University of Alberta

Corporate Risk Management: Theory and Empirical Studies

by

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Abstract

This thesis examines corporate risk management practice and tries to find out answers to the two general questions: why do firms manage risk and how to manage risk? First, a model of optimal hedging policy is developed for oil producers under incomplete information, where managers are uncertain about the long run mean of oil prices. Although managers do not know the true value of this time-varying parameter, they can learn about the parameter from the realized oil price series. The precision of their conditional estimates increases as information accrues. We show that even a moderate error in the initial estimate can persist for years. Since in our model, managers use their learning in formulating their hedging decisions, our results provide a rationale for the popularity of a practice known as "selective" hedging in which corporate derivative users appear to allow their views of future commodity prices, interest rates, and exchange rates to influence their hedging decisions. The model also predicts that the manager's attitude towards risk plays a crucial role in the firm's hedging behavior.

In order to test the hypothesis that managerial incentives are a driving force for corporate risk management operations, an empirical study is provided in this thesis to examine the interaction between managerial risk aversion and corporate risk management activities of 126 U.S. oil and gas producers between 2001 and 2004. We find that management's stock ownership and executive compensation are important determinants of corporate hedging policies. Firms with managers possessing greater equity ownership and fewer

option holdings in their compensation plan hedge more extensively. By separating CEO's equity ownership and option holdings from other officers and directors, we find that the CEO is the person who is vested with more authority in risk management program. We also separate the decision to hedge from the level of hedging to find out whether there are differences in the factors that determine both decisions. In addition, we find that a large firm whose managers are younger and have a larger equity stake and fewer option holdings in the company tends to hedge more.

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c: Comsumption

δ: Fraction of firm value, which will be paid to managers as their compensation

F: Futures price

dV: Changes in firm value

dz: An increment to a standard Brownian motion

κ: Speed of reversion in a mean-reverting process

σ: Volatility of oil price

μ: Long run mean of log oil price

t: Time

T: Time for contract delivery

W: Wealth

X: Barrels of oil

V: Firm value

Chapter 1

Introduction

1.1 Objectives

One of the most striking developments in global financial markets over the past three decades has been the ever-increasing use by non-financial corporations of derivative instrument as tools to hedge against risks, and the adoption of risk management program as a policy at the corporate level. The practice attracts academic attention and needs theoretical guidance. The extant literature related to hedging mainly attempts to answer two questions: why firms hedge and how firms should hedge. This thesis follows this general line and attempts to find answers to these two questions. A theoretical model of optimal hedging strategy is developed in this thesis, and an empirical study on the determinant of hedging policy is provided. We aim to find out whether managerial incentives determine hedging decisions.

Survey result shows that firms tend to incorporate their views of the market condition in the near future into their risk management decision. Following this real-world observation, we extend the model of Stulz (1984) to allow for a learning process introduced by Brennan (1998), and derive an optimal hedging policy based on managers' market view. This model provides a possible explanation to the widely documented cross-sectional and time series variability among corporate hedging practice.

The rest of the thesis examines the determinants of corporate risk management practice. Managers may find that their personal portfolios are poorly diversified when they have their wealth and human capital tied up in their companies. Managers will suffer from adverse consequences of operations in their companies. If risk-averse managers realize that the cost of hedging on their own account is higher than the cost of hedging at the corporate level, they will direct their firms to engage in risk management. With a unique hand-collected database from 126 U.S. independent oil and gas producers between 2001 and 2004, we find that managerial incentive could be an important decision factor in corporate hedging policy.

1.2 Literature Review

Finance theory offers two broad explanations to justify corporate hedging. One class of explanations suggests that hedging can maximize shareholder value by reducing variability of corporate cash flows, and hence various costs associated with volatile cash flows. Smith and Stulz (1985) show that hedging can reduce the expected costs of financial distress. Leland (1998) demonstrates that hedging can increase a firm's debt capacity by lowering the probability of bankruptcy and thus generate more tax advantages from more leverage. Smith and Stulz (1985) also show that when firms face a convex tax schedule, hedging can reduce expected tax payments. Finally, Froot, Scharfstein and Stein (1993) argue that when firms facing financial constraints have multiple growth opportunities, hedging can lessen the underinvestment problem by ensuring that the firm will have enough internal cash to make value-enhancing investments.

Another class of theories argues that the managerial incentive could be the driving force for corporate hedging. Corporate managers have typically a significant amount of their wealth invested in the firm they manage. Managers will suffer from adverse consequences of operations in their companies. If risk-averse managers realize that the cost of hedging on their own account is higher than the cost of hedging at the corporate level, they will direct their firms to engage in risk management. Stulz (1984) and Smith and Stulz (1985) argue that managers decide optimal hedging policy in the context of maximizing their lifetime utility. These theories predict that the nature of the compensation plan can influence a firm's risk management policy without affecting its market value.

In order to maximize firm value, firms must design hedging strategies that best suit their needs. There is evidence suggests that firms typically do not hedge systematically, but rather practice so-called selective hedging taking their views into account when assuming derivatives positions. Stulz (1996) argues that firms prefer the selective as opposed to full-coverage hedging strategies because some firms have comparative advantage in learning certain financial risks through their daily operations. Namely, corporate derivative users appear to allow their views to influence their hedging policy. Dolde (1993) sent a questionnaire to all Fortune 500 companies in 1992. A total of 244 companies responded. Of these, 85 percent reported using swaps, forwards, or options in managing financial risks. The overwhelming evidence is that a firm's market views matter and affect its hedging decision. The typical attitude of firms seems to be captured by the following quotation from a Fortune 500 manager:" hedge 30% to 50% if we think the market will move our way, 100% if we think it will move against us" (Dolde, 1993, p.40). Dolde (1993) also finds that views matter less for smaller Fortune 500 firms than for larger firms. When they hold a view, smaller firms hedge more than larger firms. Furthermore, many respondents said that their intensity of hedging depended on whether they had a view of future market movements. The 1994 Wharton/Chase survey questionnaire was sent to a random sample of 2000 nonfinancial firms. About 66 percent state that they do not use derivatives to hedge competitive exposures. Similarly, The 1995 Wharton/CIBC survey also provides evidence that firms let their views affect their hedges. A majority of firms say that their view sometimes affects the timing of their hedges for interest rate hedges and foreign exchange hedges. Interestingly, 33 percent of the users say that they sometimes "actively take positions" based on an exchange rate view. These surveys agree on that managers' market views affect hedging decision.

In the second chapter of the thesis we derive a model of optimal hedging policy for an oil producer where managers can learn about market conditions, and this learning process is interpreted as the formation of market views. The formation process of market views is modeled as a learning process in this thesis. Learning process has been introduced and applied in the studies of Detemple (1986), Dothan and Feldman (1986), Genotte (1986), and Brennan (1998). Our model extends the analysis of Stulz (1984), where an optimal hedging policy is derived without learning effect. Even though managers do not know the true value of the long run mean of oil prices, they can estimate the future oil prices as they observe the realized oil price series, i.e., they are learning about the market and their views form. Then, the firm's hedging policy is determined in a setting of optimal portfolio selection as managers maximize their expected lifetime utility.

Empirical evidence regarding the hypothesis of firm value maximization as an incentive for corporate risk management is still inconclusive. Allayannis and Weston (2001), and Graham and Rogers (2002) provide evidence that hedging increases the firm's market value. Allayannis and Weston (2001) find that the market value of firms using foreign currency derivatives is 5% higher on average than for nonusers. Graham and Rogers (2002) find that firms use derivatives to increase debt capacity which in turn increases firm value by 1.1% on average. However, Tufano (1996) examines the hedging behavior of North American gold mining companies and finds virtually no relationship between risk management and firm characteristics that value-maximizing risk management theories would predict. By examining the economic effects of derivatives positions for a sample of non-financial corporations, Guay and Kothari (2003) conclude that potential gains of derivatives are small compared to cash flows and changes in equity values, and cannot possibly have an effect of the magnitude claimed by the studies above. Jin and Jorion (2006) study the hedging activities of U.S. oil and gas producers and find that hedging does not seem to affect their market values after controlling for systematic risk.

As the value maximization hypothesis cannot fully justify the increasing popularity of corporate risk management, we want to find out in this thesis whether managerial incentive hypothesis is the determinant of risk management decisions. Smith and Stulz (1985) and Stulz (1996) predict that the nature of the compensation plan can influence a firm's risk management policy without affecting its market value. All else equal, managers with more wealth invested in a firm's equity will have greater incentives to manage the firm's risk, while the incorporation of option-based compensation reduces managers' incentive to hedge risk. Empirical studies show conflicting evidence regarding the managerial incentive hypothesis. Tufano (1995) shows that firms whose managers own more shares are firms that hedge more. This is consistent with the stakeholder argument, but it could also be consistent with entrenchment of management and maximization of private benefits. The private benefits of hedging for management are that it bears less risk. Depending on the costs of hedging, this might be expensive for shareholders. Evidence to this effect might be that in Tufano's sample firms with large nonmanagerial block ownership seem to hedge less. It therefore appears that large shareholders moderate management's desire to hedge. Finally, management hedges less when it holds more options. This evidence shows that the hedging practices of firms depend crucially on the incentives of management. If managers own a lot of shares and these shares represent a large fraction of their wealth, it would not be surprising for managers to want to reduce the risk of their shares. If managers' compensation increases with unusually good outcomes, they may be more willing to gamble to achieve such outcomes. Schrand and Unal (1998) explore the hedging behavior of savings and loans that have recently converted from the mutual form of ownership to the stock form. For savings and loans (S&Ls), a key exposure is exposure to interest rate changes. One measure of this exposure is the difference between assets whose interest rate changes within a year and liabilities whose interest rate changes within a year. As S&Ls convert from the mutual to the stock form of ownership, managers become able to acquire a stake in the firm, and compensation through options becomes possible. Schrand and Unal find that the one-year asset-liability gap of the S&L depends crucially on the nature of management's compensation. The one-year gap is narrower if management mostly holds shares in the converted S&Ls. It is wider if management is compensated through options. Haushalter (2000) studies the oil and gas industry risk management from 1992 to 1994. However, Haushalter's reported results do not support the hypothesis of managerial risk aversion.

Following this line of research, we study the risk management activities in 126 publicly-traded independent U.S. oil and gas producers during the period between 2001 and 2004. We provide detailed evidence on the interaction between the extent of hedging and managerial risk aversion that is consistent with theoretical prediction that management's equity ownership and executive compensation are important determinants of hedging decision.

1.1 Preview

The thesis is organized as follows. Chapter 2 presents our model of optimal hedging under incomplete information. We use the framework of portfolio selection under incomplete information developed by Detemple (1986), Dothan and Feldman (1986), and Genotte (1986) to analyzing optimal hedging decisions by an oil producer, and we model market view as a learning process. In the model, the firm's hedging policy is determined by its managers who maximize their expected lifetime utility. As managers observe the realized oil prices, they update their conditional estimates of the long run mean of log oil prices, in this way, they form their views about the market. Managers' compensation is modeled as a function of changes in firm value. Given that the value of a hedging firm depends on the market value of derivative positions and the spot price of oil, managers form a portfolio with these assets, and then the optimal hedging policy can be solved within the context of portfolio selection problem.

Chapter 3 provides empirical evidence for the hypothesis of managerial incentive as a determinant of hedging decisions. The risk management activities in 126 publicly-traded independent U.S. oil and gas producers during the period between 2001 and 2004 are examined in this thesis. In this chapter, hypotheses are summarized, variables are defined, and univariate and multivariate analysis are presented. The study shows great variability in corporate risk management activities in oil and gas producers. And we find that management's equity ownership and executive compensation are important determinants of hedging decision.

In Chapter 4, further regression results are presented as robustness tests of the regression models introduced in Chapter 3. The size of management team, and CEO's tenure are taken into consideration. We also separate the ownership and option holdings into CEO holdings and holdings by non-CEO officers and directors, the results suggest that CEOs could be vested with more authority in risk management program, however, non-CEO officers also show influence on hedging decisions. In addition, we separate the decision to hedge from the level of hedging to find out if there are differences in the factors that determine both decisions. In general, a large firm whose managers are younger and have a larger equity stake and fewer option holdings in the company hedges more. In addition, U.S. oil and gas producers who carry more cash reserve, lower financial leverage, and explore and produce oil and gas in other countries besides North America hedge less.

Finally, Chapter 5 summarizes and concludes. If managers have views, they may choose to do selective hedge instead of full hedge. And in the empirical study, we show that managerial risk aversion is a key determinant of hedging decisions

Chapter 2

The Role of Learning in Corporate Hedging Behavior

2.1 Introduction

All businesses face financial risks arising from changes in market variables such as commodity prices, interest rates and foreign exchange rates. A group of academic theories of corporate risk management suggest that some companies can increase their market values by using derivative securities to reduce their exposures to some market variables. These theories offer several explanations associated with the cost of financial distress, taxes, and the underinvestment problem. Smith and Stulz (1985) show that hedging can increase value by reducing the expected costs of financial distress. Leland (1998) demonstrates that hedging can increase a firm's debt capacity by lowering the probability of bankruptcy and thus generate more tax advantages from more leverage. Smith and Stulz (1985) also show that when firms face a convex tax schedule, hedging can reduce expected tax payments. Finally, Froot, Scharfstein and Stein (1993) demonstrate that when firms have many growth opportunities and external financing is costlier than internally generated funds, hedging can lessen the underinvestment problem by ensuring that the firm will have enough internal cash to make value enhancing investments.

Other theories conjecture that hedging demand is induced by managerial risk aversion. Corporate managers have typically a significant amount of their wealth invested in the firm they manage. Salary, bonus, and compensation options are all tied to the performance of the firm. Risk averse managers prefer to reduce the risk arising from under-diversification. If they find that the cost of hedging on their own account is higher than the cost of hedging at the corporate level, they will direct their firms to engage in risk management. The theoretical studies of Stulz (1984) and Smith and Stulz (1985) argue that managers decide optimal hedging policy in the context of maximizing their lifetime utility, therefore executive compensation policies can influence a firm's hedging policy by changing its management's attitude toward risk.

In deciding how to use derivatives to manage their financial risk, firms need to identify and measure their exposure to market variables. However, the parameters of the probability distribution from which the values of these variables are drawn are in general not observable, and therefore must be estimated. The errors caused by the need to estimate these parameters give rise to an additional "estimation risk" that must be taken into account when deciding the hedging policy of a firm.

In this chapter we derive a model of corporate hedging under incomplete information. Specifically we determine the optimal hedging policy for an oil producer when managers do not know the long run mean of oil prices. Although managers are uncertain about the true value of this time-varying parameter, they can learn about it from the realized oil price series. The precision of their conditional estimates increases as information accrues. However, we show even a moderate error in the initial estimate can persist for years.

Our model extends the analysis of Stulz (1984) who derives optimal hedging policies in a model in which managers maximize their expected lifetime utility and their income from the firm is an increasing function of the changes in the value of the firm. In this framework managers decide the hedging policy of the firm on behalf of its shareholders who choose managerial compensation contracts to maximize the value of the firm. Stulz's analysis focuses on hedging a foreign exchange exposure through forward contracts on foreign currencies. In his model managers know the value of the parameters that determine the dynamics of exchange rates, and thus, there are no additional problems arising from estimation errors.

Our analysis of hedging under incomplete information builds on the work of Detemple (1986), Dothan and Feldman (1986), and Genotte (1986) who characterize the portfolio problem of and investor who is unable to observe the parameters of the probability distribution from which asset returns are drawn. An important property of the problem analyzed by these authors is that the optimal portfolio decision may be separated into a filtering problem in which the investor estimates the current values of unknown parameters, and an investment problem which is solved by treating the estimated parameter values as the true parameter values themselves, and then proceeding as in the classical continuous time portfolio selection analysis of Merton (1971).

Brennan (1998) studies a special case of the analyses of Detemple (1986), Dothan and Feldman (1986), and Genotte (1986), in which the investment opportunities are represented by one riskless asset and one risky asset. The mean return of the risky asset is not observable and the investor learns about this parameter as he observes the asset price over time. Brennan (1998) shows that in an incomplete information economy, the possibility of future learning about the mean return on the risky asset induces the investor to take a larger or smaller position in the risky asset than he would under complete information, and the direction of the induced hedging demand depends on investors' risk tolerance.

In this chapter, we use the framework of portfolio selection under incomplete information developed by Detemple (1986), Dothan and Feldman (1986), and Genotte (1986) to analyze optimal hedging decisions by an oil producer. In our model, the firm's hedging policy is determined by its managers who maximize their expected lifetime utility. We model managerial compensation as a function of changes in firm value. Given that the value of a hedging firm depends on the market value of derivative positions and the spot price of oil, managers form a portfolio with these assets, and then the optimal hedging policy can be solved within the context of portfolio selection problem. As managers observe the realized oil prices, they update their conditional estimates of the long run mean of log oil prices. With the assumption that the long run mean of log oil prices is subject to a Gaussian distribution, the conditional means and variances of the long run mean can be readily estimated using the filtering formulas derived by Lipster and Shiryayev (1978). The value of the conditional variance indicates the diffusion of the beliefs of managers about the estimated long run mean of log oil prices. Greater (lower) conditional variance means lower (higher) precision of the estimate of the parameter. Following separation theorem[1] in Gennotte (1986), we can treat the estimated long run mean as the true value of the parameter and use it to solve for the optimal hedging policy.

Since in our model managers use their learning in formulating their hedging decisions, our results provide a rationale for the popularity of a practice known as "selective" hedging in which corporate derivative users appear to allow their views of future commodity prices, interest rates, and exchange rates to influence their hedging decisions. This practice seems inconsistent with the existing risk management theories. However, the 1995 Wharton survey reports that "over a third of all derivative users said they sometimes actively took positions based on their market views of interest rates and exchange rates", and the 1993 Dolde's survey reports that almost 90 percent of the derivative users said they sometimes took a view. Furthermore, many respondents said that their intensity of hedging depended on whether they had a view of future market movements. Stulz (1996) argues that firms prefer the selective as opposed to full-coverage hedging strategies because some firms have comparative advantage in learning certain financial risks through their daily operations. Namely, corporate derivative users appear to allow their views to influence their hedging policy.

The learning process can be regarded as the forming of the manager's view. Having a long-term experience observing the daily price changes, managers may have their own estimate of the evolution processes of prices. For example, if managers conjecture that the price of a commodity follows a mean-reverting process, they can estimate the uncertain parameters in the price dynamics conditional on the observations up to date. Then mangers treat the estimated values as true values of the parameters, and substitute the estimate into optimality conditions to solve for the optimal hedging policy. In a

[1] The separation theorem in Gennotte (1986) states that optimal control with partial observation can be performed as a two-stage procedure: First, the unobserved state variables are estimated: Second, investors treat the estimate as true state variables and optimal decisions are made accordingly. Investors ignore the uncertainty on the state variables when using their estimates to select optimal portfolio.

continuous time setting, the hedging position can be revised as the manager updates his estimates.

The chapter is organized as follows. Section 2.2 presents our model of optimal hedging under incomplete information. Section 2.3 analyzes the optimal hedging policies. Section 2.4 concludes.

2.2 The Model

We consider an oil producer that has a commitment to deliver X barrels of oil at time T, and the manager is in charge of designing the hedging policy of the company. Here we use an oil company as an example is because of the following reasons: (a) Oil producers tend to be single-industry firms with large price exposures. As Haushalter (2001) has mentioned in his study, the industry structure of oil companies offers a clear measure for the intensity of hedging - the fraction of annual production hedged against price fluctuations; (b) When thinking of risk management, oil producers have a wide range of hedging vehicles to implement their risk management policies, for example, oil futures and forward contracts are popular with oil companies. And the availability and effectiveness of hedging instruments lead to higher possibility that oil producers will hedge; (c) Bodnar, Hayt and Marston (1998) show that *in the industrial dimension, derivatives usage is greatest among primary product producers at 68 percent*. Therefore as primary product producers, oil companies are more likely to manage oil price risks. In this chapter, we assume that the oil company uses oil futures to hedge oil price risks. For simplicity, we assume a constant interest rate, hence our model also holds for firms using oil forward contracts in hedging.

We denote the value of the oil company by V. Since the firm uses futures in risk management program, the value of the company is changing with the market value of derivative positions and spot assets. To enhance the manager's incentive to work for the interest of shareholders, we assume that the company adopts an incentive compensation scheme, i.e., a constant fraction of δ of the changes in firm value (dV) will be paid to the manager as executive compensation. This simple compensation contract reconciles the interest of the manager with that of the company's existing shareholders. The optimal hedging policy is then chosen by the manger to maximize his lifetime expected utility. A generally accepted notion in corporate finance is that managers have a large amount of human capital tied up in their companies. Consequently, managerial risk aversion affects hedging decisions at the corporate level.

2.2.1 Price dynamics of futures

Empirical studies show that oil price exhibits significant mean reversion property (Bessembinder et.al., 1995 and Schwartz, 1997). Oil producers and exploration companies tend to increase production and exploration activities to take advantage of rising oil prices. When prices are relatively low, high-cost producers will be eliminated from the market, and the other producers may shut down part of their production capacity to save costs. These reactions lead to changes in market demand and supply, consequently oil price fluctuates around its long run mean. In this chapter, we assume spot oil price follows the mean-reverting process in Model 1 of Schwartz (1997):

(1) $dF = \kappa(\mu - \ln F)Fdt + \sigma F dz.$

As Schwartz (1997) has shown in his paper, if we define $x = \ln F$ and apply Ito's Lemma, we can see that the log oil price follows an Ornstein-Uhlenbeck stochastic process:

(2) $dx = \kappa(\mu - \frac{1}{2}\sigma^2/\kappa - x)\, dt + \sigma\, dz.$

Here κ denotes the speed of adjustment measuring the degree of mean reversion to the long-run mean log oil price, and $\kappa > 0$. σ is the volatility of log oil price and dz is an increment to a standard Brownian motion.

2.2.2 Inference process

Because of the availability of data on commodity spot prices, empirical studies of commodity spot market usually reply on the settlement prices of commodity futures at maturity (e.g., Bessembinder et al. (1995) and Schwartz (1997)) to estimate the parameters dominating the evolution of spot prices. A widely accepted notion in finance is that futures price is unbiased expectation of spot price in the future. Therefore in our model, we will base our inference process on the dynamics of oil futures in equation (1), namely, we try to estimate the long run mean of log oil price from the realized futures oil price.

For simplicity, we assume that the manager knows the true value of the speed of reversion (κ), and the volatility of oil price (σ), however, the long run mean of log oil price (μ) is unknown to the manager and has to be estimated conditional on realized oil futures price up to time t. From the mean-reverting property of oil prices, the manager may conjecture that μ follows an Ornstein - Uhlenbeck process:

(3) $d\mu = \eta(\bar{\mu} - \mu)\, dt + \sigma_\mu\, dz.$

Where, the long run mean (μ) and the volatility of μ (σ_μ) are assumed to be known constants.

At time zero the manager views the distribution of μ as a normal distribution with mean m_0 and variance υ_0. As time evolves, the manager observes more realized prices of oil futures and his information set increases, hence he can continuously update his estimates of μ. Lipster and Shiryayev (1978) show that the conditional distribution of μ is normal and derive the dynamics for the instantaneous changes in its conditional moments. We denote the conditional expectation and variance of μ at time t by m and υ. The instantaneous changes in the estimated long run mean (dm) and variance ($d\upsilon$) are given by the following equations:

(4) $dm = \eta(\bar{\mu} - m)dt + (\sigma_\mu\sigma + \kappa\upsilon)/\sigma^2\, [dF/F - \kappa(m - \ln F)\, dt];$

(5) $d\upsilon = [-2\eta\upsilon + \sigma_\mu^2 - (\sigma_\mu + \kappa\upsilon/\sigma)^2]\, dt$

Here υ is a deterministic function of time. If μ is assumed to be constant, η and σ_μ will be zero in equation (4) and (5), which means no reversion to the long run mean and zero volatility.

Equation (5) is of the Riccati type of differential equations, and can be solved as:

$$(6) \quad \upsilon = \begin{cases} \dfrac{2(\eta\sigma^2 + \kappa\sigma_\mu\sigma)\upsilon_0 \exp[-2(\eta + \kappa\sigma_\mu \ \sigma)t]}{2\eta\sigma^2 + 2\kappa\sigma_\mu\sigma + \upsilon_0\kappa^2 - \upsilon_0\kappa^2 \exp[-2(\eta + \kappa\sigma_\mu \ \sigma)t]}, & \text{if } \eta\dfrac{\sigma^2}{\kappa^2} + \sigma_\mu\dfrac{\sigma}{\kappa} \neq 0 \\ \dfrac{\upsilon_0\sigma^2}{\kappa^2\upsilon_0 t + \sigma^2}, & \text{if } \eta\dfrac{\sigma^2}{\kappa^2} + \sigma_\mu\dfrac{\sigma}{\kappa} = 0 \end{cases}$$

Equation (6) shows that the conditional volatility is a deterministic function of time t, and the value of the conditional variance can be discussed under three cases:

(a) If the true value of μ is known (i.e., $\upsilon_0 = 0$), the estimation uncertainty of μ disappears completely, and υ equals zero. This happens only in a full information economy.

(b) Under an incomplete information setting, μ is assumed to follow the Ornstein-Uhlenbeck process as in equation (3), and given that the diffusion terms (σ and σ_μ) and the speed of reversion (κ) are positive, we have $\eta\sigma^2/\kappa^2 + \sigma_\mu\sigma/\kappa > 0$, therefore the solution of υ is well defined as in equation (6). It is straightforward to verify that the limit of υ is zero as t goes to infinity. Figure 2.1 depicts the time-varying conditional variance with two different initial values: $\upsilon_0 = 0.2$ and $\upsilon_0 = 0.8$. And the figure shows the general trend of the conditional variance converging to zero over a 6-year horizon given specific parameter values. It is obvious that higher value of the initial variance leads to higher level of volatility in posterior estimation, however the volatility of estimation converges to zero rapidly.

