. Rmt (for R_{mt}), Rot (for R_{ot}), and Rgt (for R_{gt}) denote the market-index return, the oil price change and the gas price change, respectively. $s(x, d)$ denotes the nonlinear function of the variable x with d degrees of smoothness. Solid lines represent estimated nonlinear relationships. Broken lines show 95% confidence interval of nonlinear variables. Dotted lines are reference lines, which have angles of 0 and 90 respectively. The "rug" on the horizontal axis indicates the data density.

Hence we fit both linear and nonlinear models surrounding the specification of equation (3). After an intensive model search, we identify the linear model shown in Panel A of Table 6. In this linear model, the significant explanatory variables are the oil price change, the gas price change, the interaction term between the oil price change and oil reserves, and the interaction term between the market-index return and the gas price change. The estimation results for the Canadian oil and gas companies are similar to those in Rajgopal (1999) and Jin and Jorion (2005) in the sense that they are consistent with the hypotheses for negative γ_2 and γ_5 and positive γ_3 and γ_6. But these parameter estimates are not all statistically significant.[20] Only the parameter estimate associated with the oil reserves is statistically significant but quantitatively small. Hence the evidence for the above hypotheses is weak at the best. Is it likely that the linear model limits the revelation of potential underlying nonlinear relationships?

To answer this question, we once again implement the more flexible GAM approach. Panel B of Table 6 shows that in addition to the significant explanatory variables in the linear model the market-index return becomes a statistically significant factor in the nonlinear model. In order to evaluate if the nonlinear model is indeed superior to its linear counterpart, the null hypothesis under which the linear model is true is tested by the F-test based on the difference in deviances between the linear and nonlinear models with the dispersion parameter adjustment. The resultant p-value is close to zero. Hence we can conclude that the nonlinear model provides a better fit to this data. Other model selection criteria, such as the information criterion (AIC) and the goodness of fit (R^2-adj) also confirm this conclusion.

The two previously discussed hypotheses, which boil down to two sets of linear restriction hypotheses in the linear model, can no longer be tested directly any more in the nonlinear setting. Instead, the graphs for the discovered nonlinear functions from the nonlinear model are more informative and can be used to evaluate the two rela-

[20] The presented model excludes the insignificant explanatory variables except R_{mt}.

tionships. Panel B of Table 6 and Figure 4 show not only what explanatory variables are statistically significant but also how these variables affect stock returns in nonlinear ways. The first important finding is that the hedging activities on oil and gas in the Canadian companies appear to play little roles as both $Dop_{it}R_{ot}$ and $Dgp_{it}R_{gt}$ fail to be statistically significant and hence are excluded from the chosen models. Therefore, the statement that γ_2 and γ_5 are positive in the linear model cannot be supported by the Canadian data.

Figure 4 shows the estimated curves and their 95% confidence intervals for statistically significant nonlinear functions between stock returns and some explanatory variables. Specifically, Figure 4 demonstrates that the market-index return Rmt (for R_{mt}) has a nonlinear relationship with stock return s(Rmt, 8.08) [for $s(R_{mt}, 8.08)$]. This nonlinear relationship corresponds to the conventional beta for the market-index return in the linear model. When the market-index return moves up and down by about 5%, stock returns rise. However, when the market-index return moves, up or down, beyond the 5 % stock returns fall.

Figure 4 shows that when the oil price Rot [for R_{ot}] falls by 0-5%, stock returns s(Rot,6.59) [for $s(R_{ot}, 6.59)$] fall. when the oil price Rot [for R_{ot}] rises by more than 10%, stock returns s(Rot,6.59) [for $s(R_{ot}, 6.59)$] rise. There is a positive relationship between the two but the slope of the curve is not as steep. On the other hand, the relationship between the gas price Rgt [for R_{gt}] and stock returns s(Rgt,2.18) [for $s(R_{gt}, 2.18)$] is fairly flat with the 95% confidence intervals covering zero although the slope of the curve is slightly positive (negative) when $R_{gt} < 0$ ($R_{gt} > 0$). Both nonlinear relationships show some non-responsiveness of stock returns to oil/gas price movements, in particular on the downside. This is consistent with the observation obtained from the previous model that there is an indirect evidence that some form of hedging is taking place.

