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TWO ESSAYS ON CORPORATE HEDGING: THE CHOICE OF INSTRUMENTS AND METHODS

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Interdepartmental Program in Business Administration (Finance)

by
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ABSTRACT

This dissertation examines corporate use of derivative instruments and multi-period hedging methods. It studies the use of linear (e.g. futures) and nonlinear (e.g. options) derivatives in a sample of 382 U.S. non-financial firms (920 firm-year observations) between 1992 and 1996. It also measures the performance of stacked hedge techniques with applications to three investment assets (heating oil, light crude oil, and unleaded gasoline) and to three commercial commodities (British Pound, Deutsche Mark, and Swiss Franc). In a stacked hedge, corporations hedge the long-term exposures by repeatedly rolling nearby futures contracts until settlement.

Analyzing the 382 firms, I find that both value maximization and managerial incentives explain the use of linear and nonlinear derivatives by corporations. In particular, the use of nonlinear instruments is positively related to the firm's investment opportunities, size, free cash flow, prospect of financial distress, and managerial option grants. Firms are more likely to use derivative contracts with linear payoffs when their CEOs receive more compensation from bonus compensation or have been in their positions for longer periods of time.

I evaluate how well long-term exposures to asset prices can be neutralized using stacked hedge techniques with applications to investment assets and to commodities. My evidence suggests that stacked hedges perform better with investment assets than with commercial commodities. The stacked hedge produces hedge performance of at least 0.98 for investment assets and hedge performance of less than 0.83 for heating oil. The results are consistent with the hypothesis that a stochastic representation of convenience yields results in pronounced deviations from the spot-futures parity resulting in non-trivial hedge errors.

CHAPTER 1

INTRODUCTION

Recent surveys indicate that 50% of the non-financial firms in the United States use derivatives (e.g. Bodnar, Hayt, and Marston (1998)). Prior research suggests that firms use derivatives to manage risk.[1] Although researchers have identified market frictions (e.g. taxes, bankruptcy costs, or agency costs) that explain why firms hedge, financial economists have paid scant attention to the choice of derivative instruments and multi-period hedging methods. This dissertation seeks to address two general research questions. First, why do firms choose linear (e.g. futures, forwards, swaps) or nonlinear (e.g. options) instruments? I examine empirically the choice of derivative contracts by 382 U.S. corporate firms (920 firm-year observations) over the period 1992 -1996. Second, how well a long-term exposure to asset prices can be neutralized using a stacked hedge rather than a strip hedge? In a stacked hedge, firms hedge the long-term exposures by repeatedly rolling nearby futures contracts until settlement. In contrast, the strip hedge uses a portfolio of futures contracts of different maturities to match required cash flows. The approach here is to examine competing models and to test their predictions using empirical data on both investment and commercial assets.

In a perfect world, there is no justification for corporate risk management. Shareholders can efficiently hedge their own exposures by holding well-diversified portfolios. Financial economists (e.g. Smith and Stulz (1985) and Froot, Schafstein, and Stein (1993)) have relied on

[1] Bodnar, et al. (1996) provide survey evidence that firms use derivatives primarily to manage volatility in cash flows and accounting earnings. Tufano's (1998) evidence suggests that gold-mining firms use derivatives to reduce risks. Guay (1999) also finds that firms that start using interest rate or exchange rate derivatives experience a significant decrease in volatility.

market imperfections to provide theoretical backgrounds for corporate hedging. The shareholder-value-maximization paradigm suggests that hedging is a value-increasing strategy because it can reduce expected taxes, lower the costs of financial distress, or alleviate the underinvestment problem that occurs when cash flow is volatile and external financing is costly. The agency theory posits that managers engage in corporate hedging program to maximize their personal wealth. The empirical literature provides evidence that both value maximization and managerial incentives motivate corporate derivatives use (e.g. Tufano (1996), Geczy, Minton, and Schrand (1997), and Allayannis and Weston (2001)).

The goal of my dissertation is not to expand on the reasons why firms hedge but instead to take this as given and shed light on corporate use of hedging instruments and methods. In Chapter 2, I extend the testable implications of extant theories on derivatives use to explain why firms use linear or nonlinear derivatives. A substantial body of empirical research on hedging has relied primarily on survey data (e.g., Nance, Smith, and Smithson (1993), Tufano (1996, 1998), Haushalter (2000), and Adam (2003)). In contrast, my study uses publicly available information on derivatives use and thus does not suffer from non-response bias typical of survey samples. Due to the paucity of a rigorous theoretical framework, my empirical analysis remains somewhat exploratory.