(c) If μ is assumed to be an unknown constant, i.e., $\upsilon_0 \neq 0$, and $\eta = \sigma_\mu = 0$, then the condition $\eta\sigma^2/\kappa^2 + \sigma_\mu\sigma/\kappa = 0$ is satisfied. From equation (6), we can see that the limit of υ is also zero as t goes to infinity. This implies that the estimate of the expected long run mean of log oil prices converges to the true value of μ asymptotically. If the manager has a longer observation horizon, he will get a more precise estimate of the long run mean of log prices. Figure 2.2 illustrates the conditional variance with same the same parameter values as in Figure 2.1. Compared with Figure 2.1, the speed of convergence is slower in Figure 2.2. This implies that a time-varying estimator of the long run mean provides more precise estimates than a constant estimator.

Define an innovation process z' as:

(7) $dz' = 1/\sigma\,[dF/F - (\kappa m - \kappa \ln F)dt]$, and $z_0' = 0$.

And it is easy to verify the property: $(dz')^2 = (dz)^2 = dt$. Here dz' denotes the unexpected changes in oil futures prices.

Substituting equation (6) into (1) and (4), we can rewrite dF and dm as:

(8) $dF = \kappa(m - \ln F)Fdt + \sigma F dz'$;

(9) $dm = \eta(\bar{\mu} - m)dt + (\sigma_\mu + \kappa\upsilon/\sigma)dz'$.

Equation (9) can be partially solved as:

$$m = m_0 e^{-\eta t} + \bar{\mu}(1 - e^{-\eta t}) + \int_0^t e^{-\eta(t-s)}(\sigma_\mu + \kappa\upsilon/\sigma)dz'(s).$$

The integral on the right hand side is normally distributed with mean zero and variance $E\{[\int_0^t e^{-\eta(t-s)}(\sigma_\mu + \kappa\upsilon/\sigma)dz'(s)]^2\}$. Hence m is normally distributed with $E[m|m_0] = \bar{\mu} + (m_0 - \bar{\mu})e^{-\eta t}$ and $Var[m|m_0] = (\sigma_\mu + \kappa\upsilon/\sigma)^2(1 - e^{-2\eta t}) / (2\eta)$. Figure 2.3 shows the evolution of the posterior estimates of the long run mean of log oil prices given the initial expectation (m_0) of the parameter value. We can see that the estimated value converges to the true value of the uncertain parameter. This means the manager's estimated value is increasingly precise as information accrues over time. Comparing the three paths starting with different initial estimated value (m_0 = 2.5, m_0 = 3.5, and m_0 = 4), we can conclude that more biased initial estimate leads to greater estimation error afterwards. And the estimation error will diminish with time because the conditional variance (υ) converges to zero with time. Although managers can have accurate estimate of the value of the unknown parameter given a sufficient horizon, it really takes time. Figure 2.3 shows that, with the parameter value defined in our simulation, a small deviation of the estimated long run mean from the true parameter value can lead to an estimation error that persists for more than five years. In Figure 2.3(a), the long run mean (μ) of log oil price is assumed to be a constant, and in Figure 2.3(b), μ is assumed to follow a mean-reverting process. Comparing the two graphs, we can see that mean-reverting estimator converges faster than a constant estimator, i.e., time-varying estimator provides more accurate estimate for the oil prices.

2.2.3 Optimization

We assume the risk-free interest rate is a known constant and there is no transaction costs, hence the firm is indifferent between futures and forward as hedging vehicles. For simplicity, we assume the firm has no other assets[2], it is a single-industry oil producer. The company chooses to hedge risk exposure to the fluctuation of oil prices by buying N units of oil futures, therefore the value of the firm changes with the value of the portfolio formed by futures and spot assets – oil produced by the company. The instantaneous change in the value of the company (dV) before payments to the manager is given by

$$(10)\quad dV = Xd[e^{-r(T-t)}F] + NdF$$

The first term on the right hand side, $Xd[e^{-r(T-t)}F]$, represents changes in the present value of the future commitment to deliver X barrels of oil, and $e^{-r(T-t)}F$ denotes the present value of one unit of future commitment; The second term, NdF, is the total amount of trading payoffs from the N units of oil futures.

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[2] Stulz (1984) considers the effect of other assets in the firm. The absence of other assets does not weaken the generality of the result. If interested in the possible effect of other assets, please refer to Stulz (1984).

A fraction of δ of the changes in firm value (dV) are paid to the manager as his incentive compensation and $(1-\delta)$ of dV is reinvested in the company. Usually managers are compensated directly with salary, bonus, and stock options, and indirectly through equity ownership. In the model, the manager receives a fraction of δ of the changes in firm value, this compensation is actually equity ownership. And this compensation scheme aligns the interests of managers and shareholders and avoid potential agency problems. We assume that the company pays no dividend until date T and has no debt. In this setting, the manager's problem is to choose N^* to maximize his lifetime expected utility of consumption. we assume the manager has an isoelastic utility function:

$$(11)\quad U(c_t, t) = \begin{cases} e^{-\rho t}\dfrac{c_t^{1-\gamma}}{1-\gamma}, & \text{if } \gamma > 0 \text{ and } \gamma \neq 1; \\ e^{-\rho t}\ln c_t, & \text{if } \gamma = 1, \end{cases}$$

where c_t is the manager's consumption. And γ is the coefficient of relative risk aversion. We assume that the price of the manager's consumption basket is fixed and, for simplicity, equals to one. Denoting the manager's wealth by W ($W > 0$), and the manager's budget constraint is given by

$$(12)\quad dW = \delta dV + rWdt - cdt$$

The first term on the right hand side is the payment to the manager for the changes in firm value, $rWdt$ is the interest gain on the manager's wealth over a short time interval. The last term, cdt, is the manager's consumption per unit of time, and c is nonnegative, hence it is subtracted from the wealth process.

Substituting equation (8) and (10) into (12) yields the manager's wealth dynamics:

$$(13)\quad dW = \delta[X e^{-r(T-t)} + N]\,[\kappa(m - \ln F)Fdt + \sigma F dz'] + \delta r X e^{-r\tau} F dt + rWdt - cdt$$

The manager's problem is to choose consumption c^* and hedging policy N^* so as to maximize his expected utility[3] conditional on his information at time t

(14) $\max_{c,N} E_t\left(\int_t^T U(c,s)ds\right)$,

subject to the budget constraint in equation (13).

Defining the manager's indirect utility function at time t as

$$J(W, m, t) \equiv \max E_t\left(\int_t^T U(c,s)ds\right),$$

this function depends on his current wealth (W), his conditional estimate (m), and time. The necessary optimality condition for the manager's optimality problem is

$0 = \max_{c,N}[U(c,t) + E_t(dJ)]$.

And the Bellman equation is

(15) $0 = \max \{U(c,t) + J_t + J_m \cdot \eta(\bar{\mu} - m) + ½ J_{mm} (\sigma_\mu + \kappa\upsilon/\sigma)^2$

$+ J_W \cdot [\delta rXe^{-r(T-t)} F + \delta(X e^{-r(T-t)} + N)\kappa(m - \ln F)F + rW - c]$

$+ ½ J_{WW} (\delta \sigma F)^2 [X e^{-r(T-t)} + N]^2 + J_{mW} (\sigma_\mu\sigma + \kappa\upsilon)\delta[X e^{-r(T-t)} + N]F\}$,

subject to the boundary condition $J(W, m, T) = 0$ because we assume zero bequest value. From equation (15), the first-order conditions are given as:

(16) $0 = U_c(c,t) - J_W$;

(17) $0 = \delta\kappa(m - \ln F)F J_W + (\delta\sigma F)^2 [X e^{-r(T-t)} + N^*] J_{WW} + (\sigma_\mu\sigma + \kappa\upsilon)\delta F J_{mW}$.

The optimal hedging policy N^* can be solved from the optimality condition in equation (17):

(18) $N^* = \frac{1}{\delta F}\left[\frac{\kappa(m - \ln F)}{\sigma^2}\left(\frac{-J_W}{J_{WW}}\right) + \frac{(\sigma_\mu\sigma + \kappa\upsilon)}{\sigma^2}\left(\frac{-J_{Wm}}{J_{WW}}\right)\right] - Xe^{-r(T-t)}$.

[3] It is assumed for simplicity that the manager has a zero bequest function, i.e., the utility of terminal wealth is zero.

The analysis in Merton (1992) shows that, under the assumption of isoelastic utility function, the indirect utility function is separable in wealth W and in the state variables m and t[4]. Therefore we conjecture that the indirect utility functions corresponding to the power utility[5] in equation (12) can be written as:

$$(19)\quad J(W, m, t) = e^{-\rho t}\frac{W^{1-\gamma}}{1-\gamma}\phi(m,t),\ \gamma > 0 \text{ and } \gamma \neq 1.$$

$\phi(m, t)$ is the value function for the control problem, and it can be seen as the utility per unit of wealth. Taking derivatives of the indirect utility function w.r.t W, m, and t, and substituting these derivatives into (16) and (18) yield the optimal consumption ratio and hedging policies[6]::

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[4] The separability property was noted in Cass and Stiglitz (1970), Fischer (1969), Hakansson (1970), Leland (1968), Merton (1969).

[5] When $\gamma = 1$, the indirect utility function corresponding to the logarithmic utility in (13) can be written as $J(W, m, t) = a(t)\ln c + \phi(m, t)$ with a boundary condition: $a(T) = \phi(m, T) = 0$. The optimal rule is $N^* = (m - \ln F)W/(\sigma^2\gamma\delta F) - Xe^{-rt}$, which ignores learning effect (because J_{Wm} and ϕ_m drop from the optimal policies in equation (18) and (21)) and it is consistent with the optimal rules derived in Stulz (1984) under perfect information. And it is also consistent with the finding of Merton in the context of portfolio selection: Logarithmic utility function is not an interesting case to examine because *different assumptions about price behavior have no effect on the decision rules*. Since log utility is not an interesting case to examine learning effect, we assume power utility in this thesis.

[6] From equation (20), the optimal consumption is $c^* = \phi^{-1/\gamma}W$. Substituting this equation of c^* into the utility function in (11), and substituting the optimal utility, derivatives of indirect utility function in (19), and optimality condition in (21) into the Bellman equation (15), we arrive at the fundamental partial differential equation (PDE) for ϕ as a function of m, and t:

$$0 = \gamma\phi^{(\gamma-1)/\gamma} - \gamma r\phi + \phi_t + \eta(\bar{\mu} - m)\phi_m + \tfrac{1}{2}(\sigma_\mu + \kappa\upsilon/\sigma)^2\phi_{mm} + \phi\delta rXe^{-r(T-t)}F(1-\gamma)/W$$
$$+ \tfrac{1}{2}(1-\gamma)/\gamma\,[\kappa(m - \ln F)/\sigma + (\sigma_\mu\sigma + \kappa\upsilon)(\phi_m/\phi)/\sigma]^2\phi,$$

s.t. $\phi(m, T) = 0$.

(20) $\left(\frac{c}{W}\right)^{*} = \phi^{-1/\gamma}$;

(21) $N^{*} = \frac{W}{\gamma\delta F}\left[\frac{\kappa(m-\ln F)}{\sigma^{2}} + \frac{\sigma_{\mu}\sigma+\kappa\upsilon}{\sigma^{2}}\left(\frac{\phi_{m}}{\phi}\right)\right] - Xe^{-r(T-t)}$, and $\gamma > 0$.

When there is no parameter uncertainty, $m = \mu$ and $\upsilon = 0$, the optimal hedging strategy is

$$N_{b}^{*} = \frac{W}{\gamma\delta F}\left[\frac{\kappa(\mu-\ln F)}{\sigma^{2}}\right] - Xe^{-r(T-t)}.$$

2.3 Interpretation of the Optimal Hedging Policy

The hedging policy given by equation (21) can be interpreted in the following ways. First, we consider two extreme cases: The manager has no view at all, and the manager has perfect views. If the manager does not have views, and he still wants to manage risk, what he can do is to follow the variance-minimization method. In this case, the manager's problem is to choose a certain number of futures contracts to hedge the risk exposure of the firm so that $Var(dV)$ is minimized. By the predetermined compensation scheme, we know the manager receives a fraction, δ, of the changes in firm value as his compensation, consequently the manager's problem is equivalent to minimizing the instantaneous variance of the rate of changes in his personal wealth given his current estimate of μ, i.e., the manager can protect his wealth while hedging for the firm.

Given $Var(dV) = E[dV-E(dV)]^{2}$, we can substitute the dynamics of dV in equation (10) into the formula and solve for N_{a}^{*} from the first order condition with respect to N, the solution is given as:

(22) $N_{a}^{*} = -Xe^{-r(T-t)}$.

The negative sign means short position in futures. Equation (22) implies that the optimal strategy for the company is to short $Xe^{-r(T-t)}$ units of oil futures when the manager does not have ideas about market conditions in the future. Plugging equation (22) into the formula for covariance between firm value (V) and oil futures price (F), we can easily verify that $Cov(dV/V, dF/F) = 0$ and $Cov(dW/W, dF/F) = 0$. This means that the firm value of the company and the manager's personal wealth are insured against the fluctuations of future oil prices by holding N_a^* units of oil futures. For example, at time T, the firm receives a payment of $XF(T)$ on delivering oil to the contracting party, and the payoff of the futures contract is also determined. If the spot price is higher than expected, the company can make a profit on the spot market, however the short position in futures will lead to a loss, The profit gained from the spot market will be enough to meet the loss on futures. Similarly, if the spot price is low, gains on futures will cover the loss on spot oil. When deriving the hedging strategy, we introduce the current value of the future commitment in equation (10), so the discounting term $e^{-r(T-t)}$ appears in N_a^*. Similar to the model of Stulz (1984), the discounting term takes into account the probability that the oil company may default on the commitment.

In a full information economy, the manager knows the true value of the parameter that dominates the dynamics of spot oil prices, i.e., he has a perfect view about the market. In this case, he will choose the hedging policy, N_h^*.

(23) $N_h^* = \frac{W}{\gamma\delta F}\left[\frac{\kappa(\mu - \ln F)}{\sigma^2}\right] - Xe^{-r(T-t)}$, $\gamma > 0$ and $\gamma \neq 1$.

If $\kappa\mu - \kappa \ln F > 0$, given that γ, δ and $e^{-r(T-t)}$ are positive by definition, and the manager's personal wealth is nonnegative, the first term on the right hand side of equation (23) is positive. This implies that the long run mean of log oil price (μ) is higher than the current level of log prices, and the oil price in the future tends to rise due to its mean-reverting property, a short position in futures will incur loss. With this favorable knowledge of the market, the manager would like to short less and increase the company's risk exposure. Following this strategy, the firm can make a profit from the spot market even after covering its loss on the futures.

Similarly, if $\kappa\mu - \kappa \ln F < 0$, the first term in equation (23) turns to be negative, which means the current log price of oil is relatively high with respect to its long run mean. Consequently, oil price probably will decrease in the future. In this case, the manager takes more short position in futures and hedges more aggressively than required by the variance-minimization doctrine. In this way, the firm can make a larger profit on futures than the amount required to cover the loss on the spot market. Hence the first term on the right hand side of equation (23) arises from the manager's speculative motive. The speculative position is increasing in the market price of risk and is decreasing in the instantaneous variance of oil prices. The coefficient δ appears in the denominator because the firm must take a position of $1/\delta$ dollars for the manager to realize the full value of the return ($\kappa\mu - \kappa \ln F$) per unit of time. Equation (23) also implies that the wealth variable, W, has a magnifying effect: as the manager gets richer, he is more tolerant to risk and tends to be more speculative. Under the full information assumption, as long as it is possible to find the true values of the parameters dominating the dynamics of oil price, the manager can compute the firm's optimal holdings of futures using equation (23).

Figure 2.4 shows the optimal hedging policy determined by a risk-averse manager under a perfect information setting and the dotted line is the hedge ratio determined by variance-minimization method for comparison purposes. Since the manager knows the true value of the long run mean (μ) of log oil price, the manager can predict that current oil price is too high when $\mu - \ln F > 0$ and price will decrease in the near future, therefore he can make a profit by taking more short positions in oil futures. As shown in Figure 2.4 and 2.5, the optimal hedging policy deviates from the perfect hedge strategy because the manager is shorting less, and the deviation increases when the manager is less risk averse. In Figure 2.4 and 2.5, the optimal hedge policy of a conservative manager (e.g., $\gamma = 10$) is much closer to the perfect hedge strategy, but for a less risk-averse manager ((e.g., $\gamma = 5$), the optimal hedge ratio can differs greatly from the hedge ratio determined by the traditional method. The risk management behavior predicted by our model is consistent with the comments in Stulz (1996): larger companies were more inclined to *self-insure* their financial risks. Some firms have comparative advantage in learning certain financial risks through their daily operations, and their managers tend to take market views into consideration when they make hedging decisions. For example, the Treasurer of an oil company may have a view about the oil price in the near future, and he could make decision based on his estimate. If firms expected financial signals (for example, commodity prices, exchange rates and interest rates) to move in a way that would increase firm value, they might hedge only 10% (or maybe none) of their risk exposure. But if they expected market conditions to move in a way that would reduce value, they might hedge 100% of the exposure.

The hedging policy in equation (23) has a strong assumption that managers know the true value of the parameters since they have all the information needed in the learning process, including the distribution of unobservable state variables. This is an optimal scenario that makes things much easier. Relaxation of this assumption complicates the determination of hedging policies, however it is possible to derive a definite hedging policy under partial information. Although the manager does not know the distribution of the unobservable parameter, he can estimate the value of the parameters as he observes the realized oil prices up to time t, and the manager updates his conditional estimate continuously as he receives new information. Under the incomplete information setting, the optimal hedging strategy is given by N^* in equation (21).

Compared with equation (23), the estimated value of the long run mean, m, replaces the true parameter μ because the manager does not know the true value of μ, he has to resort to his view about the market condition in the future. In addition, the optimal hedging policy with learning process under partial information has an extra term: $(W / \gamma\delta F)[(\sigma_\mu\sigma + \kappa\upsilon) / \sigma^2](\phi_m / \phi)$. This term arises from the hedging demand induced by learning. If there is no uncertainty about μ, i.e., $m = \mu$, $\upsilon = 0$ (because $\upsilon_0 = 0$ in equation (6)), and ϕ_m drops, the hedging policy is exactly the same as the hedging strategy under complete information. When the parameter uncertainty problem exists, the induced hedging demand may be positive or negative depending on the sign of ϕ_m. Non-satiation implies that the manager's expected utility is increasing in his current estimate of the long run mean, i.e., $Jm > 0$. Given that γ is the relative risk aversion coefficient, by the definition of the indirect utility function in equation (19), we have $\phi_m > 0$ when $0 < \gamma < 1$, and $\phi_m < 0$ when $\gamma > 1$. Plugging the different values of ϕ_m into the optimal hedging policy, we find that the induced hedging demand may be positive or negative depending on the manager's attitude towards risk. We can discuss the optimal hedging policy in the following cases:

A. The manager is conservative, i.e., $\gamma > 1$. The value of gamma is greater than one implies that the induced hedging demand is negative, i.e., $(W / \gamma\delta F)[(\sigma_\mu\sigma + \kappa\upsilon) / \sigma^2](\phi_m / \phi) < 0$.

i. If oil price is expected to rise, i.e., $\kappa m - \kappa \ln F > 0$, the manager wants to short less than the full coverage hedging strategy due to his speculative motive, but he knows that he is employing the estimated value of the long run mean, not the true parameter, in the computation of the hedging policy, therefore he has to take into accounts the parameter uncertainty problem when he considers about taking a speculative position. Consequently, the manager decreases his speculative position and short more futures toward the full coverage hedging strategy. Here υ, representing the diffusion of the estimate at time t from the true parameter, can be interpreted as the degree of precision for the estimate, m. If the estimate is not accurate, i.e., υ is large, the manager decreases his speculative position even further.

ii. If oil price is expected to decrease, i.e., $\kappa m - \kappa \ln F < 0$, the hedging policy implies that the manager will increase his speculative position and short more futures due to speculative motive. Since the manager is conservative, the induced hedging demand is negative, therefore the manager will short more than the full coverage strategy.

B. Similarly, for a less risk averse manager (i.e., $0 < \gamma < 1$), the induced hedging demand is positive, i.e., $(W / \gamma\delta F)[(\sigma_\mu\sigma + \kappa\upsilon) / \sigma^2](\phi_m / \phi) > 0$.

i. If oil price is expected to rise, i.e., $\kappa m - \kappa \ln F > 0$, the first two terms in equation (21) are both positive, which means that the manager will increases his speculative position and short less compared with the full coverage strategy.

ii. If oil price is expected to decrease, the hedging policy implies that the manager will decrease his speculative position and the optimal hedge policy will be closer to the full coverage strategy.

The bottom line is: the hedging policy under incomplete information is different from the strategy derived with full information, and managers' view affects optimal hedging policies. The direction of the hedging demand induced by learning can be negative or positive depending on the manager's risk attitude.

2.4 Summary and Future Research

View-taking activities are widely evidenced in empirical studies of corporate hedging practice. We derive a simple model of optimal hedging policies under incomplete information to examine the potential effect of managerial view on corporate hedging behavior. Although managers cannot observe the long run mean of oil prices directly, he can learn about the true value of the parameter, and take views about the market in the future. If choosing corporate hedging policies is the manager's sole responsibility, view-taking activities can influence the hedging policy. The manager tends to avoid the down-side risk while keeping profit potentials on the up-side changes. If the prices of a commodity and the commodity futures follow mean-reverting processes, the manager's view converges to the true price process as the horizon goes to infinity because he has adequate time to observe and collect information about the true price process.

Hedging decisions are correlated with companies' capital structure and manager's compensation contract. Stulz (1996) has comments on the relation between hedging and capital structure: *risk management can be viewed as a direct substitute for equity capital......Moreover, to the extent one views risk management as a substitute for equity capital - or, alternatively, as a technique that allows management to substitute debt for equity - then it pays companies to practice risk management only to the extent that equity capital is more expensive than debt. As this formulation of the issue suggests, a company's decisions to hedge financial risks - or to bear part of such risks through selective hedging - should be made jointly with the corporate structure decision.* Theoretical work (e.g., Mello and Parsons (2000)) and empirical study (Haushalter (2000)) show that hedging is more beneficial to and popular with capital-constrained firms. Therefore, a more general model can analyze hedging within the context of a capital structure decision.

Another interesting issue with hedging is the difference among executive compensation contract across firms. Executive compensation mainly has three components: salary, bonus and stock option (see Perfect, Wiles and Howton (2000) for details). Our model considers the simplest case --- salary. Hedging literature show that the existence of stock option and executive shareholdings has negative effect on hedging (e.g., Stulz (1996), Haushaulter (2000), and PWH (2000)) corporate hedging. Therefore differences in incentive compensation are also a reason for the cross-sectional variability in corporate hedging behavior. Now it seems that a more conclusive hedging model can take capital structure and compensation contract into consideration.

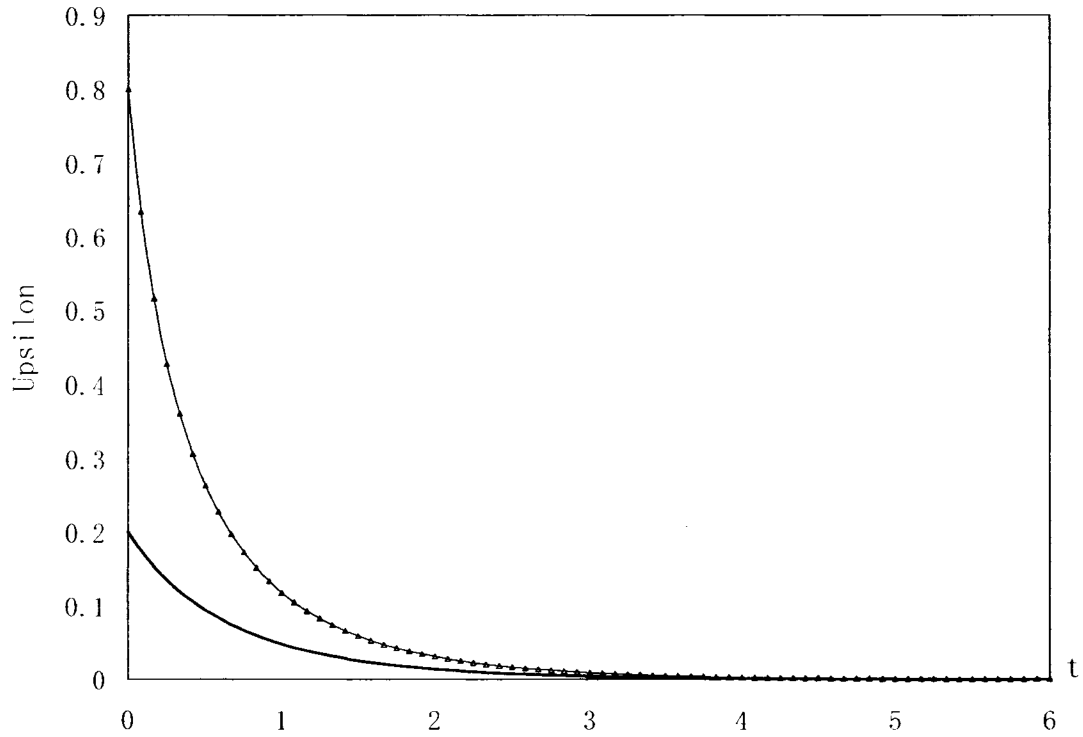

Figure 2.1: Conditional variance of the estimate of long run mean of log prices when μ is assumed to be mean reverting. This figure depicts the time-varying conditional variance (υ) of the estimator (m) of μ when the condition $\eta\sigma^2+\sigma_\mu\sigma \neq 0$ is satisfied. Parameter values are defined as: $\sigma = 0.334$, $\sigma_\mu = 0.2$, and $\eta = 0.3$. The straight line is the conditional variance with the initial value $\upsilon_0 = 0.2$. And the line with triangles is the conditional variance with the initial value $\upsilon_0 = 0.8$.