Corresponding to the hypothesis that oil and gas reserves should be positively related to stock returns (positive γ_3 and $\gamma_{3},$) in the linear model, Figure 4 shows that the relationship between oil reserves (OR/MVE)Rot [for $(OR_{it}/MVE_{it})R_{ot}$] and stock returns s((OR/MVE)Rot,7.79) [for $s((OR_{it}/MVE_{it})R_{ot}, 7.79)$] is not linear. Instead, it is nonlinear. Further, the scale of influence by (OR/MVE)Rot on the stock return s((OR/MVE)Rot,7.79) is much larger in comparison with that of other factors. Stock returns rise when oil reserves marked to the market are higher. But when oil reserves marketed to the market are lower, stock returns fall. That is, oil and gas reserves are more likely to have a positive (negative) impact on stock returns when the oil and gas prices are increasing (decreasing).

Another important finding from Figure 4 is that the interaction term, Rmt.Rgt (for $R_{mt}R_{gt}$), and their impact on stock returns, s(Rmt.Rgt,2.54) [for $s(R_{mt}.R_{gt}, 2.54)$], have a convex relationship. When this interaction term is in the range of 0.00%-0.02%, stock returns fall. However, beyond this range stock returns rise. There are several reasons for this phenomenon. First, this reflects the fact that when the gas price change and the market-index return move in the opposite direction, which leads to the negativity of the interaction term, stock returns rise. In this case, stock returns still benefit either from the rise of the stock market even if the gas price drops or from the gas price hike even if the stock market is down. Second, When the gas price change and the market-index return rise at the same time, stock returns rise as they will benefit from both the rise of the stock market as well as the gas price hike. Third, if both the stock market and gas price fall at the same time, the interaction term becomes positive. In this case, stock returns can rise if other factors such as hedging, cost cutting, and finding new reserves play significant roles. We will explore the roles of other factors in the next section when we evaluate firm value which has a direct link to stock returns.

Table 6: Effect of Hedging and Oil and Gas Prices on Stock Returns

Panel A: Linear Oil and Gas Beta Model (R_{it})				
Explanatory Variables	Coefficient	Std. dev.	t-ratio	p-value
Intercept	0.016	0.004	3.957	0.000
R_{mt}	0.001	0.061	0.013	0.990
R_{ot}	0.175	0.056	3.126	0.002
R_{gt}	0.134	0.028	4.669	0.000
$(OR_{it}/MVE_{it})R_{ot}$	0.008	0.004	2.320	0.021
$R_{mt} * R_{gt}$	0.949	0.357	2.660	0.008
No. of obs.	881			
R^2-adj	0.066			

Panel B: Nonlinear Oil and Gas Beta Model (R_{it})				
Explanatory Variables	Coefficient	Std. dev.	t-ratio χ^2 test for nonlinearity	p-value
Intercept	0.024	0.003	7.090	0.000
$s(R_{mt}, 8.08)$	—	—	68.330	0.000
$s(R_{ot}, 6.59)$	—	—	63.474	0.000
$s(R_{gt}, 2.18)$	—	—	19.593	0.022
$s(OR_{it}/MVE_{it})R_{ot}, 7.79)$	—	—	37.026	0.000
$s(R_{mt} * R_{gt}, 2.54)$	—	—	26.153	0.002
No. of obs.	881			
R^2-adj	0.222			