Analyzing the 382 non-financial firms, I find that the determinants that affect the likelihood of undertaking linear and nonlinear devices significantly influence the extent to which corporations use linear and nonlinear derivative contracts. My results suggest that both value maximization and managerial incentives explain corporate use of linear and nonlinear derivative securities.

Supporting the investment opportunity hypothesis, I find that the use of nonlinear derivatives is positively related to market-to-book assets. This evidence is consistent with the notion that firms with enhanced investment opportunities have greater incentives to use nonlinear instruments to reduce downside risk but also preserve upside gains derived from the investment opportunities. Linear securities eliminate both the lower tail and the upper tail of a cash distribution, resulting in the potential loss of the growth opportunities. This result also complements Adam's (2003) finding for gold-mining industry that corporations with larger capital expenditures are more likely to use nonlinear contracts to hedge the financing risk dynamically.

The use of nonlinear devices is also positively related to stock option grants but is negatively related to bonus compensation.[2] These findings suggest that managers who receive greater compensation from stock options have greater incentives to adopt derivatives that have nonlinear payoffs to raise their expected compensation. The negative relation with bonus payments suggests that the "stair-step" function of bonus payments induces managers whose payments are at or near the cap to use linear derivative securities. These results support Smith and Stulz's (1985) prediction that hedging policies reflect the incentives provided in compensation contracts.

I document evidence consistent with a stream of empirical research that corporate risk management is related to firm size (e.g. Nance, et al. (1993), Bodnar, et al. (1998), and Haushalter (2000)). I find a positive relation between firm size and nonlinear derivative usage.

[2] Due to data limitations, I do not report the results related to CEO compensation variables in this dissertation. See Huang, Ryan, and Wiggins (2002) for detailed discussion.

This finding supports the premise that larger firms have more resources to invest in sophisticated control systems and employees with the ability to manage (more complex) nonlinear derivative portfolios. This evidence is consistent with the existence of significant costs associated with managing nonlinear derivative contracts.

My results shed light on the relation between free cash flow and nonlinear usage. I find that corporate uses of both linear and nonlinear derivatives increase with free cash flow. This result is consistent with the hypothesis that costly external financing precludes firms from using derivatives. I also document that the proportion of nonlinear instruments in the firm's hedge portfolio is positively related to free cash flow. This evidence suggests that financial slack allows firms to use nonlinear derivative contracts to preserve upside potential for shareholders without incurring the higher costs of external financing. These results support the theory that external sources of finance are more costly than internal capital (e.g. Myers and Majluf (1984), and Froot, et al. (1993)).

Additionally, I find an inverse relation between CEO tenure and nonlinear usage. This evidence seems consistent with the hypothesis that managers who have held office longer are more risk averse (e.g. May (1995)). Alternatively, more tenured managers face a shorter horizon and thus possibly lack the incentives to gain the necessary knowledge to understand the relatively complex nonlinear contracts.

Finally, my data indicate that the use of nonlinear derivative contracts increases with the prospect of financial distress. I find that the use of nonlinear vehicles is positively related to leverage and industry-adjusted leverage, but is negatively related to Z-score and coverage ratio. These findings support the hypothesis that as the likelihood of financial distress increases, firms have greater incentives to use nonlinear instruments to mitigate the underinvestment problem that arises when the gains from profitable projects strictly accrue to bondholders. Linear securities lock in predetermined gains and thus exacerbate the debt overhang problem. I do not observe a negative relation between the use of nonlinear hedging and convertible debt. Overall, my evidence is not consistent with the risk-shifting hypothesis that firms execute a nonlinear strategy to preserve upside potential for the shareholders at the expense of debtholders.

Chapter 3 evaluates the effectiveness of stacked hedge techniques, which Metallgesellschaft A.G. used to reduce its exposures to oil prices. My hypothesis is that stacked hedges perform better with investment assets than with commercial commodities. Unlike investment assets, commercial commodities are those held for production or consumption purposes and thus have non-trivial convenience yields. Marginal convenience yield is the benefit which one derives from holding the commodity physically and generally follows a mean-reverting process (e.g. Fama and French (1987, 1988)). The effectiveness of stacked hedges depends on hedged assets obeying spot-futures parity. Since deviations from spot-futures parity are a result of stochastic convenience yields, stacked hedges should perform better with investment assets than with commercial commodities.

I examine the hedging problem facing the agent as discussed in Hilliard (1999) with applications to three investment assets and to three commercial commodities. The economic agent has long-term deterministic commodity supply commitments and wishes to hedge those long-term exposures by sequentially rolling nearby futures contracts until settlement. The commercial commodities are heating oil, light crude oil, and unleaded gasoline. The investment assets are the British Pound, Deutsche Mark, and Swiss Franc. My results suggest that stacked hedges perform better with investment assets than with commercial commodities. The stacked hedge produces an R^2 of at least 0.98 for investment assets and R^2 of less than 0.83 for heating oil. I also document that the differences in hedge performance between the two classes of assets are attributed to the stochastic nature of convenience yields of commercial commodities.