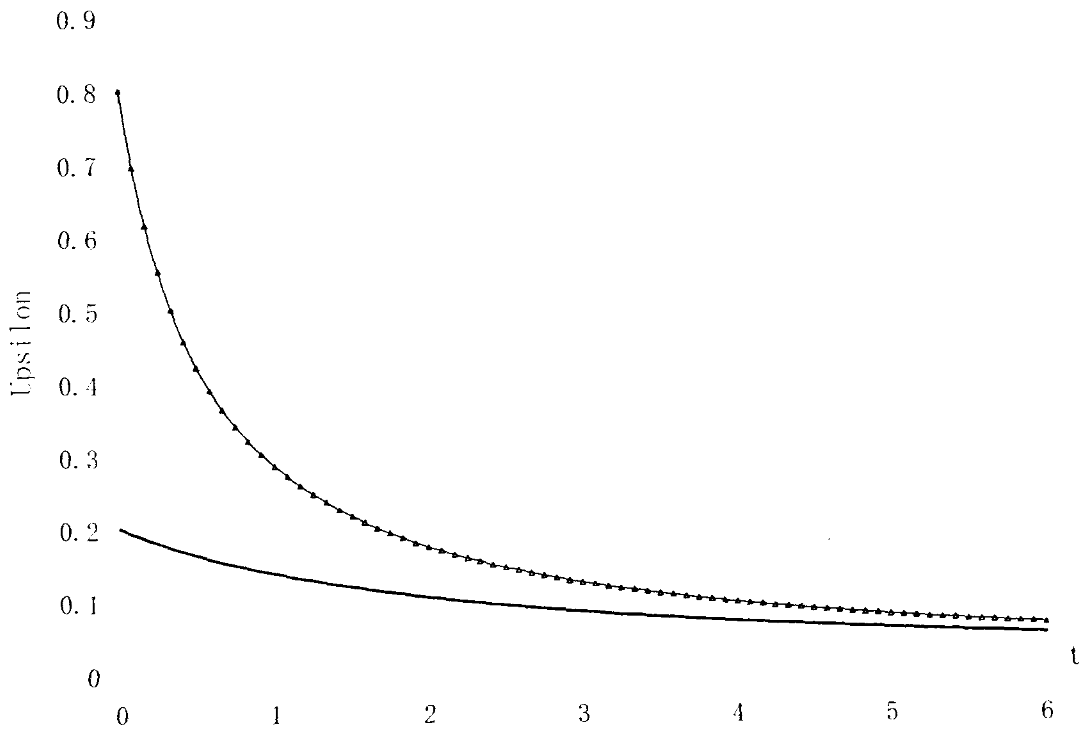

Figure 2.2: Conditional variance of the estimate of long run mean of log prices when μ is assumed to be constant ($\sigma_\mu = 0$, and $\eta = 0$). This figure depicts the time-varying conditional variance (υ) of the estimator (m) of μ when the condition $\eta\sigma^2 + \sigma_\mu\sigma = 0$ is satisfied. Parameter values are defined as: $\sigma = 0.334$, $\sigma_\mu = 0.2$, and $\eta = 0.3$. The straight line is the conditional variance with the initial value $\upsilon_0 = 0.2$. And the line with triangles depicts the conditional variance with the initial value $\upsilon_0 = 0.8$.

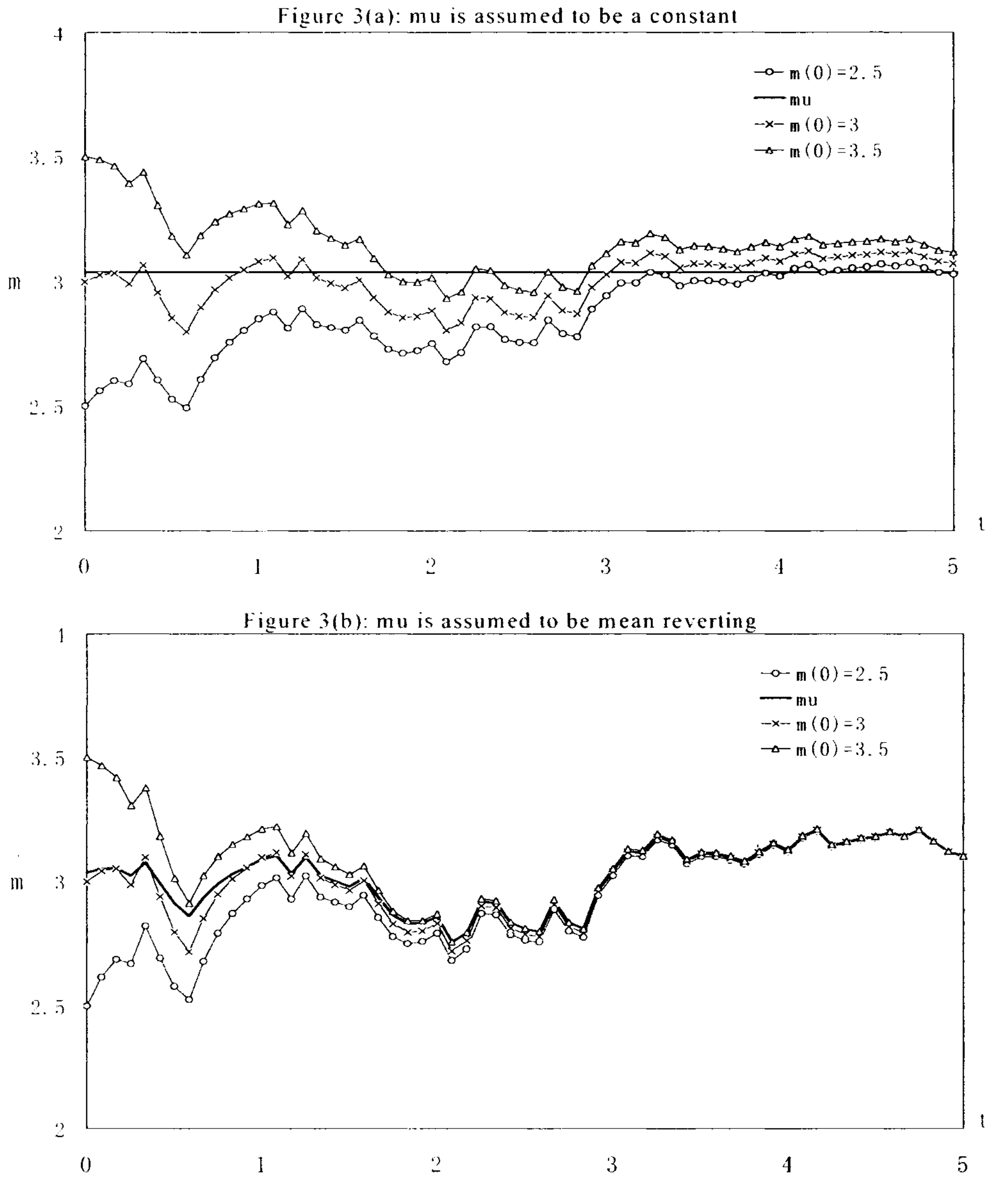

Figure 2.3: The estimate of long run mean of log prices. This figure depicts the evolution of the posterior estimate (m) of the long run mean (μ). The value of parameters in the simulation are σ = 0.334, σ_μ = 0.2, η = 0.3, $\bar{\mu}$=3.037, υ_0 = 0.2, and μ_0 = 3.037. The straight line is the simulated path of μ, the line with triangles denotes the evolution of the posterior estimate (m) with an initial value of m_0 = 2.5. The crossed line is the path of the estimate with the initial value of m_0 = 3, and the triangle is the path of the estimate with the initial value of m_0 = 3.5. μ is assumed to be a constant in Figure (a), i.e., σ_μ = 0, and η = 0. In Figure (b), μ is assumed to be mean reverting.

Figure 2.4. and 2.5 below compare the optimal hedging policy designed by a risk-averse manager under perfect information with the hedging policy derived by variance minimization approach. The optimal hedging policy under perfect information is given by:

$$N_h^* = \frac{W}{\gamma \delta F e^{-\kappa\tau}}\left[\frac{(\kappa\mu - \kappa \ln S - r)}{\sigma^2}\right] - Xe^{-r\tau}.$$

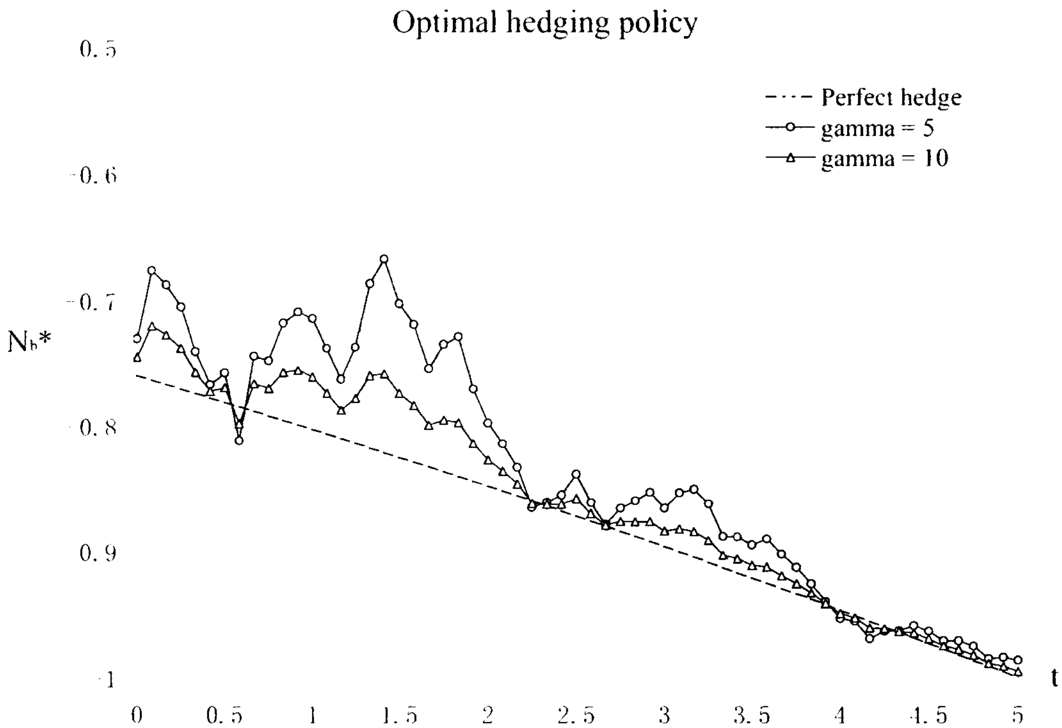

Figure 2.4: Optimal hedging policy under perfect information. This figure depicts the optimal hedge ratio in equation (23) where we assume risk-averse managers know the true value of the long run mean (μ) of log oil price. The value of parameters in the simulation are $\sigma = 0.334$, $\kappa = 0.5$. $\eta = 0.3$, $\mu = 3.3$, $\bar{\mu} = 3.5$, $\upsilon_0 = 0.2$, $\delta = 0.1$, $\sigma_\mu = 0.8$, $X = 1$, $W(0) = 1$, $r = 0.055$, $T = 5$, and $F(0) = \$25$. The two lines show the optimal hedge ratios for managers with different attitude toward risk, here the coefficient of risk aversion (γ) takes two values, $\gamma = 5$, and $\gamma = 10$. The dotted line shows the hedge ratio determined by perfect hedge strategy.

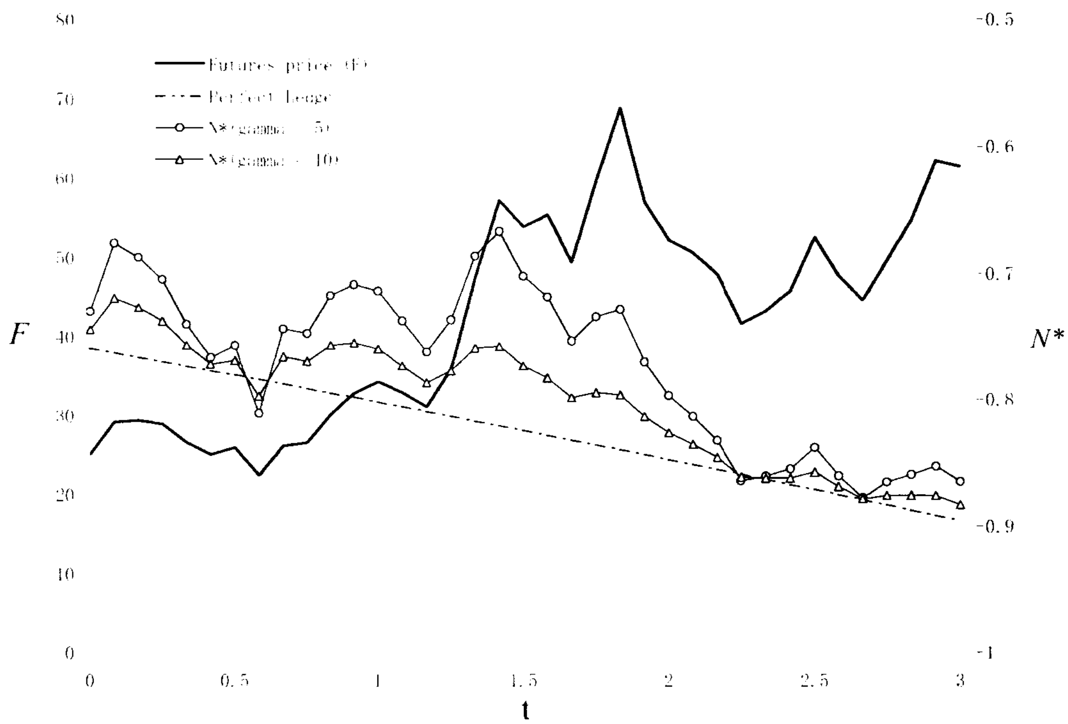

Figure 2.5: Comparison between futures price and the optimal hedging policy determined under perfect information. This figure compares the optimal hedge ratio in equation (23) with the futures price. The value of parameters in the simulation are σ = 0.334, κ= 0.5, η = 0.3, μ =3.3, $\bar{\mu}$=3.5, υ_0 = 0.2, δ = 0.1, σ_μ = 0.8, X = 1, $W(0)$ = 1, r = 0.055, T = 5, and $F(0)$ = \$25. The straight line depicts the dynamics of futures price. The two lines with circles and triangles show the optimal hedge ratios for managers with different attitude toward risk, here the coefficient of risk aversion (γ) takes two values, γ = 5, and γ = 10. The dotted line shows the hedge ratio determined by perfect hedge strategy.

Appendix I

1. To solve for N^* in equation (22)

Given the following conditions in equation (8), (10), and (12)

$$dF = mFdt + \sigma F dz'$$
$$dV = Xd[e^{-r(T-t)}F] + NdF;$$
$$dW = \delta dV + rWdt - cdt.$$

Plugging dV, dF into equation (11), we have

$$dW = \delta[Xe^{-r\tau}dF + rXFe^{-r\tau}dt + N\,dF] + rWdt - cdt$$
$$= \delta[Xe^{-r\tau} + N]\,[\kappa(m - \ln F)Fdt + \sigma F dz'] + \delta rXFe^{-r\tau}dt + rWdt - cdt$$

Plugging the dynamics of m in equation (9), and dW into the Bellman equation, we have:

$$0 = \max_{c,N}[U(c,t) + E_t(dJ)],$$
$$\Rightarrow\ 0 = U(c,t) + J_t + J_m \cdot \eta(\bar{\mu} - m) + J_W \cdot [\delta rXe^{-r(T-t)}F + \delta(Xe^{-r(T-t)} + N)\kappa(m - \ln F)F + rW - c] + \tfrac{1}{2}J_{mm}(\sigma_\mu + \kappa\upsilon/\sigma)^2 + \tfrac{1}{2}J_{WW}(\delta\sigma F)^2[Xe^{-r(T-t)} + N]^2 + J_{mW}(\sigma_\mu\sigma + \kappa\upsilon)\delta[Xe^{-r(T-t)} + N]F.$$

Taking first order condition w.r.t. N and c, we have the optimal hedging policy N^* as shown in equation (18):

$$N^* = \frac{1}{\delta F}\left[\frac{\kappa(m - \ln F)}{\sigma^2}\left(\frac{-J_W}{J_{WW}}\right) + \frac{(\sigma_\mu\sigma + \kappa\upsilon)}{\sigma^2}\left(\frac{-J_{Wm}}{J_{WW}}\right)\right] - Xe^{-r(T-t)},$$

and the optimal consumption satisfies the condition: $U_c(c,t) = J_W$.

Assume $J(W, m, t) = e^{-rt}\dfrac{W^{1-\gamma}}{1-\gamma}\phi(m,t)$ for power utility ($\gamma > 0$ and $\gamma \neq 1$), we can have the optimal consumption-wealth ratio:

$$U_c(c,t) = J_W \Longrightarrow (c/W)^* = \phi^{-1/\gamma}.$$

We can write the first-order and second-order derivatives of $J(W, m, t)$ w.r.t m, t, and W as:

$$J_W = e^{-rt}W^{-\gamma}\phi,$$
$$J_{WW} = -\gamma e^{-rt}W^{-\gamma-1}\phi \Longrightarrow J_W/J_{WW} = -W/\gamma,$$
$$J_m = e^{-rt}[W^{1-\gamma}/(1-\gamma)]\,\phi_m,$$
$$J_{mm} = e^{-rt}[W^{1-\gamma}/(1-\gamma)]\,\phi_{mm},$$
$$J_{Wm} = e^{-rt}W^{-\gamma}\phi_m \Longrightarrow J_{Wm}/J_{WW} = (W\phi_m)/(-\gamma\phi),$$
$$J_t = -re^{-rt}[W^{1-\gamma}/(1-\gamma)]\,\phi + e^{-rt}[W^{1-\gamma}/(1-\gamma)]\,\phi_t.$$

Plugging the above derivatives into equation (18), we can write the optimal hedging policy under incomplete information as:

$$N^* = \frac{W}{\gamma\delta F}\left[\frac{\kappa(m-\ln F)}{\sigma^2} + \frac{\sigma_\mu\sigma+\kappa\upsilon}{\sigma^2}\left(\frac{\phi_m}{\phi}\right)\right] - Xe^{-r(T-t)}.$$

And this is the optimal hedging policy in equation (21).

Similarly, the optimal hedging policy under perfect hedging can be solved as:

$$N^* = \frac{W}{\gamma\delta F}\left[\frac{\kappa(\mu-\ln F)}{\sigma^2}\right] - Xe^{-r(T-t)}.$$

which is given in equation (22).

2. The PDE in Footnote 9

Given $(c/W)^* = \phi^{-1/\gamma}$, the optimal consumption can be written as $c^* = \phi^{-1/\gamma}W$. Plug the optimal consumption into the utility function in equation (11), we have:

$$U(c^*, t) = \begin{cases} e^{-rt}\dfrac{(c^*)^{1-\gamma}}{1-\gamma}, & \text{if } \gamma > 0 \text{ and } \gamma \neq 1; \\ e^{-rt}\ln c^*, & \text{if } \gamma = 1, \end{cases}$$

$$\Longrightarrow e^{-rt}(\phi^{-1/\gamma}W)^{1-\gamma}/(1-\gamma)$$

$$\Longrightarrow U(c^*, t) = e^{-rt}[W^{1-\gamma}/(1-\gamma)]\,\phi^{(\gamma-1)/\gamma}.$$

Plugging the above $U(c, t)$, derivatives of $J(W, m, t)$, and the optimal hedging policy N^* into the Bellman equation:

$$0 = U(c,t) + J_t + J_m \cdot \eta(\bar{\mu} - m) + J_W \cdot [\delta r X e^{-r(T-t)} F + \delta(X e^{-r(T-t)} + N)\kappa(m - \ln F)F$$
$$+ rW - c] + \tfrac{1}{2} J_{mm}(\sigma_\mu + \kappa\upsilon/\sigma)^2 + \tfrac{1}{2} J_{WW}(\delta\sigma F)^2 [X e^{-r(T-t)} + N]^2$$
$$+ J_{mW}(\sigma_\mu\sigma + \kappa\upsilon)\delta[X e^{-r(T-t)} + N]F,$$

we can have a PDE for the control variable $\phi(m, t)$ under incomplete information:

$$0 = \gamma\phi^{(\gamma-1)/\gamma} - \gamma r\phi + \phi_t + \eta(\bar{\mu} - m)\,\phi_m + \tfrac{1}{2}(\sigma_\mu + \kappa\upsilon/\sigma)^2\phi_{mm}$$
$$+ \phi\delta r X e^{-r(T-t)} F(1-\gamma)/W + \tfrac{1}{2}(1-\gamma)/\gamma\left[\frac{\kappa(m-\ln F)}{\sigma} + \frac{(\sigma_\mu\sigma+\kappa\upsilon)}{\sigma}\left(\frac{\phi_m}{\phi}\right)\right]^2\phi$$

Similarly, the PDE for the control variable ϕ under perfect information can be written as:
$0 = \gamma\phi^{(\gamma-1)/\gamma} + \phi_t - r\gamma\phi + (1-\gamma)/W\delta rFX e^{-r(T-t)}\phi + \tfrac{1}{2}(1-\gamma)/\gamma[\kappa(\mu - \ln F)/\sigma^2]\phi.$

Chapter 3

Managerial Risk Aversion and Corporate Risk Management: Evidence from U.S. Oil and Gas Producers

3.1 Introduction

Managerial risk aversion provides a rationale for corporate risk management. Corporate managers have typically a significant amount of their wealth invested in the firm they manage. Salary, bonus, and compensation options are all tied to the performance of the firm. Risk adverse managers prefer to reduce the risk arising from under-diversification. If they find that the cost of hedging on their own account is higher than the cost of hedging at the corporate level, they will direct their firms to engage in risk management. The theoretical studies of Stulz (1984) and Smith and Stulz (1985) argue that managers decide optimal hedging policy in the context of maximizing their lifetime utility, therefore executive compensation policies can influence a firm's hedging policy by changing its management's attitude toward risk.

Other group of theories focuses on risk management as a means to maximize shareholder value. Firms can create value by reducing the various costs associated with volatile cash flow through hedging. This literature offers several explanations associated with the cost of financial distress, taxes, and the underinvestment problem. Smith and Stulz (1985) show that hedging can increase value by reducing the expected costs of financial distress. Leland (1998) demonstrates that hedging can increase a firm's debt capacity by lowering the probability of bankruptcy and thus generate more tax advantages from more leverage. Smith and Stulz (1985) also show that when firms face a convex tax schedule, hedging can reduce expected tax payments. Finally, Froot, Scharfstein and Stein (1993) demonstrate that when firms have many growth opportunities and external financing is costlier than internally generated funds, hedging can lessen the underinvestment problem by ensuring that the firm will have enough internal cash to make value enhancing investments.

The empirical studies on corporate risk management try to determine whether the behavior of the firms that manage risk using derivatives is consistent with the extant theories. In general, the existing empirical evidence finds little support for the theories that view risk management as a means to maximize shareholder value. Tufano (1996) examines the hedging behavior of North American gold mining companies and finds virtually no relationship between risk management and firm characteristics that value-maximizing risk management theories would predict. The studies of Allayannis and Weston (2001), and Graham and Rogers (2002) provide evidence that hedging increases the firm's market value. Allayannis and Weston (2001) find that the market value of firms using foreign currency derivatives is 5% higher on average than for nonusers. Graham and Rogers (2002) find that firms use derivatives to increase debt capacity which in turn increases firm value by 1.1% on average. However, by examining the economic effects of derivatives positions for a sample of non-financial corporations, Guay and Kothari (2003) conclude that potential gains of derivatives are small compared to cash flows and changes in equity values, and cannot possibly have an effect of the magnitude claimed by the studies above. Their interpretation is that the use of derivatives is associated with other risk management activities, such as operational hedges, which are value enhancing.

More recently Jin and Jorion (2006) study the hedging activities of U.S. oil and gas producers and find that hedging does not seem to affect their market values after controlling for systematic risk. However oil and gas producers show great difference in their hedging activities. There are firms that hedge a large proportion of their production, while others do not hedge at all, with firms whose hedging behavior varies between these two extremes.

The purpose of this paper is to find if the observed hedging behavior of oil and gas producers is consistent with the theories based on managerial risk aversion. These theories predict that the nature of the compensation plan can influence a firm's risk management policy without affecting its market value. Specifically, all else equal, managers with more wealth invested in a firm's equity will have greater incentives to manage the firm's risk. Therefore, we expect a positive correlation between managerial equity ownership and the extent of corporate hedging. Smith and Stulz (1985) and Stulz (1996) argue that the incorporation of option-based compensation increases the incentives for managers to take risks, i.e., firms that rely heavily on contingent compensation may hedge less than firms that mainly rely on salary and other non-contingent methods of payment. The more option-like features there are in the compensation plans, the less managers will hedge, i.e., the extent of hedging should be negatively associated with the option-based compensation.