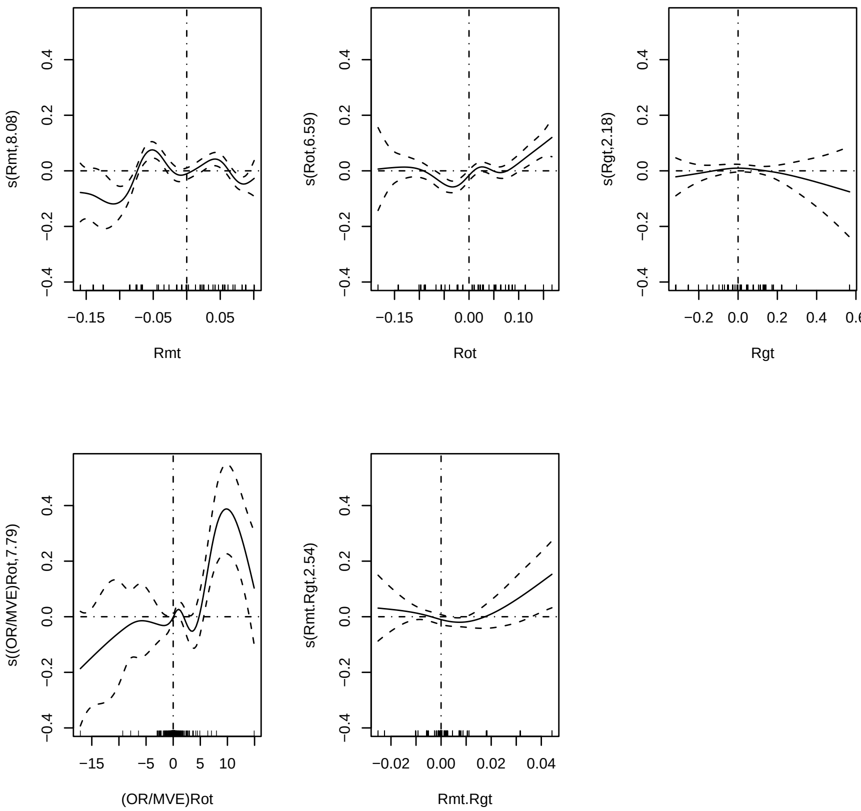
Note: The table shows the pooled cross-section time-series regressions of stock returns on the market and oil (gas) price changes, with coefficients adjusted for the effect of hedging and reserves, for the period of 2000-2002. In Panel A, the joint linear model is given by:

$$R_{it} = \alpha + \beta_m R_{mt} + [\gamma_1 + \gamma_2 Dop_{it} + \gamma_3 (OR_{it}/MVE_{it})]R_{ot}$$

$$+[\gamma_4 + \gamma_5 Dgp_{it} + \gamma_6 (GR_{it}/MVE_{it})]R_{gt} + \epsilon_{it}$$

R_{it}, R_{mt}, R_{ot}, and R_{gt} denote the stock return of company i at time t , the market-index return at time t, the percentage change in the NYMEX crude oil futures price at time t , and the percentage change in the NYMEX gas future price at time t, respectively. Dop_{it} (Dgp_{it}) is the adjusted deltas of oil (gas) production of company i at time t. OR_{it} (GR_{it}) is the value of oil (gas) reserves of company i at time t. MVE_{it} is the market value of equity of company i at time t. ε_{it} is the error term. Panel B shows GAM results. Df denotes degrees of freedom. $s(x, d)$ denotes the nonlinear function of the variable x with d degrees of smoothness. The sample includes the pooled monthly data during the period of 2000-2002.

Figure 4: Nonlinear Effect of Hedging and Oil and Gas Prices on Stock Returns



Note: This figure shows curves of the significant nonlinear relationships. Rmt (for R_{mt}), Rgt (for R_{gt}), and Rot (for R_{ot}) denote the market-index return, the gas price change and the oil price change, respectively. (OR/MVE)Rot (for $(OR_{it}/MVE_{it})R_{ot}$) denotes the sensitivities to oil reserves. Rmt.Rgt (for $R_{mt}R_{gt}$) is the interaction term between the market-index return and the gas price change. $s(x, d)$ denotes the nonlinear function of the variable x with d degree freedom. Solid lines represent the estimated nonlinear relationships. Broken lines give the 95% confidence intervals of the estimated nonlinear relationships. Dotted lines are reference lines, which have angles of 0 and 90 respectively. The "rug" on the horizontal axis indicates the data density.

5 Hedging and Firm Value

5.1 Univariate Analysis

Whether firms that hedge have a higher firm value or a higher Q ratio than those that do not is also an important question in evaluating the roles of hedging. Therefore, we compare the values of hedging firms with those of non-hedging firms. Table 7 reports the univariate analysis of differences in the Q ratio, book value of total asset, and market value of equity between oil/gas hedging and non-hedging firms. Panel A and B of Table 7 show the basic statistics for the oil hedging firms with respect to non-oil hedging and non-hedging firms, respectively. The similar analysis is reported for the gas hedging firms with respect to non-gas hedging and non-hedging firms, respectively in Panel C and D. Table 7 shows that the differences between hedging and non-hedging firms are primarily in the Q ratio and that the firms with oil and gas hedging tend to have lower Q ratios.