The dissertation proceeds as follows. In Chapter 2, I examine the determinants of the choice of derivative financial instruments. Chapter 3 measures the performance of stacked hedge techniques with applications to investment assets and to commercial commodities. Chapter 4 concludes the dissertation.

CHAPTER 2

THE DETERMINANTS OF THE CHOICE OF DERIVATIVE FINANCIAL INSTRUMENTS: AN EMPIRICAL EXAMINATION OF HEDGING PRACTICES IN US CORPORATE FIRMS

2.1 Introduction

In this chapter, I examine empirically the use of derivatives by publicly held firms. I broadly classify derivative instruments as linear (e.g. forwards, swaps) and nonlinear (e.g. options) derivatives. My research seeks to answer the following question: For those firms that use derivatives, why do they use linear or nonlinear instruments? The optimal use of derivatives can mitigate market impediments and create shareholder value. Alternatively, managers can choose derivatives to create private benefits for themselves, possibly at the expense of the shareholders. My evidence suggests that both value maximization and personal incentives explain the use of linear and nonlinear derivatives by corporations.

The finance literature suggests that hedging risks provides the primary motivation for corporations to use derivatives. In perfect capital markets, corporate hedging is irrelevant since shareholders can efficiently hedge their own risks by holding well-diversified portfolios. However, several recent theories suggest that market frictions cause widely held firms to engage in hedging programs. For example, Smith and Stulz (1985) argue that hedging is beneficial because it can lower the expected costs of financial distress or expected taxes. Froot, Scharfstein, and Stein (1993) show that hedging can mitigate the underinvestment problem that occurs when cash flow is volatile and external sources of finance are costly. Previous empirical studies lend some support to these theoretical incentives (e.g. Nance, Smith, and Smithson (1993), Mian (1996), Tufano (1996), and Haushalter (2000)). Nevertheless, few studies have addressed the choice of linear and nonlinear derivatives.

This chapter contributes to the literature on the use of derivatives by corporations in two ways. First, I propose a wide variety of testable implications that incorporate both firm characteristics and managerial incentives. Due to the lack of a rigorous theoretical framework, my study remains somewhat exploratory. I examine the firm and managerial characteristics that have been shown to influence the decision for corporations to hedge at all. In particular, I examine whether the decision to choose particular derivative securities is related to investment opportunity, free cash flow, firm size, tax incentives, capital structure, managerial compensation policy, CEO tenure and age, and managerial performance. Second, unlike early empirical research using survey data (e.g. Tufano (1996, 1998) and Haushalter (2000)), this chapter uses publicly available information on the use of derivatives by corporations and does not suffer from non-response bias.

I examine the choice of derivative securities by 382 U.S. corporate firms (920 firm-year observations) over the period 1992-1996. To gain insight into my research questions, I analyze both the extent of linear (nonlinear) derivative usage and the intensity of nonlinear derivative usage. I measure the extent of derivatives used by a corporation as the total notional value of the derivatives relative to firm size. I measure the intensity of nonlinear derivative usage as the fraction of nonlinear derivatives, as determined by notional values, in the firm's derivative portfolio.

My results suggest that the determinants that affect the likelihood of adopting nonlinear (linear) instruments significantly influence the extent of nonlinear (linear) hedging. I observe a positive relation between nonlinear derivative usage and growth opportunity, stock option grants, firm size, free cash flow, leverage, and industry-adjusted leverage. However, I document an inverse relation with CEO tenure, bonus plans, Z-score, and the coverage ratio.

The results support several explanations for corporate risk management. First, the positive coefficient on growth opportunity suggests that firms with more investment opportunities have greater incentives to undertake nonlinear devices to preserve upside potential. This finding also supports Adam's (2003) hypothesis that firms with relatively large investment programs are prone to adopt nonlinear derivatives because they frequently face more complex hedging problems.

Second, some of my results that are not reported in this study suggest that CEOs with greater compensation from stock options are more likely to use derivatives that preserve nonlinear payoffs. In addition, I document that the feature of the limited upside potential of bonus compensation discourages managers from undertaking nonlinear hedging. These findings are consistent with Smith and Stulz's (1985) prediction that the compensation package affects the hedging decision.

Third, the positive relation with firm size supports the notion that larger firms are more likely to have resources to invest in sophisticated control systems and personnel capable of administering sophisticated instruments. This result compares to a stream of empirical literature that the likelihood of hedging is related to size (e.g. Booth, Smith, and Stolz (1984), Block and Gallagher (1986), Nance, et al. (1993), and Haushalter (2000)).