We study the risk management activities in 126 publicly-traded independent U.S. oil and gas producers during the period between 2001 and 2004. The information on the financial risk management activities by these firms is obtained from their SEC fillings, which is public information. Our sample shows great variability in corporate risk management activities in oil and gas producers. We collect detailed information on executive compensation, options awarded to top officers, managerial common stock ownership, and other firm characteristics including financial leverage, business segmentation, and geographic diversification. We provide detailed evidence on the interaction between the extent of hedging and managerial risk aversion that is consistent with theoretical prediction that management's equity ownership and executive compensation are important determinants of hedging decision. We also separate the ownership and option holdings into CEO holdings and holdings by non-CEO officers and directors, the results suggest that the CEO is the person who is vested with more authority in risk management program. In addition, we separate the decision to hedge from the level of hedging to find out if there are differences in the factors that determine both decisions. In general, a large firm whose managers are younger and have a larger equity stake and fewer option holdings in the company hedges more. In addition, U.S. oil and gas producers who carry more cash reserve, lower financial leverage, and explore and produce oil and gas in other countries besides North America hedge less.

Two previous empirical studies also examine the relationship between managerial risk aversion and corporate risk management for commodity producers. Tufano (1996) examines the hedging behavior of 48 publicly traded North American gold mining companies. He finds that the only important determinant of the hedging decisions is the nature of the managerial compensation contract, i.e., the greater management's percentage of equity ownership, the larger the percentage of its gold price exposure a firm hedges. Haushalter (2000) tests multiple hypotheses using a sample of 100 oil and gas firms in order to find out explanations to justify the prevalence of risk management as a corporate policy. However, Haushalter's reported results do not support the hypothesis of managerial risk aversion.

Tufano (1996) and Haushalter (2000) use the extent of hedging as the dependent variable, which more accurately measures firms' risk exposure than the dummy variables commonly used in early empirical hedging literature (e.g., see Block and Gallagher (1986), Nance, Smith and Smithson (1993), Géczy, Minton, and Schrand (1997)). However, Tufano (1996) and Haushalter (2000) relied mainly on survey data, rather than from publicly available financial reports, to calculate the extent of hedging. This was a standard way to empirically study corporate hedging behavior in the past two decades because firms did not disclose enough information in a uniform way on risk management activities, and surveys provide flexibility in the design of the questionnaire, which may generate rich data that cannot be collected by other means. However, the adoption of survey data may have severe limitations. Triki (2005) argues that results reported with survey data suffer from two biases. One is that hedgers may be more likely to respond to the questionnaires than non-hedgers. Consequently, the sample of respondents companies may not properly reflect the characteristics of the population. Haulshalter (2000) shows that the non-respondent firms in his survey have fewer assets than respondent firms. This finding confirms the existence of a sampling bias in survey data. Another source of bias is that the dependent variable (extent of hedging) used by Tufano (1996) and Haushalter

(2000) is collected from survey data, however, the independent data are collected from reliable public information sources, there could be an inconsistency. In addition, the quality of the survey data depends on the perception of the person who fills in the questionnaire. And it could be difficult to verify the reliability of the answers provided by the survey. We also use the extent of hedging as the dependent variable in this paper, however, we collect this variable from firms' public annual report, which mitigates inconsistencies in our study.

In addition, our sample is larger than the samples in Tufano (1996), Haushalter (2000), and Jin and Jorion (2006). This generates statistically powerful and reliable results. For example the R-squares reported in our regressions are much higher than those reported by Haushalter (2000) , which implies higher explanatory power of our models.

The remainder of the chapter is organized as follows: Section 3.2 summarizes the hypotheses, which will be tested in this chapter. The definition of variables in the empirical test is also discussed in this section. The univariate analysis of these variables is presented in Section 3.3. Section 3.4 discusses the regression results of tobit model, probit model, and truncated regression. Robustness of these model specifications is also tested in this section.

3.2 Empirical Hypotheses and Variables

We identify 126 U.S. oil and gas producers between 2001 and 2004 by searching in Compustat for independent active public oil and gas companies with a primary SIC code of 1311, which means the industry of Crude Petroleum and Natural Gas Extraction. To make sure that the firms in our sample are really oil and gas *producers*, we check 10K filings and look for firms with nonzero oil and/or gas production. Since zero-production oil and gas companies essentially are not subject to energy price risk, we exclude these firms from the sample. Reading the business introduction section in firms' 10K forms, we also notice that some firms are fully involved in midstream and downstream operations in petroleum industry, including oil/gas gathering, treating, transmission, and marketing. These firms are not real oil and gas producers, we delete them from the sample and only keep the oil companies at least partially operating in the upstream sector of the oil industry. The total sample includes about 470 firm years. The missing firm years are due to paper filing, bankruptcy, merger, and deregistration with SEC, and some firms start IPO during the period of 2000 to 2004, continuous documentation of these firms is not available for the four sample years. The dependent variable and independent variables in our study are discussed in the following subsections.

3.2.1 Dependent variable: Fraction of production hedged

Oil and gas producers have a wide range of financial instruments to achieve hedging goals. Using forward agreements, fixed price contracts, volumetric production payments, forwards contracts, or swaps, oil and gas producers can lock in a fixed sales price. For example, with a long position in put option, oil and gas producers can ensure a minimum sales price and hence is insured from downside risk. The extent of hedging is defined as the fraction of the firm's production for the year that is hedged against price fluctuations. We use the hedged percentage of annual oil and gas production as the dependent variable (see Appendix for calculation detail), and collect data on ownership and executive compensation from proxy statements and 10K forms. The total annual production is measured in thousand barrels of oil equivalent (MBOE). According to the conversion convention of 1 barrel being equivalent to 6 thousand cubic feet (Mcf), we convert natural gas in Mcf into barrels of oil equivalent in order to calculate the total production (see Appendix for production calculation). Since some firms revise their hedging policies after 10K filing and they disclose this information in quarterly filings. We also check 10Q filings in order to make the hedging percentage calculation as precise as possible.

3.2.2 Independent variables: Managers' compensation and ownership

Stulz (1984), and Smith and Stulz (1985) argue that managerial risk aversion is a driver of risk management at corporate level. Management tend to have poorly diversified portfolio, and unfavorable circumstances of their companies will adversely affect their personal wealth, therefore managers have strong incentive to manage the risk at the corporate level. Smith and Stulz's (1985) show that managerial compensation plans can influence their hedging choices. A typical compensation package includes salary, performance-based bonus, and long-term incentive plan in which option-based compensation plays an important role. Smith and Stulz's (1985) model predicts that the incorporation of option-based provisions in managers' compensation packages increases the incentive for managers to take risks, because lower risk would reduce the stock's volatility and the value of their option contracts. Consequently, increasing managers' option-based compensation decreases their incentive to hedge.

To examine the relationship between hedging policy and managerial compensation, we collect data on managers' salary, bonus, and option awards from proxy statements and 10K forms. Managers are compensated by their companies in three ways: (1) direct cash payment, which includes salary, cash bonus, and other cash benefits; (2) firm-specific managerial wealth, which means the equity ownership of managers; (3) Firms could also award stock options or other type of stock appreciation right in their long-term incentive compensation plan, and managers can exercise these options to change their equity ownership in the company. In some firms, top officers and directors do not have major holdings of the firm's equity, and the firm may not implement stock option plan, in this case, salary and bonus are important components of managerial compensation and their personal wealth. We use the total value of CEO's salary and bonus as a measure for management's cash payment. Higher levels of cash payments mean that managers have more self-interests tied up with the company, therefore, managers would hedge more to protect themselves from adverse circumstances. However, Knopf, Nam and Thornton (2002) suggest that cash payment is actually a diversifiable wealth, and the presence of a diversified outside portfolio would mitigate managers' risk aversion, more cash payment could lead to less hedging, there would be a negative association between hedging intensity and cash payment.

To study the effect of option holdings on risk management activities, we use two variables to measure the extent to which options are used in managers' compensation packages. The first variable is the number of options held by officers and directors that are exercisable within 60 days. The second variable is the total number of exercisable and unexercisable options held by insiders. These two variables measure the option holdings of officers and directors as a group. To study the effect of size of management team in the following sections, we collect data for another three option measures: Exercisable option per insider is defined as the number of options held by officers and directors that are exercisable within 60 days divided by the number of officers and directors; Total number of options per insider is calculated as the total number of exercisable and unexercisable options divided by the number of officers and directors; Per capita option awards are accounted for as the number of option awarded to the five top officers divided by the number of officers, for which information is available in proxy statements. According to Smith and Stulz's (1985), all these variables are predicted to be negatively correlated with the extent of hedging. The value of all the options exercisable within 60 days and unexercisable is collected in order to study the effect of moneyness of option on managerial hedging incentive.

Besides a discussion about the effect of option compensation on hedging, Smith and Stulz's (1985) model also predicts that managers with greater equity ownership would prefer more risk management. Two variables are used to measure the level of a manager's firm-specific wealth: (1) the log of the market value of the firm's equity owned by officers and directors and (2) the fraction of the firm's outstanding shares held by officers and directors. The incentive for managers to hedge should be increasing in both of these variables. We collect the number of officers and directors in each firm, the number of shares owned by insiders from proxy statements, and year-end share price from Compustat. To test the effect of the size of management team, we also collected the market value of equity ownership per insider and the percentage ownership per insider. We test whether firms whose managers collectively own greater equity interests in firms tend to manage risk more extensively.

3.2.3 Control Variables

To test whether risk management is an outgrowth of poorly-diversified managers holding large equity stakes, rather than large equity stakes alone, we control for the presence of outside blockholders using two measures: (1) the number of outside blockholders, defined as the number of investors other than officers and directors who own at least five percent of the common shares outstanding[7] and (2) the fraction of outstanding common stock held by five percent outside blockholders as a group. To avoid any misspecification, we also collect data for the fraction of equity ownership per blockholder, which is calculated as the percentage of common shares owned by five percent outside blockholders divided by the number of blockholders, we will use this variable in the following test. Tufano (1996) argues that outside blockholders are primarily well-diversified institutional investors, and hence they are less likely to act like risk-averse poorly diversified investors, therefore greater large block ownership should be less positively associated with risk management (if at all) than would be managerial stock ownership.

Another interesting variable is the age of managers. We collect CEO's age from 10K and proxy statements. Age is a widely accepted proxy for attitude toward risk. Older people tend to be more risk averse than younger people, therefore firms may hedge more when their decision-making officers are growing older. There are some different opinions about the age effect. Tufano (1996) mentions that it is hard for older people to understand and implement the modern finance theories about sophisticated risk management strategies, therefore firms with older officers may hedge less. Literatures on learning imply that mature managers may build up more experience in oil and gas industry, and they have a better feel about the market condition and oil and gas price in the near future, they may time the market and hedge, i.e., their hedging strategy depends on their market view. Therefore the prediction for the sign of the correlation coefficient of CEO's age is uncertain.

Previous empirical research (Bodnar et.al. (1998)) shows that large firms enjoy greater economies of scale in hedging, and upfront fixed costs set high threshold for small companies to initiate hedging program. Following this hypothesis, the level of hedging

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[7] The ownership of outside five percent blockholders are adjusted according to the rules in Dlugosz et.al. (2004).

should be positively correlated with firm size. However, Tufano (1996) and Haushalter (2000) argue that firm size is a measure for financing costs because small companies are likely to have greater informational asymmetry with public investors, external financing is more costly for small firms, therefore small firms tend to hedge more in order to avoid underinvestment problem. With this hypothesis, the level of hedging is predicted to be negatively correlated with firm size.

Instead of managing risk with the financial instruments, firms could pursue alternative activities that substitute for financial risk management strategies. For example, firms could have worldwide operations to get geographic diversification, they could be engaged in multiple business segments, or they could adopt conservative financial policies such as maintaining low leverage or carrying large cash balances to protect themselves from shortage of liquidity. Greater use of these substitute risk management activities should be associated with less risk management. To examine the managerial incentive as a determinant of hedging policies, we need to control for the degree of diversification, financial leverage, and cash balances.

Firms can diversify their assets in two ways: business segmentation and geographic diversification. Firms can reduce their hedging demand by engaging in multiple business segments other than petroleum industry. The degree of business diversification is measured as the percentage of firm's total assets engaged outside the petroleum industry, and this variable is collected from segment report in Compustat. Business diversification is predicted to be negatively correlated with the level of hedging.

Many U.S. oil and gas companies explore, extract and market oil and gas in different regions besides North America, the operation conditions, production cost, and profit margin differ across production locations. Some producers believe that multinational operations provide an endogenous mechanism to reduce the financial risk of the whole company, the hedge demand of these producers would be lower. In addition, a few firms believe that the currency risk arising from multinational operations is the dominant concern of their risk management program, therefore they reduce their commodity hedge.

We define geographic diversification as the percentage of total assets engaged in oil and gas production outside North America. A higher value of geographic diversification indicates fewer operations in North America and more international operations. Firms with higher geographic diversification tend to hedge less. The geographic diversification variable could also be a measure for basis risk. Basis risk arises when the settlement price of the hedging instrument is different from the price of the asset being hedged. Ederington (1979) shows that a lower correlation between the change in the price of the asset being hedged and the change in the price of the asset underlying the hedging instruments reduces the effectiveness of hedging in reducing risk, and consequently firms would hedge less extensively to minimize risks. Haushalter (2000) shows that the location of production can have a significant impact on the basis risk for oil and gas producers. The spot prices of oil and gas can vary substantially between regions. Companies with production in regions where prices have a lower correlation with prices of the underlying assets of exchange-traded derivatives face greater basis risk when these firms use the exchange-traded derivative as hedging vehicles[8]. If a U.S. oil and gas producer has more production outside North America, the firm may have more basis risk, consequently, the firm hedges less.

Leverage is defined as the book value of debt divided by the book value of total asset. Petroleum industry requires large capital expenditure to maintain normal exploration and production activities, securing enough and stable cash flows are crucial for the survival of oil and gas companies. prior work reports that companies' financing costs are linked to their debt ratios. For example, Whited (1992) argues that highly levered firms face high premiums for external funds. Similarly, Kaplan and Zingales (1997) report that the likelihood of a firm being financially constrained increases with its leverage. Firms with

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[8] For example, the annual report of Anadarko Petroleum Corp. states that *futures contracts are generally used to fix the price of expected future gas sales and oil sales at major industry trading locations; e.g., Henry Hub, Louisiana for gas and Cushing, Oklahoma for oil.* Anadarko produces oil and gas in U.S., Canada, Algeria, and some other international regions, 15 percent of Anadarko's total production in 2002 is produced outside North America. If Anadarko use exchange-traded futures to hedge their production produced far away from Henry Hub, and Cushing, the company faces basis risk.

high financial leverage and costly external financing are more sensitive to price fluctuations than its less levered industry counterparts, and hedging could be beneficial to high leverage firm in the sense that hedging can reduce the variability of internally generated cash flows. The coefficient of leverage is predicted to be positive, i.e., highly levered firms hedge more.

The level of cash balance is accounted for using the ratio of cash and marketable securities to the book value of total assets. According to the pecking order theory, cash reserves provide a valuable source of funds for investments when current internally generated funds fall short and external financing is costly. Cash reserve is an effective way of self-insurance and a good substitute for managing risk with financial contracts, hence large cash balance leads to lower extent of hedging.

Most firms in petroleum industry produce both oil and gas, in order to control for the differences between firms operating primarily in the oil industry versus those operating primarily in the gas industry, we use the ratio of oil production to total oil and gas production as a control variable in the following tests.

Table 3.1 summarizes the definitions of the independent variables and control variables, the predicted signs of the coefficients of each variable, and the data source.

3.3 Univariate Analysis

3.3.1 Descriptive Statistics

Table 3.2 contains descriptive statistics for all the firms in the sample. The statistics for the dependent variables suggest substantial variation in the fraction of production hedged. Some firms never hedge their production, while several firms hedge more than 85 percent of their production. On average, firms hedged 18.5 percent of production in 2001, 24.4 percent in 2002, 25 percent in 2003, and 22.1 percent in 2004. The distribution of the hedging intensity for the entire sample firm years is shown in Figure 3.1. Firms do not hedge in 195 firm years, and hedge in the rest 263 firm years. Figure 3.2 presents the comparison between the number of hedgers and nonhedgers during 2001-2004. In each year, hedgers are the majority in oil and gas industry.

Table 3.3 and 3.4 show the dominance of small firms[9] among the sample firm years that firm did not hedge. Table 3.3 breaks hedging firm years down by year. On average, 5.61 percent of firms that hedge are small firms, and more than 90 percent of firms that hedge are large firms. Among the firm years that firm do not hedge, 65.5 percent are for small firms.

Table 3.3: Size Distribution of Sample Firm Year

Year	Hedge firm years			Nonhedge firm years		
	Small Firm	Large Firm	Fraction of small firms	Small Firm	Large Firm	Fraction of small firms
2001	2	61	3.17%	33	22	60.00%
2002	5	66	7.04%	29	14	67.44%
2003	5	65	7.14%	32	13	71.11%
2004	3	56	5.08%	33	19	63.46%
		Average	5.61%		Average	65.50%

In Table 3.4 and 3.5, hedgers are defined as firms that have ever hedged during the sample period, and nonhedgers are firms that have never hedged during 2001 – 2004. It shows in the table that, on average, only 9.1 percent of hedgers are small business, while among nonhedgers, 74.38 percent are small firms. And 19.88% of small firms choose to hedge, while 87.79% of large firms manage their risks. These observations are consistent with the previous empirical research that economy of scale is an important factor in hedging decision. It is easier for large firms to find a cost-efficient way to hedge, and the upfront investment to initiate a risk management program is a threshold for small firms (Mian (1996) and Géczy, Minton, and Schrand (1997)).

Table 3.4: Size Distribution of Sample Firm Year

Year	Hedger			Nonhedger		
	Small Firm	Large Firm	Fraction of small firms	Small Firm	Large Firm	Fraction of small firms
2001	7	73	8.75%	27	11	71.05%
2002	7	70	9.09%	27	9	75.00%
2003	7	70	9.09%	30	8	78.95%
2004	7	67	9.46%	29	11	72.50%
		Average	9.10%		Average	74.38%

[9] According to SEC's definition, a small business issuer is a United States issuer that had less than $25 million in revenues in its past fiscal year, and whose outstanding publicly-held stock is worth no more than $25 million.

Table 3.5: Probability of Hedging Conditional on Firm Size

	Small Firm			Large Firm		
Year	Hedger	Nonhedger	Fraction of hedgers	Hedger	Nonhedger	Fraction of hedger firms
2001	7	27	20.59%	73	11	86.90%
2002	7	27	20.59%	70	9	88.61%
2003	7	30	18.92%	70	8	89.74%
2004	7	29	19.44%	67	11	85.90%
		Average	**19.88%**		**Average**	**87.79%**

3.3.2 Comparison of hedging intensity

Table 3.6 shows the comparison of the firm characteristics between firms with different hedging level during 2001 – 2004. In this table, firms are classified into three groups according to the extent of their hedging activities: firms with no risk management (hedge percentage = 0), medium risk management (hedge percentage between 0 and 39 percent), and extensive hedging (hedge percentage exceeding 39 percent). The table reports a *t*-test of the differences in the means of these groups, as well as a nonparametric signed-rank test of the differences between the medians of these groups. The analysis of means suggests that firms employing no risk management are significantly different from those employing moderate levels of risk management in CEO compensation, value of managerial option holdings, managerial equity ownership, cash balance, financial leverage, and firm size. Compared with firms employing moderate hedging, firms with no risk management are smaller in size, carrying less debt and more cash balance, involved in more business diversification, and paying less salary and bonus to CEOs. These observations are consistent with our prediction. In addition, nonhedging firms have more blockholders and directors and officers. The market value of managerial ownership is lower in nonhedging firms, however, if we consider ownership on relative basis, managers in nonhedging firms have higher fractions of managerial equity ownership. The signed-rank test suggests that nonhedging firms award fewer options and these options are less valuable. These observations are contrary to our prediction.

Compared with firms employing moderate hedging activities, firms employing extensive risk management use more debt, carry less cash reserve, and their exploring and production activities mainly concentrate in North America. The CEO in firms with extensive hedging are younger and they receive less salary and bonus compared with firms with moderate risk management. The signed-rank test suggests that the managers in extensive hedging firms receive fewer options and the value of their options is also lower than their counterparts in moderate hedging firms. This is consistent with our prediction regarding the effect of option-based compensation.

3.3.3 Linear correlation among variables

Table 3.7 shows the Pearson correlation between the measure of hedging and the independent variables. The correlation indicates that there is fairly substantial time series variation in hedging. For example, the correlation coefficient between the fraction of production hedged in 2001 and that hedged in 2004 is 0.427. In all three years, the fraction of production hedged is positively correlated with variables for the CEO's compensation, market value of equity ownership of officers and directors, leverage and firm size. The fraction of production hedged is negatively correlated with the cash reserve variable.

3.4 Multivariate Analysis — Regression with censored data

3.4.1 Methodology

As shown in Figure 3.1, there are a significant number of zero observations for the fraction of production hedged, this distribution characteristic implies that the observed value of the dependent variable is left censored at zero, therefore a regression model with censored data may provide more meaningful analysis. The p-value of the estimates will be calculated based on a chi-square distribution. To investigate the interaction of managerial hedging incentive and corporate hedging policy, we estimate cross-sectional tobit regressions with censored data. In these regressions, the fraction of production hedged is regressed on variables that measure compensation policy, managerial equity ownership, and control variables for diversification, leverage, cash reserve, production mix, and firm size. Tufano (1996) and Haushalter (2000) indicate that heteroscedasticity may be a problem for a regression using time-series cross-sectional data. In order to avoid misrepresentation of the estimate coefficients and their *p*-values, we examine the assumption of homoscedasticity of the error terms for each regression using White test, and this statistic is reported in Table 3.8. The sample size for the regressions using pooled sample ranges between 363 and 367 observations. The *p*-values of the White test indicate that heteroscedasticity is not a serious problem. For each regression, we also report the adjusted R-square from OLS regression to indicate the explanatory power of each specification. In general, the significance level of the estimate coefficients using tobit regression does not differ materially from those using OLS regression.

Regressions on a pooled sample of oil and gas producers for 2001 through 2004 are reported in Table 3.8. Because a pooled time-series cross-sectional regression can violate the assumption of independent errors so that *t*-statistics may be overstated, we re-estimate the regression specifications using annual data. The results for regressions on annual data are presented in Table 3.9. The sample size for the regressions using annual data ranges between 88 and 95 observations. Although the magnitude of the estimated coefficients using annual data is comparable to those using the pooled sample, the estimate coefficients are less significant.

3.4.2 Result analysis

The results in Table 3.8 are generally consistent with hypotheses linking hedging to managerial ownership, firm size, leverage and geographic diversification. The regression with pooled data shows that managerial option holdings are negatively associated with the extent of hedging. This result is consistent with Smith and Stulz (1985)'s argument that stock options awarded to managers reduce their incentive to hedge, as well as with empirical evidence documented by Tufano (1996) and Haushalter (2000). And the hedging intensity is negatively associated with CEO's cash payments, this observation is inconsistent with the hypothesis that managers who receive more cash payments invest more in their companies, and therefore, they would hedge more. The result supports the prediction by Knopf, Nam and Thornton (2002) that cash payments are diversifiable wealth and they reduce managers' risk aversion, which leads to less hedge. The tobit regression indicates that the hedging intensity is positively correlated with ownership measured by two variables - the market value of equity ownership and the ownership percentage held by insiders, i.e., managers with more equity ownership in their companies hedge more. In addition, Table 3.8 shows that firms with younger CEO, higher financial leverage, and less geographic diversification hedge more than their counterparts. The positive correlation between hedging intensity and the log of total assets provides evidence the economies of scale hypothesis, and it is not an appropriate measure for financing cost argued in Tufano (1996) and Haulshalter (2000). And the negative correlation between hedging intensity and CEO's age is inconsistent with the notion that age is a measure of risk aversion. However, DeMarzo and Duffie (1995) suggest that young managers would have less well-developed reputations than older managers, and seek to more accurately signal their quality through hedging.

A couple of other results from these regressions are also noteworthy. First, the results point to a negative association between hedging and the ratio of oil production to total oil and gas production combined. Haushaulter (2000) also document this observation, it may be because gas price is more volatile than oil price during 2001 – 2004, consequently companies that are primarily gas producers hedge production more extensively than their oil-based counterparts.

The regression results using annual data are reported in Table 3.9, firm size is positively correlated with hedging intensity, while the geographic diversification is negatively associated with hedging intensity. If we exclude the variable for geographic diversification from the regression specification, the coefficient estimated for the variable of business diversification is negative, which is consistent with our prediction: engaging in multiple business segments reduces hedging demand in oil industry. The regression results with both variables for business segmentation and geographic diversification provide an opportunity to compare the influence of the two type of diversification. Compared with the importance of the geographic diversification, business segmentation is a less efficient substitute for hedging with financial contracts. In Table 3.9, hedging intensity is negatively associated with CEO compensation for 2001, 2002, and 2004, and managerial equity ownership is significant for 2001and 2002 for certain specifications. For the cash balance variable, the signs of the coefficients are consistent with hypothesis prediction, but this variable is not significant in the regression result. Table 3.9 also shows that the negative correlation between managerial option holdings and the extent of hedging is significant for 2001 and 2002, but insignificant for 2003 and 2004. The change in the significance level of the option variable could be due to the introduction of new accounting rules regarding stock-based compensation. FASB first proposed expensing employee stock options in 1995, and revised and re-issued the statement at the end of 2004. The new statement mandates the recognition of the cost of employee stock options in financial statements. Firms making significant use of options were concerned about the impact on their stock price and their ability to raise capital and recruit employees. In order to minimize that cost, firms can reduce the number of options granted, reduce the per-option cost by changing the terms of the option or the valuation assumptions. Balsam, O'Keefe and Wiedemer (2007) show that corporations reacted to the new accounting rule by decreasing their use of options and increasing their use of restricted shares and restricted stock units. Therefore, the new compensation scheme induced by the accounting rule could change managers' risk attitude.

Table 3.1: Variable Definitions and Summary of Hypotheses

This table presents the independent variables for the analysis of hedging policy of 126 U.S. oil and gas producers. It provides the variable's definition, the source of data for the variable, and the correlation between the variable and the fraction of production that oil and gas producers hedge as predicted by hypotheses.