5.2 Multivariate Analysis

The Q ratio is likely to be determined by many different factors and hence is better analyzed by separating the hedging dummy variables from oil and gas price changes and adding oil and gas deltas and other control variables. In this research, a more general regression model is employed:

$$\ln Q_{it} = \alpha + \beta_1 (Oil\ Heding\ Dummy)_{it} + \beta_2 (Gas\ Hedging\ dummy)_{it} \tag{6}$$

$$+\beta_3 Dop_{it} + \beta_4 Dor_{it} + \beta_5 Dgp_{it} + \beta_6 Dgr_{it} + \gamma (Control\ Variables)_{it} + \varepsilon_{it},$$

where subscript i is for firm i and subscript t is for time t.

Table 7: Comparison of Firm Values between Hedging and Non-hedging Firms

Panel A: Oil Hedging and Non-oil Hedging Firms					
Variables	Hedging (46 obs.)	Non-hedging (30 obs.)	Difference	t-test (mean) Z-test (median)	p-value
Q(mean)	1.35	1.87	-0.52	-2.09	0.04
Q(median)	1.27	1.55	-0.28	-2.27	0.02
BV(mean)	4356.03	3502.78	853.25	0.64	0.52
BV(median)	1857.33	433.20	1424.13	2.66	0.01
MVE(mean)	3740.24	3319.73	420.51	0.34	0.74
MVE(median)	1406.85	488.68	918.17	2.01	0.04

Panel B: Oil Hedging and Non-hedging Firms					
Variables	Hedging (46 obs.)	Non-hedging (23 obs.)	Difference	t-test (mean) Z-test (median)	p-value
Q(mean)	1.35	2.00	-0.65	-2.05	0.05
Q(median)	1.27	1.81	-0.55	-1.97	0.05
BV(mean)	4356.03	3670.47	685.56	0.43	0.67
BV(median)	1857.33	167.30	1690.03	2.83	0.00
MVE(mean)	3740.24	3663.59	76.65	0.05	0.96
MVE(median)	1406.85	260.50	1146.35	2.09	0.04

Panel C: Gas Hedging and Non-gas Hedging Firms					
Variables	Hedging (41 obs.)	Non-hedging (35 obs.)	Difference	t-test (mean) Z-test (median)	p-value
Q(mean)	1.31	1.85	-0.54	-2.47	0.02
Q(median)	1.24	1.75	-0.51	-2.63	0.01
BV(mean)	4318.25	3668.93	649.33	0.53	0.60
BV(median)	2001.12	540.60	1460.52	2.82	0.00
MVE(mean)	3180.61	4035.37	-854.76	-0.73	0.47
MVE(median)	1263.33	439.05	824.28	1.74	0.08

Panel D: Gas Hedging and Non-hedging Firms					
Variables	Hedging (41 obs.)	Non-hedging (23 obs.)	Difference	t-test (mean) Z-test (median)	p-value
Q(mean)	1.31	2.00	-0.69	-2.21	0.04
Q(median)	1.24	1.81	-0.57	-2.14	0.03
BV(mean)	4318.25	3670.47	647.79	0.40	0.69
BV(median)	2001.12	167.30	1833.82	3.04	0.00
MVE(mean)	3180.61	3663.59	-482.98	-0.33	0.75
MVE(median)	1263.33	260.50	1002.83	2.38	0.02

Note: This compares means and medians of Q ratios (Q), book values (BV) of total asset and market values of equity (MVE) between hedging and non-hedging companies. Panels A and B show the comparison between oil hedging companies and non-oil hedging and non-hedging companies respectively. Similarly, Panels C and D show the comparisons between gas hedging companies and non-gas hedging and non-hedging companies respectively. A t-test assuming unequal variances is used for comparing means. Wilcoxon ranksum Z-test is used for comparing medians. Two-side p-values are reported. Both BV and MVE are in million Canadian dollar (Cdn$M).

As in Allayannias and Weston (2001) and Jin and Jorion (2005), the control variables are return on asset, investment growth, access to financial markets, leverage, and production cost. *Return on asset* (*Roa*) is measured by the ratio of net income to book value of total asset. It is expected to have a positive association with the Q ratio because highly profitable firms tend to have a high Q ratio. *Investment growth* is measured by the ratio of capital expenditure to book value of total asset. It is expected to have a positive coefficient because firm value depends more on future investment. *Access to financial market* is measured by a dividend dummy variable that equals 1 if the company has paid a dividend in the current year, 0 otherwise. There are two different views on the information role of dividend payment. Some suggest that dividend-paying firms are less financially constrained and may invest in less optimal projects. Hence, they have lower Q ratios [see Allayannis and Weston (2001)]. Others argue that dividend-paying firms typically have good management and hence higher Q ratios [see Jin and Jorion (2005)]. *Leverage* is measured by the ratio of book value of long-term debt to market value of common equity. It is expected to be negatively related to the Q ratio. *Production cost* refers the cost of extracting oil and gas as reported in annual reports. This variable is expected to be negatively related with the Q ratio [see Jin and Jorion (2005)]. Although the book value of total asset can be a reasonable proxy for firm size, we do exclude this variable as a control variable in the model to avoid the endogenous problem because the Q ratio is also directly linked to the book value.

Table 8 illustrates the regression results for both linear and nonlinear models after an intensive model search. The resulting linear model is nested in the selected nonlinear model. Based on the AIC, R^2 and R^2-adj, the nonlinear model has a better fit for the data. The tests based on the difference in deviance and the F-tests also support the conclusion that the nonlinear model, which is the mixture of linear and nonlinear relationships, is superior to the linear model.

Table 8 shows that both selected linear and nonlinear models do not include the following explanatory variables: *investment growth*, *assess to financial market*, *production cost*, *delta values relative to oil production and reserves*, and *oil and gas hedging dummy variables*. These variables, if included in the model, are not statistically significant. Table 8 shows that in both selected linear and nonlinear models only *return on asset*, *leverage*, *adjusted delta of gas production*, and *adjusted delta of gas reserves* are statistically significant. R^2-adj of the nonlinear model is 0.359, higher than that of the linear model (0.242). The nonlinear model contains both linear and nonlinear relationships. Firm value has a positive linear relationship with return on asset and adjusted delta of gas reserves, a negative linear relationship with adjusted delta of gas production, and a nonlinear relationship with leverage.

Because the generalized additive model is fitted on the logarithm of the Q ratio, these partial effects of these explanatory variables may be interpreted as multiplicative explanatory variables for the Q ratio itself. Each penal in Figure 6 shows the partial effect of the explanatory variable on $\ln Q$ while holding other explanatory variables fixed. When Roa is set to 1%, the Q-ratio is $e^{(2.372)(0.01)} = 1.024$. In other words, 1% increase in Roa leads to an increase of 0.024 in the Q ratio. Clearly the higher the return on asset, the higher the Q ratio. When Dgp is set to 1%, the Q-ratio is $e^{(-1.731)(0.01)} = 0.983$. That is, 1% increase in Dgp leads to a decrease of 0.017 the Q ratio. When Dgr is set to 1% the Q ratio is $e^{(10.063)(0.01)} = 1.106$. That is, 1% increase in Dgr leads to an increase of 0.106 in the Q ratio. The relationship between two gas hedging variables demonstrates the need for some delicate balance between gas hedging relative to production and gas hedging relative to reserves in order to obtain the highest Q-ratio. The discovered relationships imply that within a feasible choice set, a lower ratio of Dgp to Dgr leads to a higher Q ratio. This means that higher gas reserves relative to gas production for a given level of hedging activities lead to a higher Q ratio. Finally, *leverage* appears to have a nonlinear relationship with $\ln Q$. When *leverge* takes values between 0%–15%, the Q ratio is greater than 1. However, when *leverage* rises by more than 15%, the

Q ratio falls below 1. This indicates that *leverage* is another important factor that determines firm value.

6 Concluding Remarks

In this research, we aim to uncover the relationships between hedging activities and firm value in large Canadian oil and gas companies by examining the impact of oil and gas hedging for the period of 2000-2002. This is perhaps the first systematic study of this kind with the Canadian oil and gas data.

We extend the methodology in the existing studies by employing nonlinear semi-parametric additive models to accommodate nonlinear payoffs of various hedging strategies. This approach is useful for identifying nonlinear roles of hedging that would otherwise not be possible within a linear framework. Indeed, the data analysis in this paper indicates that nonlinear semi-parametric additive models are superior to their linear parametric counterparts.