Variable	Specification [information source]	Hypothesis Prediction
Managerial Compensation		
Exercisable options owned by insiders (in MM)	Number of options held by officers that are exercisable within 60 days [proxy statement and 10k]	-
Total Options held by insiders (MM)	Total number of exercisable and unexercisable options held by officers [proxy statement and 10k]	-
Exercisable options per insider (MM)	Number of exercisable options owned by insiders divided by number of officers [proxy statement and 10k]	-
Total options per officer (MM)	Number of exercisable and unexercisable options held by officers divided by number of officers for which information is available [proxy statement and 10k]	-
Value of exercisable options ($MM)	Value of exercisable options held by officers that are exercisable within 60 days [proxy statement and 10k]	-
Total value of managerial options ($MM)	Total value of exercisable and unexercisable options held by officers [proxy statement and 10k]	-
No. of exercisable options owned by CEO (MM)	Number of options held by CEO that are exercisable within 60 days [proxy statement and 10k]	-
Value of exercisable options owned by CEO ($MM)	Value of options held by CEO that are exercisable within 60 days [proxy statement and 10k]	-
No. of exercisable option owned by non-CEO officers (MM)	Number of options held by non-CEO officers that are exercisable within 60 days [proxy statement and 10k]	-
Total No. of options owned by CEO (MM)	Total number of exercisable and unexercisable options held by CEO [proxy statement and 10k]	-
• Value of options owned by CEO ($MM)	• Value of exercisable and unexercisable options held by CEO [proxy statement and 10k]	• -
No. of options owned by non-CEO officers (MM)	Total number of exercisable and unexercisable options held by non-CEO officers [proxy statement and 10k]	-
Value of total option held by insiders other than CEO ($MM)	Value of exercisable and unexercisable options held by non-CEO officers [proxy statement and 10k]	-
No. of unexercisable option owned by CEO (MM)	Number of options held by CEO that are not exercisable within 60 days [proxy statement and 10k]	-
No. of unexercisable option owned by non-CEO officers (MM)	Number of options held by non-CEO officers that are not exercisable within 60 days [proxy statement, 10k]	-
CEO compensation ($MM)	CEO's salary plus bonus compensation [proxy statement and 10k]	+
Ownership structure		
Insider ownership	Log of: Number of shares owned by officers and directors * Year-end market price per share [proxy statement, 10k, and Compustat]	+
Insider ownership percentage (%)	Percentage of total outstanding common shares owned by officers and directors [proxy statement and 10k]	+
Per capita insider ownership	Log of: market value of common sotcks held by officers and directors divided by total number of officers and directors [proxy statement, 10k, and Compustat]	+
Per capita ownership percentage (%)	Percentage of total outstanding common shares owned by officers and directors divided by number of insiders [proxy statement and 10k]	+
Equity ownership of CEO	Log of: Number of shares owned by CEO * Year-end market price per share [proxy statement, 10k, and Compustat]	+
Equity ownership of non-CEO officers	Log of: Number of shares owned by non-CEO officers * Year-end market price per share [proxy statement, 10k, and Compustat]	+
Percentage equity ownership of CEO (%)	Percentage of total outstanding common shares owned by CEO [proxy statement and 10k]	+
Percentage equity ownership of non-CEO officers (%)	Percentage of total outstanding common shares owned by non-CEO officers [proxy statement and 10k]	+
Number of officers and directors	Total number of officers and directors [10K, proxy statement]	-

Fraction of blockholder ownership (%)	Percentage of common shares owned by outside five percent blockholders. [proxy statement, 10k]	-
Per capita blockholder ownership (%)	Percentage of common shares owned by outside five percent blockholders divided by number of blockholders. [proxy statement, 10k]	-
Number of blockholders	Number of outside beneficial owners of more than five percent of outstanding shares of common stock, excluding officers and directors [proxy statement and 10k]	-
Risk attitude		
CEO Age	CEO's age [10K, proxy statement]	+
CEO tenure	Years in CEO position [10K, proxy statement]	+
Control Variables		
Geographic diversification	Percentage of assets engaged in operations outside North America [Compustat segment reporting and 10K]	-
Business diversification	One minus percentage of assets engaged in oil and gas exploration and extraction. [Compustat segment reporting, 10k]	-
Cash balance	Value of cash and cash equivalents divided total assets [Compustat]	-
Production mix	Log of the fraction of oil production in total oil and gas production [10K]	-
Leverage	Ratio of total debt to total assets [Compustat]	+
Firm size	Log of total assets [Compustat]	+

Figure 3.1: Fraction of annual production hedged by petroleum producers during 2001 to 2004. This figure is based on data for 126 U.S. oil and gas producers. The fraction of production hedged is defined as the fraction of total annual oil and gas production of oil and gas—expressed as thousand barrels of oil equivalent (MBOE)—hedged against price fluctuations. Gas is converted to barrels at a rate of 6,000 cubic feet (mcf) per barrel.

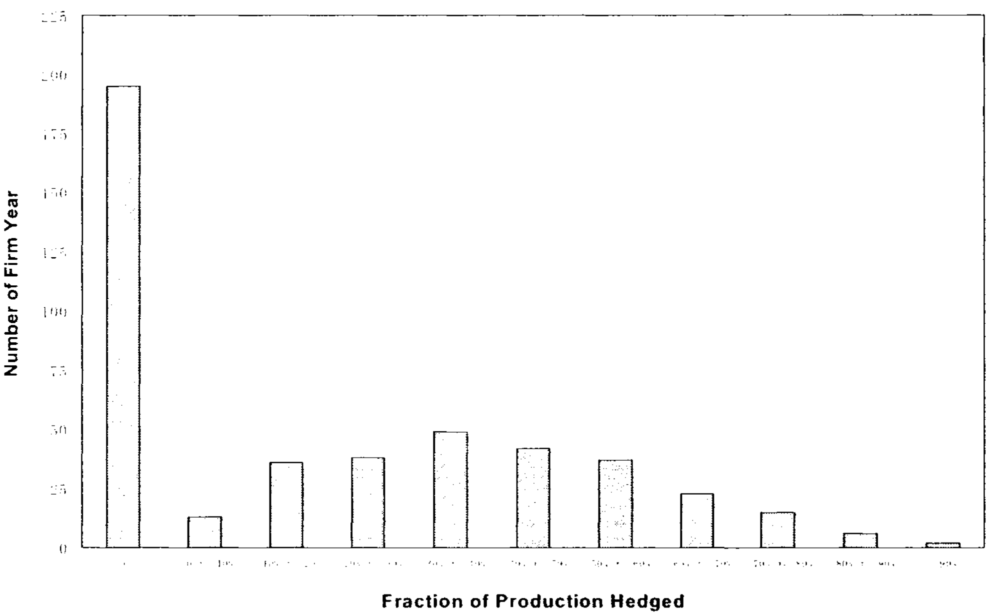

Figure 3.2: Number of hedgers and nonhedgers during 2001 to 2004. This figure is based on data for 126 U.S. oil and gas producers. Hedgers in each sample year are defined as firms hedging their oil and gas production in that year, and nonhedgers are those firms involved in no risk management activities. The grey columns in the graph indicate the number of hedging firms and the columns with wide upward diagonal indicate the number of firms that did not hedge in each year.

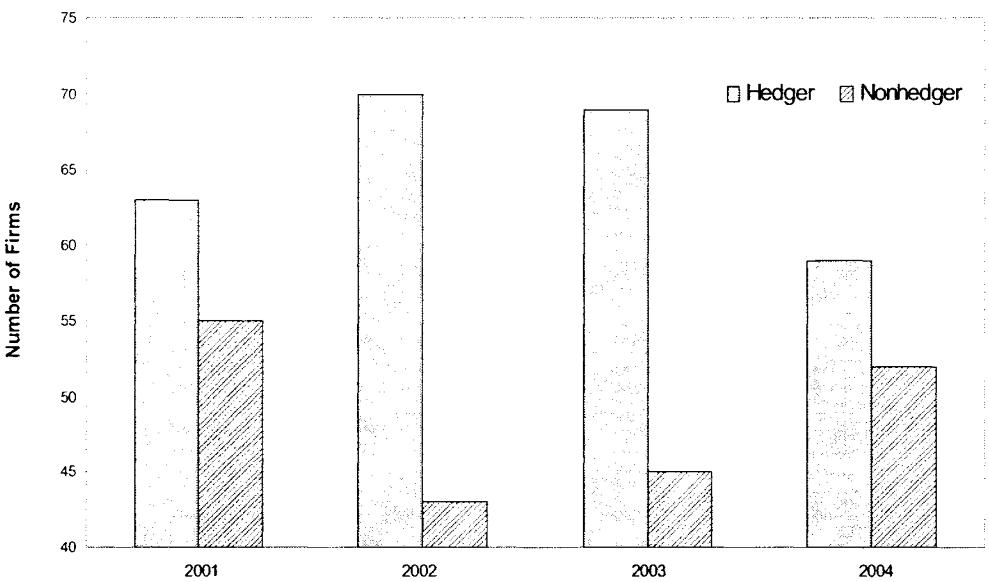

Table 3.2: Oil and Gas Producer Sample Characteristics

This table presents descriptive statistics for firm characteristic variables for 126 U.S. oil and gas producers for the year 2001 to 2004. The fraction of production hedged is defined as the fraction of total annual oil and gas production – expressed as thousand barrels of oil equivalent (MBOE) – protected from price fluctuations. Gas is converted to barrels at a rate of 6,000 cubic feet (mcf) per barrel. The other variables in the table are defined in Table 3.1.

Variable	*N*	Mean	Median	First Quartile	Third Quartile	Minimum	Maximum	Standard Deviation
Fraction of production hedged (in percentage):								
2001	117	0.185	0.045	0	0.313	0	0.894	0.239
2002	112	0.244	0.194	0	0.444	0	0.919	0.252
2003	112	0.250	0.230	0	0.464	0	0.873	0.250
2004	109	0.221	0.122	0	0.406	0	0.761	0.243
All firm years	450	0.224	0.147	0	0.420	0	0.919	0.247
Managerial Compensation:								
Exercisable options owned by insiders (in MM)	436	0.734	0.408	0.071	0.408	0	8.454	1.092
Total Options held by insiders (MM)	436	1.162	0.779	0.137	0.779	0	14.297	1.798
Exercisable options per insider (MM)	436	0.186	0.101	0.026	0.203	0	1.691	0.266
Total options per officer (MM)	436	0.280	0.174	0.057	0.329	0	3.350	0.402
Value of exercisable options ($MM)	435	4.593	0.336	0	3.699	0	140.275	12.589
Total value of managerial options ($MM)	442	6.397	0.456	0	5.325	0	185.521	17.187
No. of exercisable options owned by CEO (MM)	435	0.346	0.145	0	0.459	0	4.020	0.532
Value of exercisable options owned by CEO ($MM)	435	2.261	0.086	0	1.282	0	73.233	7.043
No. of exercisable option owned by non-CEO officers (MM)	435	0.390	0.190	0.001	0.480	-0.448	5.017	0.643
Total No. of options owned by CEO (MM)	431	0.526	0.292	0.050	0.615	0	8.899	0.872
Value of options owned by CEO ($MM)	431	3.081	0.269	0	2.196	0	94.047	8.794
No. of options owned by non-CEO officers (MM)	431	0.644	0.397	0.020	0.850	-0.596	9.614	1.093
Value of total option held by insiders other than CEO ($MM)	431	3.476	0.259	0	2.813	0	91.474	9.266
No. of unexercisable option owned by CEO (MM)	432	0.181	0.050	0	0.178	0	7.690	0.526
No. of unexercisable option owned by non-CEO officers (MM)	431	0.251	0.090	0	0.308	-0.148	9.087	0.639
Value of unexcersiable option owned by CEO ($MM)	431	0.802	0	0	0.532	0	22.634	2.470
Value of unexcersiable option owned by non-CEO officers ($MM)	431	1.122	0.006	0	0.786	0	40.075	3.522
CEO compensation ($MM)	462	0.519	0.300	0.158	0.630	0	4.871	0.643
Ownership Structure								
Insider ownership	446	16.362	16.568	15.132	17.849	8.006	20.617	2.047
Insider ownership percentage (%)	457	0.255	0.181	0.074	0.353	0.002	0.960	0.233
Per capita insider ownership	445	14.183	14.409	13.206	15.286	7.313	19.008	1.701
Per capita ownership percentage (%)	456	0.043	0.021	0.006	0.051	0	0.380	0.061
Equity ownership of CEO	446	15.077	15.341	14.038	16.535	0	20.617	2.243
Equity ownership of non-CEO officers	446	1.285	0.968	0.497	1.768	-0.033	16.151	1.387
Percentage equity ownership of CEO (%)	455	0.122	0.050	0.014	0.148	0	0.907	0.177
Number of officers and directors	456	10	10	7	13	1	31	5.153
Fraction of blockholder ownership (%)	455	0.177	0.124	0	0.269	0	0.806	0.185

Per capita blockholder ownership (%)	451	0.085	0.071	0	0.104	0	0.560	0.093
Number of blockholders	452	2	1	0	3	0	7	1.496
Risk attitude								
CEO age	454	53.548	52	47	59	31	78	8.828
CEO tenure	455	9.002	6	3	13	1	52	8.001
Control Variables								
Geographic diversification	432	0.084	0	0	0	0	1	0.223
Business diversification	453	0.063	0	0	0	0	1	0.166
Cash balance	462	0.118	0.030	0.011	0.145	0	0.922	0.182
Production mix	430	-0.614	-0.714	-1.557	0.026	0	6.015	1.781
Leverage	463	0.297	0.276	0.029	0.412	0	3.588	0.354
Firm size	463	4.588	4.548	2.884	6.310	0	10.210	2.492

Figure 3.3: Oil and gas futures price

This graph describes the monthly closing price of NYMEX crude oil and gas futures contracts during 1999 to 2004. The solid line indicates the price of crude oil futures, and the dashed line depicts the gas futures price.

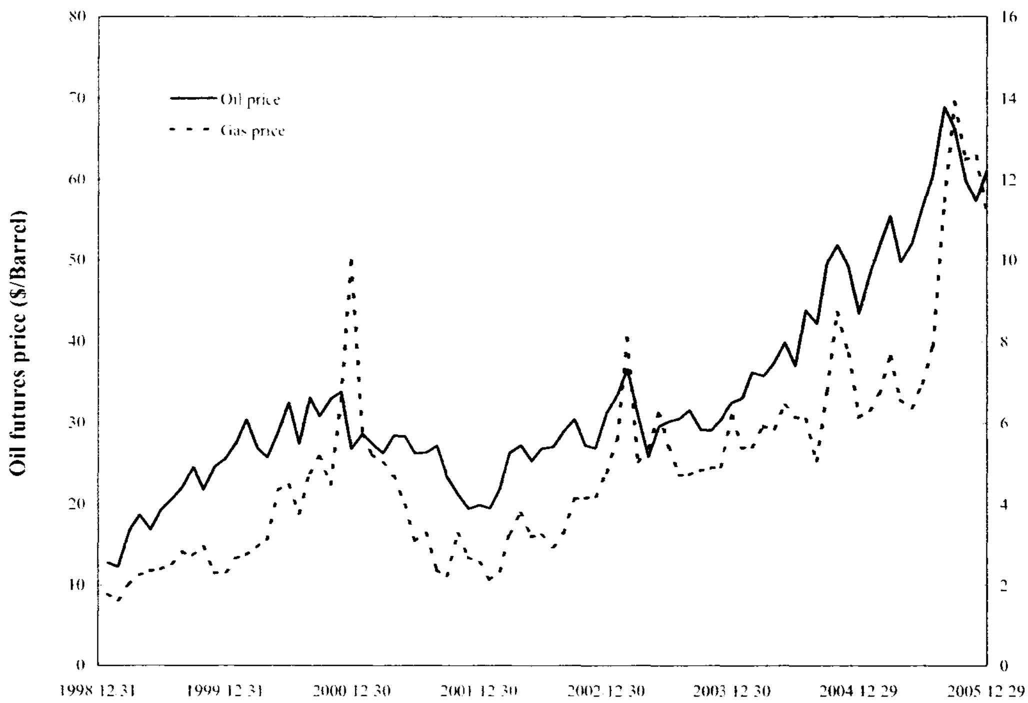

Table 3.6: Characteristics of U.S. Oil and Gas Producers, Conditioned on the Level of Financial Risk Management Employed during 2001 to 2004.
This table compares the characteristics of 126 U.S. oil and gas producers, conditioned on the level of financial risk management activity for the year. The fraction of production hedged is defined as the fraction of total annual oil and gas production—expressed as thousand barrels of oil equivalent (MBOE)—protected from price fluctuations. Gas is converted to barrels at a rate of 6mcf per barrel. All other variables are defined in Table 3.1. For each year between 2001 and 2004, a company is classified as a nonhedger if it does not hedge production during the year, a medium hedger if it hedges between zero and 39 percent of the year's production, and an extensive hedger if it hedges 39 percent or more of annual production. The table reports mean, standard deviation, and median for each variable describing firm characteristics. The table also reports *p*-values from *t*-tests and signed-rank tests for the differences in the mean and median of each characteristics between zero hedgers and extensive hedgers and between minor hedgers and extensive hedgers. *p*-values that are less than 10 percent are in bold.

	Value of Firm-Year Characteristics by Level of Risk Management Activity												*p*-Value			
	None				Medium				Extensive				None vs. Medium		Medium vs. Extensive	
Variable	*N*	**Mean**	**Median**	**Std. Dev.**	*N*	**Mean**	**Median**	**Std. Dev.**	*N*	**Mean**	**Median**	**Std. Dev.**	**Mean**	**Median**	**Mean**	**Median**
Fraction of production hedged	195	0	0	0	129	0.234	0.247	0.097	126	0.562	0.542	0.124				
Compensation Structure:																
Exercisable options owned by insiders (in MM)	182	0.643	0.138	1.205	125	0.869	0.550	1.032	120	0.734	0.396	0.990	0.632	**0.045**	0.206	**0.044**
Total Options held by insiders (MM)	182	0.843	0.266	1.559	125	1.380	0.934	1.728	120	1.418	0.893	2.168	0.148	**0.015**	0.947	0.648
Exercisable options per insider (MM)	182	0.198	0.060	0.324	125	0.195	0.125	0.229	120	0.157	0.093	0.202	0.501	0.792	0.134	**0.021**
Total options per officer (MM)	182	0.250	0.110	0.387	125	0.297	0.197	0.335	120	0.304	0.181	0.488	0.751	0.299	0.968	0.317
Value of exercisable options ($MM)	181	2.107	0	11.318	125	7.744	2.162	14.971	120	5.075	1.062	11.200	**0.008**	**0.000**	**0.086**	**0.060**
Total value of managerial options ($MM)	182	2.856	0	14.968	126	10.671	3.918	20.750	120	7.574	2.041	15.899	**0.007**	**0.000**	0.107	0.170
No. of exercisable options owned by CEO (MM)	181	0.338	0.070	0.614	125	0.389	0.238	0.507	120	0.317	0.147	0.432	0.941	0.332	0.186	**0.090**
Value of exercisable options owned by CEO ($MM)	181	1.174	0	5.963	125	3.682	0.754	8.945	120	2.395	0.272	6.187	**0.036**	**0.000**	0.170	0.113
No. of exercisable option owned by non-CEO officers (MM)	181	0.309	0.036	0.662	125	0.480	0.293	0.625	120	0.417	0.262	0.636	0.371	**0.018**	0.295	0.189
Total No. of options owned by CEO (MM)	178	0.421	0.099	0.783	124	0.600	0.408	0.769	120	0.604	0.307	1.086	0.321	**0.038**	0.913	0.326
Value of options owned by CEO ($MM)	178	1.551	0	7.753	124	4.908	1.074	10.846	120	3.434	0.720	7.709	**0.023**	**0.000**	0.187	**0.096**
No. of options owned by non-CEO officers (MM)	178	0.431	0.071	0.872	124	0.787	0.516	1.049	120	0.814	0.528	1.383	**0.075**	**0.004**	0.990	0.934
Value of total option held by insiders other than CEO ($MM)	178	1.362	0	7.486	124	5.935	1.905	11.006	120	4.140	1.215	9.258	**0.002**	**0.000**	**0.088**	**0.059**
No. of unexercisable option owned by CEO (MM)	178	0.088	0	0.239	124	0.213	0.102	0.413	120	0.287	0.122	0.837	**0.026**	**0.000**	0.401	0.964
No. of unexercisable option owned by non-CEO officers (MM)	178	0.117	0	0.270	124	0.303	0.154	0.595	120	0.397	0.228	0.972	**0.012**	**0.000**	0.363	0.126
Value of unexcersiable option owned by CEO ($MM)	178	0.364	0	1.812	124	1.196	0.165	3.004	120	1.039	0.239	2.662	**0.050**	**0.000**	0.482	0.530
Value of unexcersiable option owned by non-CEO officers ($MM)	178	0.413	0	2.046	124	1.840	0.333	4.973	120	1.461	0.373	3.394	**0.015**	**0.000**	0.339	0.469
CEO compensation ($MM)	195	0.281	0.165	0.496	127	0.805	0.540	0.758	126	0.634	0.457	0.603	**0.000**	**0.000**	**0.051**	**0.089**
Ownership structure																
Insider ownership	189	15.245	15.318	1.744	122	17.357	17.627	1.644	121	17.401	17.406	1.501	**0.000**	**0.000**	0.844	0.985
Insider ownership percentage (%)	192	0.323	0.287	0.235	126	0.186	0.115	0.214	124	0.223	0.128	0.230	**0.000**	**0.000**	0.206	0.391
Per capita insider ownership	188	13.422	13.577	1.494	122	14.897	15.090	1.475	121	14.874	14.901	1.408	**0.000**	**0.000**	0.906	0.699
Per capita ownership percentage (%)	191	0.069	0.043	0.076	126	0.023	0.010	0.037	124	0.020	0.010	0.025	**0.000**	**0.000**	0.497	0.845
Equity ownership of CEO	189	14.173	14.595	2.350	122	16.053	16.230	1.734	121	15.773	15.758	1.637	**0.000**	**0.000**	0.244	0.192
Equity ownership of non-CEO officers	189	1.072	0.681	1.801	122	1.304	1.131	0.841	121	1.628	1.457	1.047	0.740	**0.002**	**0.009**	**0.029**
Percentage equity ownership of CEO (%)	191	0.182	0.096	0.196	126	0.088	0.025	0.173	123	0.065	0.028	0.120	**0.000**	**0.000**	0.151	0.487
Number of officers and directors	191	7.126	7	3.641	126	12.532	12	5.480	124	13.000	12.5	3.945	**0.000**	**0.000**	0.494	0.332
Fraction of blockholder ownership (%)	191	0.155	0.066	0.197	126	0.182	0.155	0.167	123	0.217	0.182	0.184	0.661	0.231	0.172	0.170
Per capita blockholder ownership (%)	188	0.086	0.062	0.107	126	0.079	0.073	0.070	122	0.097	0.076	0.095	0.512	0.786	0.138	0.244
Number of blockholders	188	1.138	1	1.284	126	1.929	2	1.540	123	2.098	2	1.544	**0.002**	**0.001**	0.537	0.604
Risk attitude																
CEO age	190	55.274	54	9.572	126	53.476	52	8.023	123	51.333	51	7.689	0.831	0.992	**0.024**	**0.025**
CEO tenure	191	10.131	8	8.264	126	9.127	5	8.390	123	7.512	6	7.123	0.797	0.736	**0.048**	**0.087**
Control Variables																
Geographic diversification	177	0.110	0	0.288	123	0.101	0	0.189	120	0.036	0	0.132	0.909	0.350	**0.000**	**0.000**
Business diversification	187	0.086	0	0.208	127	0.056	0	0.141	126	0.038	0	0.109	**0.066**	0.102	0.211	0.288
Cash balance	193	0.214	0.127	0.229	126	0.053	0.018	0.080	126	0.030	0.016	0.046	**0.000**	**0.000**	**0.011**	**0.082**
Production mix	176	-0.480	-0.788	2.234	127	-0.608	-0.639	1.295	122	-0.790	-0.737	1.285	0.5565	0.754	0.192	0.227
Leverage	193	0.206	0.047	0.401	126	0.320	0.299	0.240	126	0.403	0.374	0.213	**0.047**	**0.000**	**0.007**	**0.001**
Firm size	193	2.827	2.802	1.915	126	6.117	5.837	2.093	126	6.092	6.124	1.363	**0.000**	**0.000**	0.913	0.995

Table 3.7: Pearson Correlation Coefficients

This table presents Pearson correlation coefficients for selected variables. The fraction of production hedged is defined as the fraction of total annual oil and gas production protected from price fluctuations. Gas is converted to barrels at a rate of 6mcf per barrel. The other variables are defined in Table 3.1. Coefficients in bold are significantly different from zero at the 10 percent level.