By examining the impact of hedging on relationships between stock returns and oil/ gas price changes, we find that stock returns indeed respond to these price changes in nonlinear ways and stock returns do not fall as oil and gas prices are falling. We also find that gas hedging appears to be more effective than oil hedging is. These findings are not observable in the linear model.

Then we further incorporate into the model direct measures of oil and gas hedging and the direct measures of oil and gas reserves. Once again, the direct measures of oil and gas hedging are not as important as the oil and gas reserves are in influencing stock returns. The evidence shows that Canadian oil and gas firms are able to have some down side protection against unfavorable changes in oil and gas prices. In addition, oil

Table 8: Hedging and Firm Value

Linear Model				
Explanatory Variable	Coefficient	Std. dev.	t-ratio	p-value
Intercept	0.437	0.085	5.173	0.000
Dgp	-1.857	0.704	-2.640	0.001
Dgr	10.003	3.735	2.679	0.009
Roa	1.845	0.578	3.194	0.002
Leverage	-0.685	0.182	-3.763	0.000
No. of Obs.	76			
R^2-adj	0.242			
Nonlinear Model				
Explanatory Variable	Coefficient	Std. dev.	t-ratio χ^2 test for nonlinearity	p-value
Intercept	0.194	0.063	3.070	0.003
Dgp	-1.731	0.660	-2.623	0.011
Dgr	10.063	3.492	2.882	0.005
Roa	2.372	0.563	4.213	0.000
$s(Leverage, 6.363)$	—	—	37.671	0.000
No. of Obs.	76			
R^2-adj	0.359			

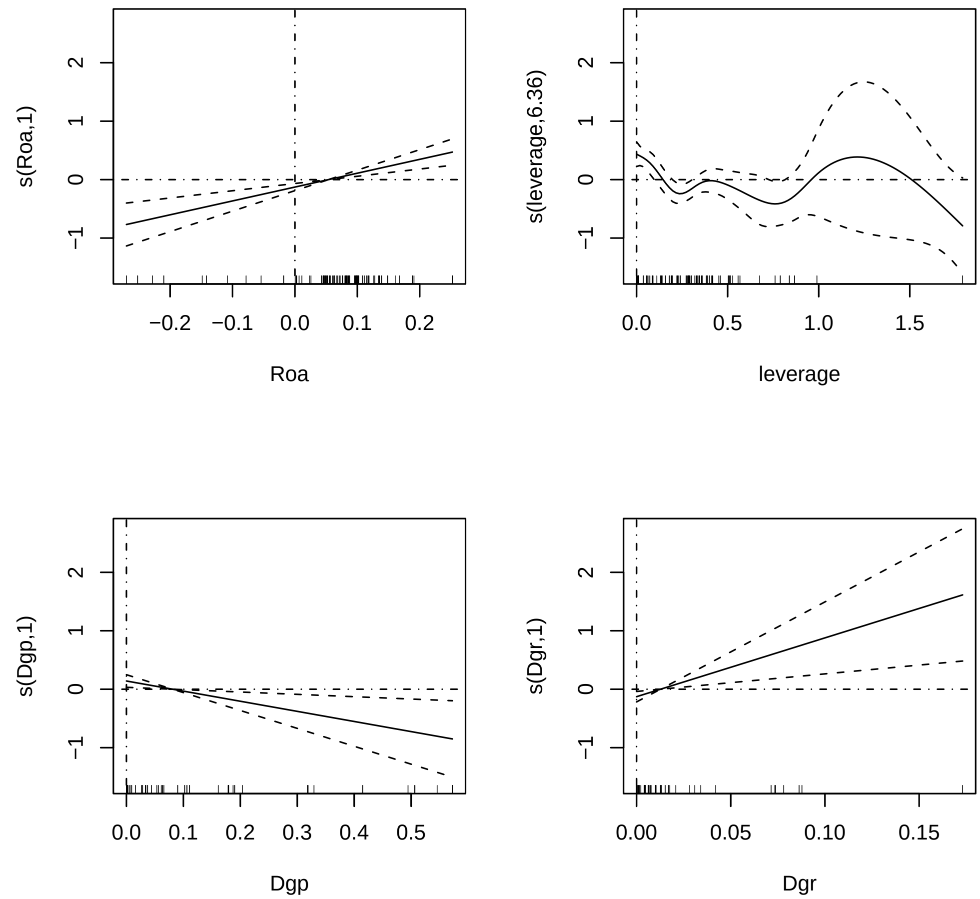
Note: This table shows the selected linear and nonlinear regression models for analyzing the impact of hedging on firm value. These models are variants of the following specification:

$$\ln Q_{it} = \alpha + \beta_1(Oil\ Heding\ Dummy)_{it} + \beta_2(Gas\ Hedging\ dummy)_{it}$$

$$+\beta_3 Dop_{it} + \beta_4 Dor_{it} + \beta_5 Dgp_{it} + \beta_6 Dgr_{it} + \gamma(Control\ Variables)_{it} + \varepsilon_{it},$$

This sample includes twenty-eight firms and seventy-six firm-years from 2000 to 2002. *Dgp* is the delta value relative to gas production. *Dgr* is the delta value relative to gas reserves. *Roa* is the ratio of net income over book value of total asset. *Leverage* is measured by the book value of long-term debt to market value of common equity. $s(Leverage, 6.363)$ denotes the nonlinear function of the variable leverage with 6.363 degrees of smoothness. Df denotes degrees of freedom.

Figure 5: Linear and Nonlinear Relationships for Firm Value



Note: This figure shows the estimated linear and nonlinear relationships in solid lines for $\ln Q$. *Roa* is the ratio of net income to book value of total asset. The partial impact of *Roa* on lnQ $[s(Roa, 1)]$ is linear. *Leverage* is measured by the ratio of book value of long-term debt to market value and has a nonlinear relationship with $\ln Q$ $[s(Leverage, 3.36)]$. The higher the leverage is, the lower the firm value is. *Dgp* denotes the delta value relative to gas production and it has a negative linear relationship with $\ln Q$ $[s(Dgp, 1)]$. *Dgr* denotes the delta value relative to gas reserves and it has a positive linear relationship with $\ln Q$ $[s(Dgr, 1)]$. Broken lines give the 95% confidence intervals of the estimated nonlinear relationships. Dotted lines are reference lines, which have angles of 0 and 90 respectively. The "rug" on the horizontal axis indicates the data density.

reserves are more likely to have a positive (negative) impact on stock returns when oil prices are increasing (decreasing).

Finally, we examine the impact of hedging on firm value measured by Tobin's Q ratio using both linear and nonlinear models. We find that profitability (return on asset) has a positive impact on firm value and that borrowing has a negative impact on firm value. In addition, we find that hedging activities relative to gas production have a significant negative impact on firm value at the margin while hedging activities relative to gas reserves have a significant positive impact on firm value. This may indicate the need for some delicate balance between gas hedging relative to production and gas hedging relative to reserves in order to obtain the highest Q-ratio. The discovered relationships imply that higher gas reserves relative to gas production for a given level of gas hedging activities lead to a higher Q ratio.

There are several other issues left for future studies. First, the hedging information from annual reports may be incomplete as some companies may under-report their hedging activities in their annual reports. If Canada has a new regulation like FRR 48 in the U.S. more information will be available. Second, most of Canadian oil and gas companies export oil and gas directly to the U.S. and many of them may rely on hedging more on foreign-exchange-rate exposure rather than oil-and-gas-price exposure. These interesting issues are left for future research.

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Appendix 1 Hedging Information in 2002 Annual Report of Acclaim Energy Trust

A. Information in Management's Discussion & Analysis

COMMODITY MARKETING AND PRICE RISK MANAGEMENT

Upon closing the acquisition of Elk Point, Acclaim's natural gas weighting increased to 53 percent of production, while conventional oil and NGLs and heavy oil comprise 39 percent and 8 percent respectively.

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WTI averaged US$26.11 per bbl in 2002, a slight increase to the average of US$25.97 per bbl in 2001. Acclaim's price is also influenced by the Canadian$/US$ exchange rate as well as the degree of gravity of the oil and hedging activity. The majority of Acclaim's production is classified as light oil which trades at a premium relative to medium and heavy oil. Early in 2003, the benchmark WTI has been very strong averaging US$34.86 per bbl in the first quarter due primarily to uncertainties associated with the conflict in the Middle East.