	Fraction hedged, 2001	Fraction hedged, 2002	Fraction hedged, 2003	Fraction hedged, 2004	Managerial exercisable options	Total managerial option holding	Exer. options per officer	CEO's exer. option	CEO's total no. of options	CEO compe-nsation	Value of manageria l equity ownership	Managerial percentage equity ownership	Value of share holdings of CEO	Percentage equity ownership of CEO	Number of officers and directors	Blockhol-der's percentage equity ownership	No. of blockhol-ders	CEO age	Geo. Diver.	Cash balance	Financial leverage	Firm size
Fraction hedged, 2001	1	**0.302**	**0.465**	**0.427**	-0.122	0.013	**-0.208**	**-0.160**	-0.048	**0.217**	**0.422**	-0.079	**0.216**	**-0.273**	**0.405**	**0.280**	**0.199**	**-0.171**	-0.066	**-0.373**	**0.387**	**0.477**
Fraction hedged, 2002		1	**0.311**	**0.517**	-0.046	0.050	-0.116	-0.068	0.042	**0.205**	**0.450**	-0.153	**0.296**	**-0.232**	**0.422**	0.135	**0.297**	**-0.232**	**-0.166**	**-0.414**	**0.174**	**0.494**
Fraction hedged, 2003			1	**0.567**	0.096	**0.221**	-0.013	0.017	**0.168**	**0.237**	**0.521**	**-0.246**	**0.373**	**-0.368**	**0.486**	0.088	**0.267**	**-0.261**	-0.142	**-0.421**	**0.178**	**0.629**
Fraction hedged, 2004				1	0.141	**0.248**	0.023	0.051	0.119	**0.302**	**0.518**	**-0.270**	**0.417**	**-0.206**	**0.550**	0.061	**0.304**	-0.139	-0.139	**-0.412**	**0.294**	**0.626**
Fraction hedged, full sample					0.036	**0.145**	-0.064	-0.026	0.079	**0.241**	**0.464**	**-0.186**	**0.307**	**-0.271**	**0.459**	**0.138**	**0.258**	**-0.200**	**-0.127**	**-0.407**	**0.248**	**0.557**
Managerial exercisable options					1	**0.870**	**0.882**	**0.915**	**0.811**	**0.561**	**0.343**	**-0.204**	**0.319**	**-0.222**	**0.308**	0.036	**0.082**	-0.008	0.028	**-0.162**	0.041	**0.357**
Total managerial option holding						1	**0.727**	**0.757**	**0.899**	**0.549**	**0.373**	**-0.229**	**0.344**	**-0.215**	**0.321**	0.032	**0.094**	-0.049	0.015	**-0.185**	**0.083**	**0.414**
Exercisable options per officer							1	**0.888**	**0.751**	**0.383**	**0.244**	-0.064	**0.221**	**-0.192**	**0.142**	0.006	0.030	0.015	-0.012	-0.052	-0.022	**0.180**
CEO's exercisable option								1	**0.825**	**0.523**	**0.312**	**-0.148**	**0.320**	**-0.184**	**0.253**	0.050	0.074	0.015	-0.008	**-0.114**	0.007	**0.289**
CEO's total no. of options									1	**0.497**	**0.328**	**-0.180**	**0.334**	**-0.167**	**0.236**	0.063	**0.114**	-0.025	-0.022	**-0.136**	0.066	**0.340**
CEO compensation										1	**0.527**	**-0.377**	**0.487**	**-0.284**	**0.637**	**0.093**	**0.237**	**0.093**	**0.092**	**-0.262**	0.069	**0.705**
Value of managerial equity ownership											1	-0.037	**0.795**	**-0.197**	**0.649**	0.030	**0.191**	-0.070	0.021	**-0.419**	0.072	**0.750**
Managerial percentage equity ownership												1	**-0.134**	**0.643**	**-0.407**	**-0.288**	**-0.360**	0.005	**-0.177**	**0.203**	-0.050	**-0.455**
Value of share holdings of CEO													1	**0.083**	**0.472**	0.056	**0.191**	0.010	-0.023	**-0.310**	0.053	**0.604**
Percentage equity ownership of CEO														1	**-0.434**	**-0.229**	**-0.289**	**0.128**	**-0.176**	**0.240**	-0.022	**-0.435**
Number of officers and directors															1	**0.218**	**0.332**	0.030	0.044	**-0.453**	**0.110**	**0.820**
Blockholder's percentage equity ownership																1	**0.726**	**-0.101**	0.074	**-0.212**	**0.082**	**0.205**
No. of blockholders																	1	-0.067	0.008	**-0.277**	0.073	**0.370**
CEO age																		1	0.020	**0.165**	-0.051	-0.025
Geographic diversification																			1	0.022	0.062	**0.136**
Cash balance																				1	**-0.220**	**-0.499**
Financial leverage																					1	**0.128**
Firm size																						1

Table 3.8: Tobit Regression—Analysis of Hedging Policy, Pooled Data

The dependent variable is the fraction of the firm's annual oil and gas production that is hedged. The independent variables are defined in Table 3.1. The coefficients are estimated using a one-sided tobit model with left censoring at zero. The pooled sample consists of 126 oil and gas producers during the period 2001 to 2004. The data are presented as coefficients estimated with *p*-values in parentheses. Coefficients significant at the 10 percent level are in bold. Two variables are used to measure managerial option-based compensation: the number of options held by top officers which are exercisable within 60 days, and the total number of options owned by officers including exercisable and unexercisable options. Specification (2) and (4) replace the market value of managerial equity ownership with percentage ownership.

Independent Variable	(1)	(2)	(3)	(4)
Intercept	-0.0642	0.1221	-0.0539	0.1029
	(0.651)	(0.109)	(0.707)	(0.171)
Options held by insiders				
No. of exercisable options owned by insiders	**-0.0301**	**-0.0270**		
	(0.006)	(0.015)		
Total managerial option holding			-0.0096	-0.0074
			(0.153)	(0.267)
CEO compensation	**-0.0768**	**-0.0754**	**-0.0909**	**-0.0892**
	(0.001)	(0.002)	(0.000)	(0.000)
Managerial stock ownership				
Value of share holdings of insiders	**0.0156**		**0.0137**	
	(0.059)		(0.099)	
Fraction of managerial equity ownership		**0.0905**		**0.0916**
		(0.074)		(0.066)
Number of officers and directors	-0.0018	0.00003	-0.0016	0.0002
	(0.582)	(0.993)	(0.625)	(0.951)
Fraction of outside blockholder's share holding	-0.0867	-0.1033	-0.0900	-0.1035
	(0.237)	(0.165)	(0.223)	(0.157)
Number of outside five percent blockholders	0.0101	0.0133	0.0101	0.0133
	(0.271)	(0.161)	(0.277)	(0.153)
CEO age	**-0.0040**	**-0.0043**	**-0.0040**	**-0.0041**
	(0.001)	(0.000)	(0.001)	(0.000)
Cash balance	-0.0766	-0.0753	-0.0686	-0.0673
	(0.300)	(0.318)	(0.356)	(0.365)
Leverage	**0.1661**	**0.1356**	**0.1635**	**0.1357**
	(0.000)	(0.002)	(0.000)	(0.001)
Firm size	**0.0656**	**0.0751**	**0.0682**	**0.0760**
	(0.000)	(0.000)	(0.000)	(0.000)
Production mix	-0.0049	-0.0063	-0.0042	-0.0055
	(0.374)	(0.272)	(0.454)	(0.335)
Business diversification	0.0204	0.0016	0.0301	0.0120
	(0.736)	(0.979)	(0.621)	(0.842)
Geographic diversification	**-0.2806**	**-0.2746**	**-0.2853**	**-0.2753**
	(0.000)	(0.000)	(0.000)	(0.000)
Number of observations	363	367	363	367
Log likelihood	114.282	114.506	111.543	112.034
p-vaule of White test	0.272	0.329	0.385	0.428
Adjusted R-squared	0.448	0.444	0.439	0.437

Table 3.9: Tobit Regression—Analysis of Hedging Policy, Annual Data

The specifications in Table 3.8 are reestimated using annual data and the regression results are presented in this table. The dependent variable is the fraction of the firm's annual oil and gas production that is hedged. The independent variables are defined in Table 3.1. The coefficients are estimated using a one-sided tobit model with left censoring at zero. The data are presented as coefficients estimated with *p*-values in parentheses. Coefficients significant at the 10 percent level are in bold. The variable for business diversification is ignored in regression (3) in year 2002 because the coefficient for this variable is almost zero (-0.0000235), and the *p*-value is 0.9999. The regression results with and without this variable are consistent for the 2002 specification.

	2001				2002				2003				2004			
Independent Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**
Intercept	-0.115	0.008	-0.115	-0.014	-0.095	**0.328**	-0.202	**0.302**	-0.104	0.092	-0.112	0.054	-0.202	0.043	-0.122	0.009
	(0.67)	(0.95)	(0.68)	(0.92)	(0.79)	(0.06)	(0.57)	(0.07)	(0.65)	(0.51)	(0.63)	(0.70)	(0.49)	(0.76)	(0.67)	(0.95)
Options held by insiders																
No. of exercisable options owned by insiders	**-0.063**	**-0.062**			**-0.074**	**-0.069**			0.002	0.008			-0.004	0.002		
	(0.00)	(0.00)			(0.00)	(0.01)			(0.90)	(0.68)			(0.85)	(0.92)		
Total managerial option holding			**-0.032**	**-0.029**			**-0.052**	**-0.052**			0.014	0.019			0.013	0.014
			(0.01)	(0.02)			(0.00)	(0.00)			(0.26)	(0.13)			(0.21)	(0.16)
CEO compensation	**-0.105**	**-0.098**	**-0.099**	**-0.096**	0.024	0.022	0.015	0.015	**-0.177**	**-0.171**	**-0.189**	**-0.183**	**-0.110**	**-0.120**	**-0.124**	**-0.132**
	(0.02)	(0.03)	(0.05)	(0.05)	(0.59)	(0.62)	(0.72)	(0.73)	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)	(0.01)	(0.01)	(0.01)
Managerial stock ownership																
Value of share holdings of insiders	0.013		0.013		0.029		**0.034**		0.015		0.014		0.019		0.011	
	(0.39)		(0.43)		(0.15)		(0.07)		(0.26)		(0.30)		(0.31)		(0.54)	
Fraction of managerial equity ownership		**0.169**		**0.173**		0.086		0.089		0.051		0.059		0.040		0.045
		(0.06)		(0.06)		(0.42)		(0.40)		(0.54)		(0.48)		(0.67)		(0.63)
Number of officers and directors	0.002	0.004	0.0005	0.003	0.004	0.005	0.005	0.005	-0.005	-0.0002	-0.003	0.002	0.003	0.003	0.005	0.004
	(0.72)	(0.47)	(0.93)	(0.60)	(0.53)	(0.44)	(0.51)	(0.44)	(0.48)	(0.97)	(0.71)	(0.77)	(0.69)	(0.66)	(0.50)	(0.57)
Fraction of outside blockholder's share holding	**0.211**	**0.207**	**0.206**	**0.203**	-0.147	-0.205	-0.142	-0.200	-0.068	-0.115	-0.075	-0.116	**-0.310**	**-0.332**	**-0.316**	**-0.326**
	(0.08)	(0.08)	(0.09)	(0.10)	(0.36)	(0.18)	(0.36)	(0.19)	(0.63)	(0.41)	(0.60)	(0.40)	(0.05)	(0.03)	(0.04)	(0.03)
Number of outside five percent blockholders	-0.017	-0.015	-0.020	-0.017	0.022	0.025	0.022	0.024	0.015	0.023	0.018	0.025	**0.032**	**0.032**	**0.034**	**0.034**
	(0.24)	(0.32)	(0.17)	(0.25)	(0.29)	(0.23)	(0.28)	(0.24)	(0.42)	(0.24)	(0.33)	(0.18)	(0.09)	(0.09)	(0.07)	(0.07)
CEO age	**-0.004**	**-0.004**	**-0.004**	**-0.003**	**-0.005**	**-0.006**	**-0.005**	**-0.006**	**-0.004**	**-0.004**	**-0.003**	**-0.004**	-0.003	-0.003	-0.003	-0.003
	(0.05)	(0.07)	(0.05)	(0.08)	(0.06)	(0.02)	(0.08)	(0.02)	(0.06)	(0.03)	(0.09)	(0.06)	(0.13)	(0.12)	(0.19)	(0.20)
Cash balance	-0.013	-0.050	-0.008	-0.044	-0.098	-0.128	-0.083	-0.120	0.061	0.058	0.065	0.062	-0.168	-0.150	-0.158	-0.150
	(0.92)	(0.67)	(0.95)	(0.71)	(0.56)	(0.45)	(0.62)	(0.47)	(0.70)	(0.71)	(0.68)	(0.69)	(0.21)	(0.26)	(0.23)	(0.26)
Leverage	**0.227**	**0.199**	**0.237**	**0.209**	**0.191**	0.111	**0.245**	0.130	**0.130**	0.089	0.124	0.086	**0.166**	**0.156**	**0.151**	**0.149**
	(0.00)	(0.01)	(0.00)	(0.01)	(0.10)	(0.28)	(0.02)	(0.21)	(0.09)	(0.22)	(0.11)	(0.23)	(0.04)	(0.05)	(0.06)	(0.06)
Firm size	**0.064**	**0.070**	**0.069**	**0.074**	0.018	**0.039**	0.016	**0.044**	**0.090**	**0.093**	**0.086**	**0.087**	**0.062**	**0.077**	**0.061**	**0.073**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.49)	(0.08)	(0.51)	(0.04)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Production mix	-0.009	-0.008	-0.008	-0.006	-0.014	-0.017	-0.012	-0.016	0.005	0.002	0.006	0.003	-0.010	-0.011	-0.008	-0.009
	(0.30)	(0.36)	(0.40)	(0.50)	(0.25)	(0.20)	(0.32)	(0.22)	(0.63)	(0.87)	(0.58)	(0.80)	(0.39)	(0.33)	(0.44)	(0.42)
Business diversification	**0.192**	0.163	**0.211**	**0.182**	-0.029	-0.055		-0.029	-0.062	-0.097	-0.068	-0.099	0.063	0.042	0.040	0.032
	(0.07)	(0.12)	(0.05)	(0.09)	(0.83)	(0.69)		(0.83)	(0.59)	(0.40)	(0.56)	(0.39)	(0.56)	(0.68)	(0.71)	(0.76)
Geographic diversification	**-0.454**	**-0.417**	**-0.468**	**-0.426**	**-0.284**	**-0.312**	**-0.235**	**-0.324**	**-0.230**	**-0.200**	**-0.210**	**-0.177**	**-0.185**	**-0.201**	-0.164	**-0.177**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.06)	(0.04)	(0.05)	(0.03)	(0.03)	(0.07)	(0.05)	(0.10)	(0.07)	(0.05)	(0.11)	(0.08)
Number of observations	88	90	88	90	89	89	90	89	94	95	94	95	92	93	92	93
Log likelihood	42.625	43.454	40.900	41.349	21.115	20.420	22.004	20.928	39.439	38.800	40.064	39.851	36.887	36.974	37.665	37.966
Adjusted R-squared	0.511	0.508	0.492	0.485	0.315	0.303	0.330	0.306	0.498	0.482	0.504	0.493	0.462	0.464	0.471	0.475

Chapter 4

Other Empirical Considerations

To avoid any misspecification of the tobit regression, we re-estimate the models in Chapter 3 using alternative measures considering the size of management team, the number of blockholders, the value and moneyness of the managerial option compensation, and the tenure of CEO.

4.1 The size of management team and blockholders

The relation between hedging intensity and the stock and option ownership by the management team and the equity ownership of outside blockholders found in Table 3.8 and 3.8 could be due to the fact that some firms have larger management teams, which does not necessarily indicate larger holdings per manager or per blockholder. Thus, total managerial equity ownership, option compensation, and blockholders' common stock ownership may be proxies for firm size, there are significant positive correlation between firm size and managerial equity ownership, managers' option holdings, and blockholders' equity ownership, as can be seen in Table 3.7, even though the correlation may not be very strong ranging from 0.205 to 0.750. To address this concern, we relate the hedging intensity variable to per capita managerial equity, option holdings per officer and equity ownership per blockholder rather than total stock and option holdings. If the results in Table 3.8 and 3.9 with respect to equity ownership, option-based compensation, and blockholders' ownership are due to size effect, but disappear when analyzed using per capita variables, this would raise serious doubts about the interpretation of the results. Tufano (1996) suggests identifying per capita option holdings across a consistent group of top officers and directors at each company in order to keep consistency and avoid extreme values. In our sample, firms generally disclose option-based compensation for their top five chief managers.

Table 4.1 reports the tobit regression results for pooled data. Specification (1) and (2) replace total managerial common stock ownership, option holdings, and blockholders' ownership with per capita equity ownership, option holdings per insider, and equity ownership per blockholder. Column (3) and (4) replace the dollar value of per capita managerial equity ownership as in (1) and (2) with percentage ownership. Firms with greater per capita option holdings among the top officers manage less risk, and the results provide no support for the hypothesis about managerial equity ownership per insider. The result of specification (3) indicates negative association between the per capita blockholder's equity ownership and hedging intensity. Although the coefficients in column (2) and (4) are not significant, the negative sign of the coefficients is consistent with hypothesis prediction, outside blockholders who are considered to own well-diversified portfolios hedge less compared with the officers and directors in the company.

We re-examine the specification using annual data and the results are presented in Table 4.2. The median coefficient estimates are reported and the median *p*-values are in parentheses. The coefficient of CEO compensation is consistently significant in each specification.

4.2 Officer tenure

Holding constant the amount of wealth they have invested in the firm, managers who are more risk averse would be more likely to manage risk. Unfortunately, there is no direct measure of the degree of risk aversion by managers. Age might serve as a proxy for risk aversion. Others have noted that managerial tenure might play a similar role, with new managers more likely to adopt new ideas like derivative-based price risk management. If this conjecture holds, firms whose managers have shorter tenures on the job would be more inclined to manage risk. We collect information on the tenure of CEOs of each firm, and tenure is measured as years in this position. Specification (5), (6), and (7) in Table 4.1 and 4.2 replace the CEO age with the tenure variable (in years) in the tobit model, and there is no significant relationship between CEO tenure and hedging intensity in both the pooled regression and annual results. The sign of the coefficient is always negative which is consistent with the prediction: managers with shorter tenure are more likely to hedge. This observation could be due to the signaling hypothesis suggested by DeMarzo and Duffie (1995): short-tenure managers would have less well-developed reputations than longer-tenure managers, and seek to more accurately signal their quality through hedging. If variables for CEO's tenure and CEO's age are added together to the specification, the variable for CEO's age shows greater influence on hedging intensity than CEO's tenure.

4.3 Decision-making person: CEO Versus Non-CEO Officers

Who is the person in charge of the risk management program? The CEO or the whole management team? This is the question we want to shed light on in this subsection. Theoretical models often presume that a single manager runs the firm, and empirical research often defines this manager to be the CEO. However, in the real world, decision-making authority might be vested in a larger group of persons. To the extent that a CEO has exclusive control over firm activities, his or her holdings might be more highly associated with risk management activities than would be the shareholdings of other officers and directors. Alternatively, if risk management policies result from a decision of the whole officer and director team, one might expect that the extent of firm risk management decisions would also be related to holdings by officers and directors other than the CEO. To address whether shareholder and option holdings by the CEO alone or by the entire officer and director group are more likely to be associated with greater risk management, the analysis from Table 3.8 and 3.9 has been re-examined, separating CEO share and option holdings from stock and option ownership by the rest of the firm's officers and directors. Table 4.3 reports the results for the whole sample and each year. The results show that the fraction of production hedged is positively associated with the common stock ownership of non-CEO officers, and the CEO's option holdings are negatively related to hedging intensity, however, the total number of options held by non-CEO managers as a group is positively related to hedging intensity. It seems the CEO's hedging incentive dominates that of the other officers', the CEO is the person vested with greater authority in risk management decision.

4.4 The Value of Managerial Option Compensation

The sensitivity of the value of managerial options to the underlying stocks' price and volatility is changing as the moneyness condition of exercisable options changes. As discussed by Guay (1999), these sensitivities determine the effect stock options have on convexity of the relation between the managers' wealth and a company's value. All else equal, the wealth of a manager whose options holdings are deep in the money is not as sensitive to a change in the underlying risk of a company's equity as one whose options holdings are slightly out of the money. Therefore managers whose option awards and holdings are in the money may hedge less. Because of the limitation on data, it is not possible to calculate delta and theta for managerial exercisable options. We collect data from proxy statements on the value of exercisable options, and use this as a proxy for the moneyness of managerial options. There may be noise in this data because some firms use Black-Scholes formula to determine the option value, while other firms use intrinsic value method, and many firms do not explicitly disclose their valuation method in the proxy statements, we cannot control for the difference in the valuation methods. Specification (3) and (4) in Table 4.3 replace the number of option holdings with dollar value of options. The regression results with annual data indicate significant negative association between risk management activities and the dollar value of CEO's option holdings which are unexercisable within 60 days. And the unexercisable options held by non-CEO officer collectively are positively associated with hedging intensity. However, these associations are not significant in the pooled results.

4.5 Separating the decision to hedge from the extent of hedging

Risk management is a two-step decision. First, firms have to decide whether they should put down the upfront costs and set up a risk management program. Then they decide how much they should hedge and how to achieve their goal of risk management efficiently by implementing financial contracts. The two decisions could depend on different factors. As mentioned by Haushalter (2000), tobit regression in the prior section only tests the combined effect of the two decisions. To separate the propensity to hedge from the level of risk management activities, we use probit regression to re-estimate the model specifications from Table 3.8 and 3.9 using probit model and the results from these regressions are presented in Table 4.3 for the pooled data and in Table 4.4 for the annual data. These regressions are of particular interest because they are comparable to studies using a dummy variable to classify a company as a hedger or nonhedger (e.g., Nance et al. (1993), Dolde (1993), Mian (1996), and Géczy et al. (1997)).

4.5.1 Probit Regression

As discussed by Smith and Stulz (1985), hedging can be beneficial to firms in the sense that hedging can save various costs associated with financing costs, financial distress, and underinvestment. Since information asymmetry is more severe for small firms, small firms are more likely to be financially constrained and incur distress costs, consequently, as a means to reduce the possibility of these costs, hedging could be more valuable to small firms than large firms. Therefore small firms should have a greater propensity to hedge. However, empirical studies show that most small firms do not hedge because they cannot find a cost-efficient way to manage their price risk. There is a strong and positive correlation between firm size and hedging intensity, as shown in prior sections. Based on this argument, a firm's size should be negatively related to the probability that the firm hedges, and the extent to which a firm hedges, once it decides to hedge, is predicted to be positively correlated with size. Table 4.4 and 4.5 show that hedging intensity is negatively associated with the log of total assets.

The results show that firms whose managers own more options are more likely to hedge. During data collection, we empirically observe that many small firms who have never hedged do not have stock option compensation program. The positive correlation between option holdings and the decision to hedge arises from the fact that only firms with a fair scale have option compensation. And the positive correlation between CEO age and the decision to hedge indicates that older managers are more risk averse. One way to improve the model is to scale the managerial option and ownership by the firm size.

These regressions also suggest that several variables related to the extent of hedging are not significantly associated with the decision to hedge. For example, although the leverage has a strong correlation with hedging intensity, it is not statistically significant for most of the annual probit regression specifications. The differences in these results from the tobit regressions show that a test using a binary measure as proxy for hedging may not detect variables associated with the extent of hedging. Indeed, previous empirical studies that use binary measures (e.g., Nance et al. (1993), Dolde (1993), Mian (1996), and Géczy et al. (1997) find little or no evidence that hedging is significantly related to financial leverage. Moreover, the differences in the probit regression results from the tobit regressions suggest that differences in results between this study and previous empirical studies can at least partially be attributed to differences in the measure of hedging.

In Table 4.6, we add variables of dollar value of managerial option holdings to indicate the moneyness of managerial options and separate managerial ownership into CEO's equity ownership and ownership of non-CEO officers and directors. The results for managerial ownership variables are consistent with the results in Table 4.3 and 4.4. The variable for dollar value of option-based compensation is significant only for year 2000, and the negative sign of the coefficients indicates that managers are less likely to hedge if their options are in-the-money, this is consistent with the notion that managers with their option deep in-the-money are less sensitive to the adverse consequences of their companies' operations.

4.5.2 Conditional Regressions' Results — The Extent of Hedging among Hedgers

To further disentangle the determinants of hedging decision and hedging intensity, regressions with truncated data are also estimated in this chapter. In this regression model, only hedgers are considered in the sample. And the regression results for pooled data annual data are reported in Table 4.7. The explanatory power of these regressions is slightly lower than it is using the probit or the tobit models. However, the variables which are significant in the tobit regression are more pronounced in the regression with truncated data. And there seems to be negative association between hedging activities and the number of officers and directors in the company. As the number of management team increases, there may be dissenters and it is more difficult for managers to agree with each other on risk management strategies.

Table 4.1: Tobit Regression—Managerial Characteristics and the Intensity of Hedging, Pooled Data

The dependent variable is the fraction of the firm's annual oil and gas production that is hedged. The independent variables are defined in Table 3.1. The coefficients are estimated using a one-sided tobit model with left censoring at zero. The pooled sample consists of 126 oil and gas producers during the period 2001 to 2004. The first column, marked "Base" repeats the results from Table 3.8 to serve as a point of reference against which to compare the other specifications. Column (1) and (2) replaces managerial equity ownership, option holdings, and outside blockholders' equity ownership with per capita ownership and option holding variables. Column (3) and (4) replace the value of per capita managerial equity ownership with percentage ownership held by each officer. Specification (5), (6), and (7) test the effect of CEO's tenure. The data are presented as coefficients estimated with p-values in parentheses. Coefficients significant at the 10 percent level are in bold.

	Regressions with pooled data							
Independent Variable	**Base**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Intercept	0.1029	-0.0437	-0.0193	**0.1820**	**0.1672**	**-0.3058**	**-0.0934**	**-0.0793**
	(0.171)	(0.745)	(0.886)	(0.016)	(0.028)	(0.012)	(0.042)	(0.094)
Options held by insiders								
Total managerial option holding	-0.0074						-0.0033	-0.0045
	(0.267)						(0.621)	(0.505)
No. of total options per insider			**-0.0551**		**-0.0497**			
			(0.063)		(0.091)			
No. of exercisable options owned by insiders						**-0.0253**		
						(0.022)		
No. of exercisable options per insider		**-0.1045**		**-0.1058**				
		(0.008)		(0.007)				
CEO compensation	**-0.0892**	**-0.0856**	**-0.0909**	**-0.0826**	**-0.0887**	**-0.0826**	**-0.0962**	**-0.0949**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Managerial stock ownership								
Fraction of managerial equity ownership	**0.0916**						**0.1013**	**0.0930**
	(0.066)						(0.044)	(0.067)
Value of share holdings of insiders						**0.0193**		
						(0.020)		
Value of share holdings per insider		**0.0155**	0.0135					
		(0.066)	(0.109)					
Fraction of ownership per insider				0.0232	0.0427			
				(0.925)	(0.863)			
Number of officers and directors	0.0002	-0.0006	-0.0009	-0.0005	-0.0003	-0.0029	-0.0008	-0.0010
	(0.951)	(0.856)	(0.778)	(0.870)	(0.919)	(0.365)	(0.791)	(0.759)
Fraction of outside blockholder's share holdings	-0.1035	-0.0895				-0.0699	-0.0930	
	(0.157)	(0.224)				(0.349)	(0.212)	
Per capita blockholders' equity percentage ownership			-0.1680	**-0.2217**	**-0.2096**			**-0.1854**
			(0.112)	(0.034)	(0.046)			(0.085)
Number of outside five percent blockholders	0.0133	0.0113	0.0049	0.0049	0.0043	0.0093	0.0129	0.0067
	(0.153)	(0.222)	(0.474)	(0.472)	(0.534)	(0.319)	(0.173)	(0.340)
CEO age	**-0.0041**	**-0.0039**	**-0.0040**	**-0.0042**	**-0.0042**			
	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)			
CEO tenure						-0.0019	**-0.0023**	**-0.0024**
						(0.147)	(0.073)	(0.055)
Cash balance	-0.0673	-0.0713	-0.0694	-0.0774	-0.0743	-0.0997	-0.0891	-0.0893
	(0.365)	(0.334)	(0.350)	(0.294)	(0.317)	(0.184)	(0.236)	(0.235)
Leverage	**0.1357**	**0.1631**	**0.1732**	**0.1490**	**0.1506**	**0.1886**	**0.1533**	**0.1663**
	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Firm size	**0.0760**	**0.0650**	**0.0684**	**0.0709**	**0.0730**	**0.0635**	**0.0762**	**0.0758**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Production mix	-0.0055	-0.0052	-0.0049	-0.0053	-0.0045	-0.0044	-0.0053	-0.0056
	(0.335)	(0.352)	(0.387)	(0.350)	(0.428)	(0.441)	(0.359)	(0.328)
Business diversification	0.0120	0.0122	0.0228	-0.0120	0.0031	0.0125	-0.0005	-0.0007
	(0.842)	(0.841)	(0.707)	(0.841)	(0.959)	(0.835)	(0.993)	(0.990)
Geographic diversification	**-0.2753**	**-0.2722**	**-0.2829**	**-0.2800**	**-0.2882**	**-0.2797**	**-0.2775**	**-0.2801**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Number of observations	367	363	362	366	366	364	368	367
Log likelihood	112.034	113.843	111.724	113.005	110.880	110.069	108.130	108.123
Adjusted R-squared	0.437	0.446	0.441	0.441	0.434	0.434	0.424	0.228
p-vaule of White test	0.428	0.111	0.198	0.251	0.341	0.118	0.259	0.425

Table 4.2: Tobit Regression—Managerial Characteristics and the Intensity of Hedging, Annual Data

The specifications in Table 4.1 are reestimated using annual data and the regression results are presented in this table. The dependent variable is the fraction of the firm's annual oil and gas production that is hedged. The independent variables are defined in Table 3.1. The coefficients are estimated using a one-sided tobit model with left censoring at zero. In order to save space, only the medians of coefficient estimates and *p*-values of four annual specifications are reported. The first column, marked "Base" repeats the results from Table 3.9 to serve as a point of reference against which to compare the other specifications. Column (1) and (2) replaces managerial equity ownership, option holdings, and outside blockholders' equity ownership with per capita ownership and option holding variables. Column (3) and (4) replace the dollar value of per capita managerial equity ownership with percentage ownership held by each officer. Specification (5), (6), and (7) adds information on the tenure (in years) for the firm's CEO. The data are presented as coefficients estimated with *p*-values in parentheses. Coefficients significant at the 10 percent level are in bold.

	Median of regressions with annual data							
Independent Variable	**Base**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Intercept	0.032	-0.1488	-0.1343	0.1052	0.0914	-0.3843	-0.1231	-0.1311
	(0.81)	(0.538)	(0.570)	(0.450)	(0.502)	(0.120)	(0.149)	(0.137)
Options held by insiders								
Total managerial option holding	**-0.007**						**-0.0043**	**-0.0049**
	(0.08)						(0.048)	(0.067)
No. of total options per officer			-0.0680		-0.0567			
			(0.239)		(0.166)			
No. of exercisable options owned by officers						-0.0299		
						(0.277)		
No. of exercisable options per insider		-0.1302		-0.1168				
		(0.263)		(0.360)				
CEO compensation	**-0.114**	**-0.1139**	**-0.1119**	**-0.1251**	**-0.1192**	**-0.1093**	**-0.1192**	**-0.1223**
	(0.03)	(0.017)	(0.031)	(0.010)	(0.027)	(0.026)	(0.023)	(0.022)
Managerial stock ownership								
Value of share holdings of insiders						0.0203		
						(0.165)		
Fraction of managerial equity ownership	0.074						0.0864	0.0715
	(0.44)						(0.369)	(0.460)
Value of share holdings per insider		0.0214	0.0197					
		(0.205)	(0.290)					
Fraction of ownership per insider				-0.0201	0.0470			
				(0.570)	(0.539)			
Number of officers and directors	0.003	0.0038	0.0040	0.0035	0.0036	0.0014	0.0028	0.0030
	(0.58)	(0.526)	(0.384)	(0.557)	(0.558)	(0.748)	(0.656)	(0.612)
Fraction of outside blockholder's share holdings	-0.158	-0.1195				-0.0800	-0.1408	
	(0.15)	(0.169)				(0.303)	(0.196)	
Per capita blockholders' equity percentage ownership			-0.0939	-0.1724	-0.1430			-0.1229
			(0.363)	(0.356)	(0.418)			(0.605)
Number of outside five percent blockholders	0.025	0.0202	0.0107	0.0073	0.0085	0.0187	0.0245	0.0108
	(0.21)	(0.279)	(0.429)	(0.611)	(0.566)	(0.289)	(0.224)	(0.486)
CEO tenure						-0.0013	-0.0015	-0.0022
						(0.614)	(0.547)	(0.378)
CEO age	**-0.004**	**-0.0037**	**-0.0039**	**-0.0042**	**-0.0042**			
	(0.07)	(0.065)	(0.056)	(0.034)	(0.037)			
Cash balance	-0.082	-0.0329	-0.0350	-0.0541	-0.0531	-0.0867	-0.1202	-0.1206
	(0.58)	(0.668)	(0.604)	(0.633)	(0.602)	(0.536)	(0.442)	(0.412)
Leverage	0.140	**0.1714**	**0.1661**	0.1359	0.1367	**0.1992**	**0.1479**	**0.1497**
	(0.13)	(0.055)	(0.083)	(0.146)	(0.136)	(0.038)	(0.088)	(0.109)
Firm size	**0.074**	**0.0594**	**0.0639**	**0.0741**	**0.0747**	**0.0594**	**0.0733**	**0.0742**
	(0.00)	(0.002)	(0.001)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)
Production mix	-0.008	-0.0084	-0.0069	-0.0079	-0.0064	-0.0079	-0.0065	-0.0064
	(0.46)	(0.409)	(0.499)	(0.460)	(0.531)	(0.442)	(0.527)	(0.542)
Business diversification	0.001	0.0030	0.0078	-0.0302	-0.0180	0.0125	-0.0194	-0.0210
	(0.57)	(0.592)	(0.570)	(0.419)	(0.477)	(0.638)	(0.569)	(0.530)
Geographic diversification	**-0.251**	**-0.2455**	**-0.2608**	**-0.2808**	**-0.2813**	**-0.2565**	**-0.2588**	**-0.2756**
	(0.05)	(0.050)	(0.039)	(0.027)	(0.028)	(0.044)	(0.051)	(0.033)
Number of observations	91.5	90.5	90.5	91.5	91.5	90.5	92	92
Log likelihood	38.908	38.399	37.766	36.694	37.110	37.379	38.672	37.564
Adjusted R-squared	0.480	0.483	0.467	0.461	0.461	0.469	0.468	0.453

Table 4.3: Tobit Regression—Separating CEO's Option-Based Compensation and Equity Ownership from Other Officers and Directors

The dependent variable is the fraction of the firm's annual oil and gas production that is hedged. The independent variables are defined in Table 3.1. The coefficients are estimated using a one-sided tobit model with left censoring at zero. The pooled dataset includes all firm-year observations. For the regressions with annual data, only the medians of coefficient estimates and *p*-values of four annual specifications are reported in order to save space. Different measures for managerial option compensation and equity ownership are used alternatively in Specification (1) – (7). The data are presented as coefficients estimated with *p*-values in parentheses. Coefficients significant at the 10 percent level are in bold.

	Regressions with pooled data							*Regressions with annual data*						
Independent Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Intercept	0.062	-0.044	0.063	-0.053	0.102	0.091	0.054	0.031	-0.087	0.050	-0.084	0.060	0.041	0.046
	(0.40)	(0.76)	(0.40)	(0.71)	(0.17)	(0.22)	(0.46)	(0.82)	(0.76)	(0.56)	(0.76)	(0.67)	(0.77)	(0.52)
Options held by insiders														
No. of unexercisable option owned by CEO	**-0.074**	**-0.076**						**-0.240**	**-0.233**					
	(0.03)	(0.03)						(0.08)	(0.10)					
No. of unexercisable option owned by non-CEO officers	**0.046**	**0.042**						**0.121**	**0.115**					
	(0.02)	(0.03)						(0.07)	(0.07)					
Value of unexercisable option owned by CEO			-0.017	-0.019						**-0.044**	**-0.045**			
			(0.15)	(0.12)						(0.09)	(0.07)			
Value of unexercisable option owned by non-CEO officers			0.011	0.011						**0.038**	**0.038**			
			(0.18)	(0.19)						(0.06)	(0.05)			
No. of exercisable option owned by CEO					**-0.075**							-0.064		
					(0.00)							(0.24)		
No. of exercisable option owned by non-CEO officers					0.006							-0.010		
					(0.78)							(0.34)		
No. of options owned by CEO						**-0.071**							-0.062	
						(0.00)							(0.20)	
No. of options owned by non-CEO officers						**0.029**							0.029	
						(0.02)							(0.19)	
Value of total option holdings of CEO							0.000							0.002
							(0.85)							(0.69)
Value of total option held by non-CEO officers							-0.001							0.000
							(0.67)							(0.81)
CEO compensation	**-0.087**	**-0.093**	**-0.092**	**-0.097**	**-0.064**	**-0.066**	**-0.085**	**-0.119**	**-0.129**	**-0.144**	**-0.148**	**-0.100**	-0.087	**-0.1384**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.05)	(0.15)	(0.008)
Managerial stock ownership														
Value of share holdings of CEO		0.011		0.012					0.011		0.008			
		(0.17)		(0.15)					(0.46)		(0.58)			
Value of share holdings of non-CEO officers		**0.021**		**0.021**					0.020		0.021			
		(0.04)		(0.04)					(0.34)		(0.33)			

Percentage equity ownership of CEO	-0.014		-0.009		-0.023	-0.021	-0.009	-0.019		0.012		-0.018	-0.027	0.002
	(0.83)		(0.89)		(0.72)	(0.75)	(0.89)	(0.56)		(0.78)		(0.68)	(0.58)	(0.69)
Percentage equity ownership of non-CEO officers	**0.230**		**0.229**		**0.187**	**0.230**	**0.230**	**0.218**		**0.239**		0.184	**0.231**	**0.225**
	(0.00)		(0.00)		(0.00)	(0.00)	(0.00)	(0.07)		(0.07)		(0.12)	(0.06)	(0.08)
Number of officers and directors	-0.003	-0.003	-0.003	-0.003	-0.002	-0.003	-0.002	0.001	0.001	0.001	0.002	0.003	0.001	0.003
	(0.34)	(0.32)	(0.41)	(0.37)	(0.59)	(0.29)	(0.62)	(0.71)	(0.67)	(0.74)	(0.76)	(0.58)	(0.70)	(0.52)
Fraction of outside blockholder's share holdings	-0.096	-0.090	-0.095	-0.089	-0.084	-0.087	-0.091	-0.161	-0.128	-0.166	-0.133	-0.138	-0.143	-0.138
	(0.19)	(0.22)	(0.19)	(0.23)	(0.24)	(0.22)	(0.21)	(0.14)	(0.21)	(0.14)	(0.21)	(0.13)	(0.14)	(0.15)
Number of outside five percent blockholders	**0.015**	0.013	0.014	0.012	0.012	0.014	0.012	0.027	0.024	0.024	0.021	0.022	0.025	0.018
	(0.10)	(0.16)	(0.12)	(0.21)	(0.18)	(0.12)	(0.19)	(0.17)	(0.18)	(0.23)	(0.22)	(0.27)	(0.21)	(0.34)
CEO age	**-0.003**	**-0.004**	**-0.003**	**-0.004**	**-0.004**	**-0.003**	**-0.003**	-0.003	-0.004	-0.003	-0.003	-0.003	-0.003	-0.003
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.14)	(0.13)	(0.16)	(0.15)	(0.10)	(0.12)	(0.17)
Cash balance	-0.048	-0.055	-0.052	-0.059	-0.064	-0.045	-0.050	-0.052	-0.037	-0.060	-0.045	-0.070	-0.054	-0.062
	(0.52)	(0.46)	(0.48)	(0.43)	(0.38)	(0.53)	(0.49)	(0.57)	(0.64)	(0.53)	(0.62)	(0.58)	(0.57)	(0.54)
Leverage	**0.130**	**0.155**	**0.124**	**0.149**	**0.132**	**0.129**	**0.121**	0.1299	**0.171**	**0.128**	**0.142**	0.1351	0.1328	0.1290
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.128)	(0.10)	(0.10)	(0.08)	(0.122)	(0.137)	(0.108)
Firm size	**0.078**	**0.070**	**0.079**	**0.071**	**0.075**	**0.077**	**0.078**	**0.069**	**0.064**	**0.073**	**0.071**	**0.070**	**0.069**	**0.071**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Production mix	-0.003	-0.003	-0.004	-0.004	-0.008	-0.006	-0.004	-0.006	-0.007	-0.007	-0.008	-0.010	-0.008	-0.007
	(0.53)	(0.60)	(0.45)	(0.51)	(0.18)	(0.29)	(0.43)	(0.53)	(0.50)	(0.52)	(0.43)	(0.30)	(0.40)	(0.55)
Business diversification	-0.013	-0.006	0.006	0.012	-0.004	-0.017	0.004	-0.021	0.001	-0.012	0.003	-0.014	-0.027	-0.013
	(0.83)	(0.92)	(0.92)	(0.84)	(0.95)	(0.78)	(0.95)	(0.58)	(0.71)	(0.58)	(0.65)	(0.55)	(0.55)	(0.55)
Geographic diversification	**-0.272**	**-0.278**	**-0.281**	**-0.287**	**-0.284**	**-0.284**	**-0.280**	**-0.265**	**-0.265**	**-0.256**	**-0.265**	**-0.275**	**-0.269**	**-0.270**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.04)	(0.04)	(0.05)	(0.04)	(0.03)	(0.03)	(0.04)
Number of observations	363	359	363	359	367	363	363	91	90	91	90	92	91	91
Log likelihood	116.64	111.60	114.49	109.93	119.99	119.67	113.78	42.09	39.88	41.13	38.87	40.13	40.52	39.03
Adjusted R-squared	0.452	0.441	0.534	0.595	0.458	0.461	0.444	0.498	0.479	0.488	0.467	0.484	0.493	0.464
p-vaule of White test	0.279	0.461	0.446	0.436	0.381	0.178	0.339							

Table 4.4: Probit Regression—Determinants of Decision to Hedge, Pooled Data

Regressions in this table use a binary probit model to estimate the likelihood that a firm hedges. The dependent variable is a dichotomous variable to indicate whether a firm hedges. it is one if the firm hedges. otherwise. it is zero. The pooled sample consists of all firm-year observations from 126 U.S. oil and gas producers during the period 2001 to 2004. The independent variables are defined in Table 3.1. The data are presented as coefficients estimated with *p*-values in parentheses. Coefficients significant at the 10 percent level are in bold.

Independent Variable	(1)	(2)	(3)	(4)
Intercept	**2.7056**	**2.5337**	**2.5892**	**2.5475**
	(0.077)	(0.078)	(0.077)	(0.078)
Options held by insiders				
No. of exercisable options owned by insiders	**0.3258**			
	(0.004)			
Total managerial option holding		**0.1883**		
		(0.004)		
Total No. of options owned by CEO			**0.5646**	
			(0.001)	
No. of exercisable option owned by CEO				**0.7231**
				(0.002)
CEO compensation	**0.4708**	**0.5433**	0.4204	0.4222
	(0.081)	(0.035)	(0.165)	(0.142)
Managerial stock ownership				
Value of share holdings of insiders	-0.1078			
	(0.222)			
Value of share holdings per insider		-0.0954	-0.1089	-0.1137
		(0.280)	(0.224)	(0.204)
Number of insiders	-0.0264	-0.0405	-0.0386	-0.0344
	(0.509)	(0.305)	(0.344)	(0.399)
Per capita blockholders' equity percentage ownership	**2.8186**	**2.7838**	**2.9046**	**2.7532**
	(0.010)	(0.010)	(0.010)	(0.012)
Number of outside five percent blockholders	-0.089	-0.075	-0.099	-0.098
	(0.20)	(0.27)	(0.16)	(0.17)
CEO age	**0.0231**	**0.0233**	**0.0267**	**0.0238**
	(0.052)	(0.048)	(0.029)	(0.045)
Cash ratio	**1.5685**	**1.5022**	**1.5456**	**1.5968**
	(0.052)	(0.062)	(0.062)	(0.050)
Leverage	**-0.9187**	**-0.8737**	**-0.9976**	-0.9282
	(0.043)	(0.053)	(0.033)	(0.043)
Firm size	**-0.6054**	**-0.6347**	**-0.6396**	**-0.5960**
	(0.000)	(0.000)	(0.000)	(0.000)
Production mix	0.0842	0.0856	0.1107	0.0908
	(0.177)	(0.168)	(0.099)	(0.154)
Business diversification	0.7082	0.5678	0.6980	0.8375
	(0.378)	(0.471)	(0.401)	(0.303)
Geographic diversification	**1.7610**	**1.7899**	**1.8699**	**1.7843**
	(0.024)	(0.020)	(0.020)	(0.025)
Number of observations	364	364	360	364
Log likelihood	-109.999	-110.906	-105.507	-108.916
Adjusted R-squared	0.545	0.541	0.548	0.545

Table 4.5: Probit Regression—Determinants of Decision to Hedge, Annual data

Regressions in Table 4.4 are reestimated using annual data and the results are reported in this following table. Probit model is implemented here to estimate the likelihood that a firm hedges in each year. The dependent variable is a dichotomous variable to indicate whether a firm hedges, it is one if the firm hedges, otherwise, it is zero. The independent variables are defined in Table 3.1. The data are presented as coefficients estimated with *p*-values in parentheses. Coefficients significant at the 10 percent level are in bold.

	2001				2002				2003				2004			
Independent Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**
Intercept	8.744	6.442	6.199	**7.064**	3.465	3.237	3.620	4.171	4.479	4.715	10.720	4.432	**5.832**	5.112	**5.434**	**5.897**
	(0.12)	(0.14)	(0.17)	(0.13)	(0.46)	(0.44)	(0.39)	(0.35)	(0.26)	(0.21)	(0.10)	(0.24)	(0.09)	(0.11)	(0.09)	(0.07)
Options held by insiders																
No. of exercisable options owned by insiders	**0.994**				**1.339**				**0.587**				0.3206			
	(0.05)				(0.03)				(0.08)				(0.248)			
Total managerial option holding		0.240				**0.653**				**0.368**				0.192		
		(0.15)				(0.06)				(0.04)				(0.18)		
Total No. of options owned by CEO			**0.819**				1.070				**1.946**				**0.739**	
			(0.07)				(0.12)				(0.02)				(0.06)	
No. of exercisable option owned by CEO				**1.816**				**1.765**				**1.318**				**1.045**
				(0.05)				(0.06)				(0.04)				(0.07)
CEO compensation	**2.114**	**2.252**	**1.809**	**1.823**	-2.727	-1.136	-1.415	-2.439	1.928	**2.221**	**3.927**	1.651	0.969	1.062	0.869	0.870
	(0.04)	(0.03)	(0.09)	(0.09)	(0.17)	(0.39)	(0.38)	(0.22)	(0.12)	(0.08)	(0.09)	(0.24)	(0.16)	(0.11)	(0.22)	(0.23)
Managerial stock ownership																
Value of share holdings of insiders	-0.190				-0.308				-0.318				-0.328			
	(0.50)				(0.28)				(0.18)				(0.12)			
Value of share holdings per insider		-0.090	**-0.105**	-0.144		-0.195	-0.216	-0.306		-0.329	**-0.836**	-0.397		-0.302	**-0.367**	**-0.407**
		(0.72)	(0.68)	(0.58)		(0.45)	(0.40)	(0.27)		(0.18)	(0.07)	(0.12)		(0.15)	(0.09)	(0.07)
Number of insiders	**-0.222**	**-0.243**	**-0.228**	**-0.249**	-0.148	-0.212	-0.225	-0.235	**0.218**	0.185	**0.292**	**0.203**	0.050	0.015	0.050	0.063
	(0.09)	(0.04)	(0.06)	(0.05)	(0.39)	(0.15)	(0.15)	(0.16)	(0.08)	(0.11)	(0.06)	(0.10)	(0.56)	(0.86)	(0.59)	(0.51)
Per capita blockholders' equity percentage ownership	5.324	4.303	4.729	5.138	**13.558**	**10.074**	**9.621**	**11.271**	1.198	1.301	1.978	0.718	3.612	3.492	3.903	3.837
	(0.15)	(0.23)	(0.19)	(0.16)	(0.04)	(0.04)	(0.04)	(0.04)	(0.59)	(0.56)	(0.54)	(0.75)	(0.15)	(0.16)	(0.14)	(0.15)
Number of outside five percent blockholders	0.010	0.091	0.066	0.022	**-0.983**	**-0.627**	-0.531	**-0.668**	-0.178	-0.165	**-0.370**	-0.246	-0.127	-0.115	-0.157	-0.187
	(0.96)	(0.65)	(0.75)	(0.92)	(0.057)	(0.085)	(0.11)	(0.08)	(0.27)	(0.30)	(0.10)	(0.16)	(0.39)	(0.43)	(0.30)	(0.24)
CEO age	-0.011	-0.005	0.0002	-0.004	0.076	0.052	0.043	0.052	0.040	0.037	**0.086**	0.049	0.031	0.032	0.037	0.036
	(0.78)	(0.89)	(0.997)	(0.92)	(0.12)	(0.21)	(0.26)	(0.21)	(0.16)	(0.18)	(0.05)	(0.12)	(0.21)	(0.19)	(0.14)	(0.15)
Cash ratio	0.491	1.555	1.351	0.866	3.778	2.281	2.073	3.123	1.918	1.591	2.706	2.313	**2.942**	**2.869**	**3.251**	**3.492**
	(0.85)	(0.58)	(0.62)	(0.74)	(0.21)	(0.40)	(0.43)	(0.29)	(0.31)	(0.38)	(0.22)	(0.23)	(0.08)	(0.09)	(0.06)	(0.05)
Leverage	-0.876	-0.700	-0.796	-0.769	-0.478	-0.530	-0.196	0.040	**-2.235**	**-2.299**	**-5.436**	**-2.464**	-1.590	-1.519	**-1.858**	**-1.948**
	(0.45)	(0.53)	(0.48)	(0.49)	(0.81)	(0.76)	(0.91)	(0.98)	(0.08)	(0.07)	(0.04)	(0.07)	(0.12)	(0.13)	(0.10)	(0.09)
Firm size	**-1.149**	**-1.034**	**-1.025**	**-1.024**	-0.340	-0.440	-0.300	-0.188	**-1.107**	**-1.190**	**-1.888**	**-1.058**	**-0.718**	**-0.749**	**-0.754**	**-0.736**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.52)	(0.32)	(0.53)	(0.70)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
Production mix	-0.139	-0.062	-0.077	-0.099	**0.518**	**0.444**	0.421	**0.496**	0.110	0.115	0.333	0.112	0.021	0.028	0.028	0.024
	(0.52)	(0.74)	(0.70)	(0.63)	(0.08)	(0.08)	(0.12)	(0.09)	(0.33)	(0.32)	(0.12)	(0.34)	(0.89)	(0.85)	(0.85)	(0.87)
Business diversification	0.402	-0.378	-0.087	0.185	**7.145**	**5.751**	**5.763**	**6.585**	-0.430	-0.508	-2.522	-0.403	-1.420	-1.465	-1.404	-1.401
	(0.86)	(0.87)	(0.97)	(0.93)	(0.02)	(0.04)	(0.03)	(0.03)	(0.80)	(0.76)	(0.28)	(0.82)	(0.34)	(0.31)	(0.36)	(0.36)
Geographic diversification	**7.608**	**6.563**	**7.382**	**7.684**	1.376	2.444	2.327	1.859	1.601	1.653	2.137	1.738	1.752	1.789	1.935	1.861
	(0.01)	(0.02)	(0.01)	(0.01)	(0.68)	(0.42)	(0.44)	(0.59)	(0.20)	(0.18)	(0.15)	(0.20)	(0.21)	(0.19)	(0.20)	(0.22)
Number of observations	88	88	87	88	90	90	89	90	94	94	93	94	92	92	91	92
Log Likelihood	-17.101	-18.777	-17.814	-16.929	-15.697	-17.562	-17.782	-16.803	-24.628	-24.646	-18.538	-23.544	-28.126	-28.233	-27.267	-27.125
Adjusted R-squared	0.602	0.584	0.589	0.602	0.545	0.537	0.534	0.543	0.491	0.492	0.529	0.496	0.485	0.485	0.483	0.491

Table 4.6: Probit Regression – Moneyness of Managerial Option Holdings

The coefficients are estimated using a probit model to estimate the likelihood that a firm hedges in each year. The dependent variable is a dichotomous variable to indicate whether a firm hedges, it is one if the firm hedges, otherwise, it is zero. The independent variables are defined in Table 3.1. The pooled sample consists of all firm-year observations from 126 U.S. oil and gas producers during the period 2001 to 2004. In Specification (1) – (3), the dollar value of managerial options is added to each regression in order to test the effect of moneyness of managerial option-based compensation. The data are presented as coefficients estimated with *p*-values in parentheses. Coefficients significant at the 10 percent level are in bold.