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As of March 2003, Acclaim had hedging contracts in place originating from Acclaim, Ketch Energy, Elk Point and various predecessor companies. Since the combination of Acclaim with Ketch Energy, the Trust has layered on additional marketing contracts and will continue to do so on an ongoing basis, in order to maintain the stability of long-term cash distributions.

B. Information in Notes of Consolidated Financial Statement

15. HEDGING AND FINANCIAL INSTRUMENTS

The Trust's financial instruments recognized on the consolidated balance sheets include accounts receivable, accounts payable and accrued liabilities, bank debt and hedging and capital lease obligations. The fair values of financial instruments other than bank debt approximates their carrying amounts due to the short-term nature of these instruments. The carrying value of bank debt approximates its fair value due to floating interest terms; the fair value of the obligation under capital lease approximates carrying value due to current rates for comparable terms of the lease obligation. The fair value of the interest rate swaps associated with bank debt is disclosed in Note 6.

The Trust is exposed to the commodity price fluctuations of crude oil and natural gas and to fluctuations of the Canada - US dollar exchange rate. The Trust manages this risk by entering into various on and off balance sheet derivative financial instruments. A portion of the Trust's exposure to these fluctuations is hedged through the use of swaps and forward contracts. The Trust's exposure to interest rate fluctuations is disclosed in Note 6. The Trust is exposed to credit risk due to the potential non-performance of counter parties to the above financial instruments. The Trust mitigates this risk by dealing only with larger, well-established commodity marketing companies and with major national chartered banks. As a result of commodity hedging transactions, petroleum and natural gas sales for 2002 increased by \$0.5 million (2001 - \$5.5 million).

December 31, 2002 outstanding contracts (see the following table)

Crude Oil: Outstanding Contracts

Financial Instrument	Daily Volume (bbls)	Floor/Ceiling	Term
Three way collar	1,000	US$20.00–25.00–29.00	Jan.1, 2003–Jul.31, 2003
Three way collar	1,000	US$22.00–24.00–28.60	Jan.1, 2003–Dec.31, 2003
Collar	500	US$22.00–29.00	Jan.1, 2003–Dec.31, 2003
Collar	500	US$22.00–29.50	Jan.1, 2003–Dec.31, 2003
Collar	500	US$24.00–29.00	Jan.1, 2003–Jun.30, 2003
Collar	500	US$24.00–29.07	Jan.1, 2003–Jun.30, 2003

Appendix 2 Hedging Instruments

In hedging activities, fixed-price contracts, forwards, received-fixed swaps and options (including collars and three-way options) are the main instruments used by Canadian oil and gas companies.

A fixed-price contract obliges the supplier to deliver a defined commodity to a consumer at a predetermined price. Many such contracts include significant penalties for non-delivery. A fixed-price contract shifts most or all risks from the buyer to the supplier, and simultaneously shifts the management burden from the buyer to the supplier.

Forward or a forward contract is an over-the-counter contractual obligation to buy or sell a financial instrument/a commodity at an agreed price and to make a payment or a delivery at a pre-set future time between the two counterparties. Forward contracts generally are arranged to have zero mark-to-market value at inception, although they may be off-market. Examples include forward foreign exchange contracts in which one party is obligated to buy foreign exchange from another party at a fixed rate for delivery on a pre-set date. Off-market forward contracts are often used in structured combinations, with the value on a forward contract offsetting the value of another instrument or other instruments.

Received-fixed commodity swaps are the swaps in which exchanged flows are dependent on the prices of a commodity (or an underlying commodity index). The commodity producer who wishes to avoid the commodity price fluctuation can engage in this kind of swaps by paying a fee to a financial institution that is willing to pay the producer the fixed payments for the commodity and accept the commodity price fluctuation.

A collar, or a zero cost collar option, is a positive-carry collar that secures a return through the purchase of a floor and sale of a cap. An example of a zero cost option collar for selling commodity is the purchase of a put option and the sale of a call option with a higher strike price. The sale of the call will cap the return if the price of the underlying commodity rises, but the premium collected from the sale of the call will offset the cost of the purchased put.

The three-way options is an option strategy created by adding to a collar, another long put (call) option position whose strike price is lower (higher) than that of put (call) option in the collar to benefit from falling (rising) prices. In other words, the motive of those hedging activities for each oil and gas companies is to sell oil and gas with ideal prices.