Independent Variable	Pooled Data (1)	Pooled Data (2)	Pooled Data (3)	2001 (1)	2001 (2)	2001 (3)	2002 (1)	2002 (2)	2002 (3)	2003 (1)	2003 (2)	2003 (3)	2004 (1)	2004 (2)	2004 (3)
Intercept	2.5367	**2.7168**	**2.6953**	9.484	7.026	5.704	-0.263	0.225	0.492	5.330	5.941	7.370	5.451	**6.935**	**6.913**
	(0.106)	(0.081)	(0.083)	(0.14)	(0.22)	(0.26)	(0.96)	(0.97)	(0.92)	(0.24)	(0.19)	(0.15)	(0.13)	(0.05)	(0.05)
Options held by insiders															
No. of exercisable options owned by officers	**0.3307**			**1.660**			**2.338**			**0.753**			0.333		
	(0.007)			(0.05)			(0.03)			(0.04)			(0.29)		
Value of exercisable options owned by officers	0.0014			-0.082			**-0.754**			-0.052			0.004		
	(0.915)			(0.31)			(0.06)			(0.44)			(0.88)		
No. of exercisable options owned by CEO		**0.7385**			**3.663**			**4.473**			**1.675**			0.973	
		(0.004)			(0.02)			(0.02)			(0.03)			(0.19)	
Value of exercisable options owned by CEO		-0.0064			-0.212			-2.755			-0.134			0.010	
		(0.781)			(0.13)			(0.11)			(0.23)			(0.81)	
Total No. of options owned by CEO			**0.5199**			**1.277**			**2.201**			**1.706**			0.475
			(0.003)			(0.09)			(0.03)			(0.01)			(0.35)
Value of options owned by CEO			0.0052			-0.080			-0.729			-0.143			0.040
			(0.768)			(0.36)			(0.49)			(0.25)			(0.32)
CEO compensation	**0.4739**	0.4149	**0.3647**	**2.069**	1.779	**1.934**	-2.729	-2.473	-0.974	**2.662**	**2.544**	**3.354**	1.084	0.737	0.526
	(0.090)	(0.154)	(0.247)	(0.05)	(0.12)	(0.08)	(0.36)	(0.42)	(0.64)	(0.06)	(0.08)	(0.05)	(0.18)	(0.33)	(0.52)
Managerial stock ownership															
Value of CEO's equity ownership	-0.0850	-0.1051	-0.1018	-0.124	0.032	0.031	0.081	0.064	0.052	-0.320	-0.397	-0.519	-0.281	**-0.435**	**-0.434**
	(0.353)	(0.251)	(0.262)	(0.69)	(0.91)	(0.91)	(0.82)	(0.86)	(0.87)	(0.25)	(0.18)	(0.15)	(0.20)	(0.06)	(0.06)
Value of stocks owned by non-CEO officers	**-0.1857**	**-0.1772**	**-0.1735**	-0.324	-0.230	-0.161	-0.146	-0.216	-0.239	**-0.837**	**-0.835**	**-1.015**	-0.504	-0.526	-0.485
	(0.077)	(0.092)	(0.098)	(0.32)	(0.44)	(0.56)	(0.82)	(0.63)	(0.54)	(0.03)	(0.04)	(0.04)	(0.14)	(0.12)	(0.15)
Number of officers and directors	-0.0264	**-0.0160**	-0.0195	-0.253	**-0.324**	**-0.286**	-0.260	-0.303	-0.184	**0.326**	**0.365**	**0.445**	0.054	0.121	0.087
	(0.525)	(0.703)	(0.632)	(0.11)	(0.06)	(0.07)	(0.34)	(0.26)	(0.33)	(0.03)	(0.02)	(0.01)	(0.59)	(0.28)	(0.43)
Per capita managerial ownership fraction	**2.5364**	**2.6626**	**2.7575**	**7.382**	**8.037**	6.302	**18.882**	**16.439**	**13.297**	0.886	0.552	0.974	3.918	3.586	3.804
	(0.026)	(0.017)	(0.014)	(0.08)	(0.07)	(0.14)	(0.03)	(0.02)	(0.01)	(0.74)	(0.83)	(0.73)	(0.19)	(0.20)	(0.18)
Number of outside five percent blockholders	-0.0947	-0.1085	-0.0930	-0.104	-0.168	-0.011	**-1.813**	**-1.258**	**-0.985**	-0.224	**-0.363**	**-0.410**	-0.136	-0.181	-0.127
	(0.194)	(0.141)	(0.198)	(0.70)	(0.55)	(0.96)	(0.06)	(0.04)	(0.05)	(0.22)	(0.08)	(0.05)	(0.40)	(0.28)	(0.42)
CEO tenure	-0.0186			0.014			0.068			-0.029			-0.060		
	(0.265)			(0.63)			(0.38)			(0.49)			(0.12)		
CEO age	**0.0271**	**0.0222**	**0.0245**	-0.025	-0.018	-0.006	0.056	0.054	0.048	0.039	0.036	0.049	**0.047**	0.034	0.037
	(0.036)	(0.064)	(0.044)	(0.58)	(0.68)	(0.88)	(0.37)	(0.29)	(0.30)	(0.22)	(0.28)	(0.22)	(0.10)	(0.20)	(0.16)
Cash ratio	**1.6864**	**1.5741**	**1.4669**	-0.752	-0.215	0.924	1.684	2.933	2.592	2.397	2.450	2.724	**3.104**	**3.594**	**3.537**
	(0.042)	(0.055)	(0.073)	(0.81)	(0.95)	(0.77)	(0.65)	(0.38)	(0.39)	(0.22)	(0.22)	(0.20)	(0.07)	(0.05)	(0.05)
Leverage	-0.7433	**-0.8563**	**-0.8425**	-0.869	-0.478	-0.543	-2.940	-2.082	-1.759	**-2.511**	**-2.771**	**-3.299**	-1.546	-1.785	-1.796
	(0.120)	(0.066)	(0.071)	(0.51)	(0.70)	(0.66)	(0.23)	(0.36)	(0.33)	(0.09)	(0.07)	(0.06)	(0.23)	(0.15)	(0.16)
Firm size	**-0.6441**	**-0.6083**	**-0.6412**	**-1.341**	**-1.268**	**-1.165**	-0.200	-0.127	-0.469	**-1.400**	**-1.342**	**-1.650**	**-0.844**	**-0.736**	**-0.709**
	(0.000)	(0.000)	(0.000)	(0.01)	(0.01)	(0.01)	(0.77)	(0.84)	(0.41)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
Production mix	0.0886	0.0903	0.0930	-0.274	-0.283	-0.169	**0.716**	**0.701**	**0.609**	0.114	0.081	0.099	0.090	0.024	0.036
	(0.162)	(0.167)	(0.156)	(0.31)	(0.27)	(0.46)	(0.08)	(0.08)	(0.06)	(0.37)	(0.54)	(0.47)	(0.59)	(0.88)	(0.81)
Business diversification	1.1742	1.0025	0.9130	1.869	3.332	1.437	**13.521**	**12.189**	**10.308**	-0.022	0.081	-0.409	-0.772	-1.452	-1.609
	(0.174)	(0.225)	(0.270)	(0.51)	(0.25)	(0.60)	(0.03)	(0.03)	(0.02)	(0.99)	(1.00)	(0.85)	(0.63)	(0.34)	(0.31)
Geographic diversification	**1.7043**	**1.8124**	**1.9572**	**9.472**	**9.206**	**8.142**	2.169	1.050	1.727	1.924	2.261	2.799	1.499	1.963	2.054
	(0.030)	(0.025)	(0.017)	(0.01)	(0.01)	(0.02)	(0.74)	(0.82)	(0.51)	(0.19)	(0.15)	(0.10)	(0.30)	(0.21)	(0.20)
Number of observations	364	364	364	88	88	88	90	90	90	94	94	94	92	92	92
Log likelihood	-108.655	-108.267	-108.143	-15.980	-15.119	-17.036	-11.557	-11.931	-14.502	-22.252	-21.134	-19.956	-26.586	-26.791	-26.535
Adjusted R-squared	0.542	0.545	0.544	0.590	0.598	0.589	0.528	0.534	0.529	0.486	0.506	0.509	0.484	0.4823	0.485

Table 4.7: Truncated Regression – Intensity of Hedging and Firm Characteristics and Managerial Traits, Conditional on Hedging

The coefficients are estimated using regressions with truncated data. Only firms that hedge are included in the sample. The dependent variable is the fraction of the firm's annual oil and gas production that is hedged. The independent variables are defined in Table 3.1. The pooled sample consists of all firm-year observations from hedging firms during the period 2001 to 2004. The data are presented as coefficients estimated with p-values in parentheses. Coefficients significant at the 10 percent level are in bold.

	Pooled Data			**2001**			**2002**			**2003**			**2004**		
Independent Variable	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
Intercept	0.008	**0.329**	**0.360**	-0.535	-0.008	0.020	0.346	**0.441**	**0.549**	-0.149	0.230	0.280	-0.358	-0.214	-0.190
	(0.97)	(0.00)	(0.00)	(0.31)	(0.97)	(0.94)	(0.57)	(0.02)	(0.00)	(0.74)	(0.37)	(0.31)	(0.57)	(0.46)	(0.55)
Options held by insiders															
No. of exercisable options owned by insiders	**-0.025**			**-0.145**			**-0.093**			0.022			0.007		
	(0.05)			(0.01)			(0.01)			(0.41)			(0.78)		
Total managerial option holding		-0.001			-0.023			**-0.068**			0.031			0.0208	
		(0.91)			(0.62)			(0.00)			(0.29)			(0.433)	
No. of exercisable options owned CEO			-0.042			-0.098			**-0.170**			0.065			(0.04)
			(0.16)			(0.36)			(0.06)			(0.37)			(0.52)
CEO compensation	-0.032	**-0.048**	-0.028	0.011	-0.071	-0.063	0.076	0.067	0.069	**-0.140**	**-0.141**	**-0.147**	**-0.112**	**-0.132**	**-0.129**
	(0.12)	(0.01)	(0.19)	(0.90)	(0.45)	(0.50)	(0.12)	(0.14)	(0.18)	(0.04)	(0.03)	(0.04)	(0.09)	(0.08)	(0.06)
Managerial stock ownership															
Value of share holdings of insiders	**0.027**			**0.053**			0.014			0.029			0.018		
	(0.03)			(0.04)			(0.71)			(0.27)			(0.56)		
Fraction of ownership		**0.154**	**0.153**		**0.363**	**0.354**		0.117	0.1297		0.103	0.090		0.076	0.080
		(0.05)	(0.04)		(0.05)	(0.06)		(0.43)	(0.385)		(0.44)	(0.51)		(0.65)	(0.66)
Number of officers and directors	-0.005	-0.002	-0.002	-0.003	-0.002	0.0003	0.002	0.002	0.002	-0.005	0.005	0.001	0.011	0.010	0.011
	(0.22)	(0.54)	(0.53)	(0.70)	(0.78)	(0.96)	(0.81)	(0.83)	(0.85)	(0.53)	(0.56)	(0.88)	(0.28)	(0.21)	(0.26)
Fraction of outside blockholder's share holding	0.121	0.089	0.075	**0.319**	**0.336**	**0.340**	0.161	0.186	0.086	0.179	0.078	0.085	0.029	0.044	-0.010
	(0.23)	(0.37)	(0.44)	(0.04)	(0.03)	(0.03)	(0.49)	(0.36)	(0.71)	(0.45)	(0.71)	(0.72)	(0.93)	(0.88)	(0.97)
Number of outside five percent blockholders	-0.005	0.002	0.001	-0.019	-0.016	-0.016	-0.025	-0.026	-0.020	0.002	0.019	0.0163	-0.002	-0.004	-0.004
	(0.65)	(0.85)	(0.93)	(0.49)	(0.50)	(0.48)	(0.293)	(0.278)	(0.478)	(0.89)	(0.33)	(0.41)	(0.95)	(0.89)	(0.89)
CEO age	**-0.004**	**-0.004**	**-0.004**	-0.004	-0.003	-0.003	-0.002	-0.001	-0.002	-0.003	-0.004	-0.006	0.001	0.004	0.002
	(0.04)	(0.01)	(0.01)	(0.23)	(0.35)	(0.41)	(0.59)	(0.62)	(0.45)	(0.40)	(0.34)	(0.15)	(0.74)	(0.32)	(0.58)
Cash ratio	-0.103	-0.059	-0.084	-0.338	-0.517	-0.488	-0.104	-0.061	-0.156	-0.033	-0.058	0.071	0.019	-0.014	0.036
	(0.66)	(0.81)	(0.73)	(0.52)	(0.27)	(0.30)	(0.86)	(0.90)	(0.78)	(0.94)	(0.91)	(0.89)	(0.98)	(0.98)	(0.95)
Leverage	**0.191**	**0.116**	**0.119**	**0.321**	0.224	0.200	**0.305**	**0.335**	**0.219**	0.100	-0.004	0.021	**0.227**	**0.185**	**0.208**
	(0.00)	(0.02)	(0.02)	(0.02)	(0.10)	(0.11)	(0.05)	(0.00)	(0.03)	(0.27)	(0.96)	(0.80)	(0.04)	(0.04)	(0.02)
Firm size	**0.027**	**0.044**	**0.041**	0.028	**0.076**	**0.065**	-0.025	-0.006	-0.014	**0.058**	**0.054**	**0.071**	0.036	**0.045**	**0.0545**
	(0.05)	(0.00)	(0.00)	(0.36)	(0.01)	(0.05)	(0.50)	(0.83)	(0.63)	(0.06)	(0.02)	(0.00)	(0.19)	(0.11)	(0.04)
Production mix	0.0059	-0.0016	-0.002	-0.0029	-0.0055	-0.0074	0.0112	0.012	-0.001	0.024	0.0070	0.009	-0.034	-0.028	-0.033
	(0.579)	(0.884)	(0.84)	(0.883)	(0.797)	(0.734)	(0.660)	(0.63)	(0.96)	(0.27)	(0.764)	(0.72)	(0.21)	(0.29)	(0.24)
Business diversification	0.071	0.0098	0.017	0.216	0.1780	0.173	**0.571**	**0.654**	**0.536**	-0.1023	-0.213	-0.222	0.078	-0.005	0.065
	(0.48)	(0.920)	(0.86)	(0.19)	(0.294)	(0.32)	(0.03)	(0.00)	(0.02)	(0.700)	(0.45)	(0.43)	(0.71)	(0.98)	(0.74)
Geographic diversification	**-0.415**	**-0.372**	**-0.388**	**-0.646**	**-0.676**	**-0.682**	**-0.776**	**-0.806**	**-0.754**	**-0.345**	-0.199	-0.261	-0.181	-0.134	-0.198
	(0.00)	(0.00)	(0.00)	(0.01)	(0.07)	(0.09)	(0.00)	(0.00)	(0.00)	(0.06)	(0.28)	(0.19)	(0.56)	(0.68)	(0.52)
Number of observations	222	224	224	49	49	49	58	58	58	62	63	63	53	54	54
Log likelihood	81.423	80.687	81.752	26.272	25.493	24.952	25.093	27.687	25.063	31.864	32.639	30.559	29.250	31.873	30.034
Adjusted R-squared	0.448	0.437	0.449	0.511	0.485	0.503	0.309	0.306	0.301	0.498	0.493	0.482	0.462	0.475	0.459
p-vaule of White test	0.272	0.428	0.176												

Appendix II

1. Determination of Annual Total Production (in MBOE)
Companies generally tabulate their production in the discussion of result of operation in annual reports, e.g., Berry Petroleum Co.'s 2004 Annual Report:

The following table sets forth certain information regarding production for the years ended December 31, as indicated:

	2004	2003	2002
Net annual production: [1]			
Oil (Mbbls)	7,044	5,827	5,123
Gas (Mmcf)	2,839	1,277	769
Total equivalent barrels [2]	7,517	6,040	5,251
Average sales price:			
Oil (per Bbl) before hedging	$33.43	$24.41	$20.27
Oil (per Bbl) after hedging	29.89	22.37	19.54
Gas (per mcf) before hedging	6.13	4.40	2.22
Gas (per mcf) after hedging	6.12	4.43	2.22
Per BOE before hedging	33.64	24.48	20.11
Per BOE after hedging	30.32	22.52	19.39
Average operating cost – oil and gas production (per BOE)	10.96	10.37	8.61

Mbbls - Thousands of Barrels
Mmcf - Million Cubic Feet
BOE - Barrels of Oil Equivalent

The oil production in 2004 is 7,044 thousand barrels, and gas production is 2,839 million cubic feet. Since one barrel is equivalent to 6 thousand cubic feet, the total production is about 7517 (7,044 + 2,839 / 6) thousand barrels of oil equivalent (MBOE).

2. Determination of the Extent of Hedging from SEC filings
Companies generally report their hedging either as the number of barrels of oil and cubic feet of natural gas hedged or as the percentage of production hedged in the section of Item 7A: Quantitative and Qualitative Disclosure about Market Risks in 10K and 10Q forms. For example, Stone Energy Corp.'s 2004 Annual Report disclose both hedging percentage and hedging volume:

Hedging. *...Our contracts totaled 2,513 MBbls of oil and 38,430 BBtus of natural gas, which represented approximately 46% and 73%, respectively, of our total oil and gas production during 2004. We realized a net decrease in revenue during 2003 from our hedging contracts of $1.6 million. During 2003, we hedged 37,775 BBtus of natural gas, which represented approximately 60% of our natural gas production. There were no oil hedges during 2003. During 2002, we realized a net increase in revenue from our hedging transactions of $6.0 million. Our contracts totaled 4,218 MBbls of oil and*

24,940 BBtus of natural gas, which represented approximately 68% and 37%, respectively, of our oil and gas production for the year.

Alternatively, Bill Barrett Corp's 2004 Annual Report discloses the percent of production hedged:

Hedging Activities. *In 2004 we hedged approximately 38% of our natural gas volumes, which resulted in a reduction in revenues of $12.4 million. No oil volumes were hedged in 2004. In 2003 we hedged approximately 45% of our natural gas volumes, incurring a reduction in revenues of $7.7 million, and in 2003 we hedged approximately 38% of our oil volumes, resulting in an immaterial increase to revenues.*

If sample firms report risk management activities in their 10K forms as a percentage of production hedged, the data collection will be much easier. However, firms usually report the number of barrels of oil and the cubic feet of gas hedged, we have to convert these data into the percentage of total production hedged. Using the above example for Berry Petroleum Co., the production hedged for year 2004 is tabulated in the annual report:

The following table summarizes the hedge position of the Company as of February 9, 2004:

Crude Oil and Natural Gas Hedges
(Based on NYMEX Pricing)

		Floor		*Ceiling*	
Term	*Barrels Per Day*	*Sell Put*	*Buy Put*	*Sell Call*	*Buy Call*
Crude Oil Hedges					
01/01/2004 – 03/31/2004	*2,500*	*$ 18.25*	*$ 22.10*	*$ 25.40*	*$ 30.10*
01/01/2004 - 03/31/2004	*2,500*	*$ 18.25*	*$ 22.10*	*$ 25.45*	*$ 30.10*
04/01/2004 – 12/31/2004	*1,000*	*$ 19.00*	*$ 22.00*	*$ 25.50*	*$ 29.40*
04/01/2004 – 12/31/2004	*1,000*	*$ 19.50*	*$ 23.00*	*$ 26.00*	*$ 29.75*
04/01/2004 – 12/31/2004	*1,000*	*$ 19.50*	*$ 23.00*	*$ 26.00*	*$ 29.50*
04/01/2004 – 12/31/2004	*1,000*	*$ 19.50*	*$ 23.00*	*$ 26.25*	*$ 29.85*
01/01/2004 – 04/30/2004	*1,000*	*$ -*	*$ 25.00*	*$ 25.00*	*$ -*
01/01/2004 – 12/31/2004	*1,500*	*$ -*	*$ 29.25*	*$ 29.25*	*$ -*
01/01/2004 – 12/31/2004	*1,500*	*$ -*	*$ 29.00*	*$ 29.00*	*$ -*
Natural Gas Hedges	*MMBtu Per Day*				
01/01/2004 – 06/30/2006	*2,500*	*$ -*	*$ 4.85*	*$ 4.85*	*$ -*
01/01/2004 – 06/30/2006	*2,500*	*$ -*	*$ 4.85*	*$ 4.85*	*$ -*

The following table summarizes the calculation of the total production hedged:

Term	Barrels Per Day (1)	Number of Days during Contract Term (2)	Production Hedged (1) * (2)
Crude Oil Hedges			
01/01/2004 – 03/31/2004	2,500	90	225,000
01/01/2004 – 03/31/2004	2,500	90	225,000

04/01/2004 – 12/31/2004	1,000	270	270,000
04/01/2004 – 12/31/2004	1,000	270	270,000
04/01/2004 – 12/31/2004	1,000	270	270,000
04/01/2004 – 12/31/2004	1,000	270	270,000
01/01/2004 – 04/30/2004	1,000	90	90,000
01/01/2004 – 12/31/2004	1,500	365	547,500
01/01/2004 – 12/31/2004	1,500	365	547,500
		Oil Total	**2,715,000**
Natural Gas Hedges	MMBTU Per Day		
01/01/2004 – 06/30/2006	2,500	365	912,500
01/01/2004 – 06/30/2006	2,500	365	912,500
		Gas Total	**1,825,000**

Given that 1 barrel is equivalent to 5.8 million British thermal units, and from the above table, Berry's total production hedged is about 3030 (2,715 + 1,825 / 5.8) MBOE. We have calculated that the total oil and gas production for 2004 is 7517 MBOE, then 40 percent (i.e., 3030/7517) of its oil production is hedged. This is the method we use to determine the percentage of total production hedged.

In another case, if a firm does not have risk management activities, the firm discloses this in the annual report. Eg., Arena Resources Inc.'s 2003 annual report states:

Commodity Price Risk

We have ***not*** *historically entered into derivative contracts to manage our exposure to oil and natural gas price volatility. Normal hedging arrangements have the effect of locking in for specified periods the prices we would receive for the volumes and commodity to which the hedge relates. Consequently, while hedges are designed to decrease exposure to price decreases, they also have the effect of limiting the benefit of price increases.*

Or a firm can state that new accounting rules on hedging do no have material impact on the firm's operation, which implies that the firm does not have risk management activities. Eg., Barnwell Industries Inc.'s 2000 annual report states: *Management does not expect adoption of SFAS No. 133, as amended by SFAS No. 138, will have a material effect on the Company's financial condition, results of operations or liquidity*

Chapter 5

Conclusions

In this thesis, we derive a theoretical model of optimal hedging strategy, which allows managers to incorporate their views in hedging decisions, and provide an empirical study testing the hypothesis that managerial risk aversion is a determinant of risk management decisions.

In the model, managers are uncertain about the true value of long run mean of oil prices, but they can learn about the parameter by observing the realized oil price series. As information accrues, manager's estimate becomes more and more accurate. With this learning process, managers acquire views about the market in the future. And managers take their views into account when they decide hedging strategy by maximizing their expected lifetime utility in a portfolio selection setting. Since this model allows managers to use their learning in formulating their hedging decisions, the analysis in this thesis provide a rationale for the popularity of a practice known as "selective" hedging in which corporate derivative users appear to allow their views of future commodity prices, interest rates, and exchange rates to influence their hedging decisions. The model also predicts that the manager's attitude toward risk plays a crucial role in the firm's hedging behavior.

Empirical studies are presented in this thesis to find out the determinant of risk management operations. Theories suggest that poorly diversified managers, as risk-averse economic agents, have incentives to reduce risks. we study the risk management activities of 126 U.S. independent oil and gas producers with a sample period from 2001 to 2004, and run regressions to test the interaction between hedge ratio and various incentive variables including equity ownership and option compensation. The results show that management's stock ownership and executive compensation are important determinants of corporate hedging policies. Firms with managers possessing greater equity ownership and less option holdings in their compensation plan hedge more extensively. The results are consistent with the prediction by managerial incentive hypothesis.

To avoid possible misspecification in our regression model, we do robustness check and consider the size of management team and CEO tenure. We find that younger managers tend to hedge more. By separating CEO's equity ownership and option holdings from non-CEO officers and directors, we find that CEOs are vested with more authority in risk management program. However, non-CEO officers also have great influence on the decision. Finally, hedging decisions are actually a two-step decision problem. First, firms have to decide to hedge or not; second, once firms choose to hedge, they still need to decide how much to hedge, i.e., hedging intensity. We separate the decision to hedge from the level of hedging to find out whether there are differences in the factors that determine the two decisions. The results show that the determinants of hedging decisions could be different from the determinants of hedging intensity.

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