Fourth, I find that relative to firm size, free cash flow is positively related to the notional amounts of both linear and nonlinear derivatives. For firms that are the heaviest derivative users, I also find that the mix of nonlinear derivatives in the derivative portfolio is positively related to free cash flow. These findings suggest that financial slack is valuable to firms and that firms use derivatives to hedge against the loss of this slack. As free cash flow increases, firms are more likely to have the internal resources to fund nonlinear derivatives to preserve upside potential for shareholders. Together, these findings support the concept that external financing is more costly than internal capital because of the adverse selection problem (Myers and Majluf (1984), Froot, et al. (1993)).

Fifth, the negative coefficient on CEOs tenure supports the view that more tenured CEOs are more risk averse (e.g. May (1995)). Alternatively, this result is also consistent with the premise that managers with longer tenures are closer to retirement and face a horizon problem. Given their short horizons, they possibly lack the incentives to invest effort to understand the more complex nonlinear instruments.

Finally, my results outlined above for the variables pertaining to leverage, industry-adjusted leverage, Z-score, and coverage ratio are consistent with the underinvestment hypothesis. As the probability of distress increases, the likelihood that the firm would forgo valuable investment opportunities also increases (Myers (1977)). My evidence suggests that firms facing the prospect of financial distress use nonlinear instruments to hedge against this underinvestment problem but also preserve upside potential for the shareholders. I do not observe a negative relation between nonlinear usage and convertible debt. Thus, my evidence lends no support to the risk-shifting hypothesis that corporations adopt nonlinear devices at the expense of the debtholders.

The chapter is organized as follows. In Section 2.2, I review the existing theories and previous empirical studies on the choice of derivative contracts. Section 2.3 identifies firm characteristics and managerial incentives that affect the choice of derivative instruments. I propose hypotheses and explore a variety of empirical implications that are related to the choice of hedging instruments. I describe my sample and dependent variables in Section 2.4 and present my empirical results in Section 2.5 and Section 2.6. Section 2.7 concludes the chapter.

2.2 Prior Research on the Choice of Derivatives

The financial economics literature (e.g. Black (1976), Moriarty, Phillips, and Tosini (1981)) classifies instruments whose payoff structure is linear in the price of the underlying asset as linear derivatives. Linear securities include forwards, futures, swaps, etc. Nonlinear instruments, such as options, produce a payment only in certain states of nature. The nonlinear strategy protects against the lower tail of the payoff and maintains the upper tail of a cash distribution. In contrast, the linear hedge, under price convergence, results in a risk-less payoff. In the absence of market frictions, it costs nothing to enter linear instruments because the delivery prices are chosen so that the values of the linear derivatives to both sizes are zero. However, it is not costless to use nonlinear contracts since they confer the holder the right to buy or sell the underlying asset for a certain price.

Detemple and Adler (1988) argue that investors facing borrowing constraints have the incentives to use options because financing the margin on futures with short sale of risky securities would generate additional risk. Froot, et al. (1993) show that if the sensitivities of investment spending to changes in the risk variable are constant, linear strategies will be optimal; otherwise firms would prefer the nonlinear hedge. Brown and Toft (2002) show that when the levels of quantity risk are nontrivial, or when hedgable and unhedgable risks are negatively correlated, firms benefit substantially from undertaking nonlinear hedging. They also demonstrate that customized exotic derivatives are typically better than vanilla derivatives when these circumstances arise. Gay, Nam, and Turac (2002a) derive a similar result. Their model shows that the negative correlation between output levels and prices exacerbates the over-hedging problem and hence induces the firm to use nonlinear vehicles.

Perhaps because of the paucity of rigorous models that produce testable hypotheses, the existing empirical research into corporate choice of derivatives is limited. Tufano (1996) lends no support to Detemple and Adler's (1988) model that firms facing financial constraints are more likely to use option contracts. Kim, Nam, and Thornton (2001) provide evidence that CEOs who receive more compensation from option grants are prone to undertake nonlinear hedging. Their evidence is consistent with Smith and Stulz (1985) who argue that that the management compensation package affects the hedging that managers undertake. Gay, et al. (2002b) support the theory that nonlinear derivative usage will increase with the costs of over-hedging. Supporting Froot, et al.'s hypothesis (1993), Adam (2003) finds that gold mining firms facing a more complex hedging problem are more likely to adopt nonlinear derivatives.

2.3 Hypotheses Development

Despite the lack of models that produce specific testable hypotheses, I can extend corporate finance theory and risk management theory to suggest rationales for the choice of derivative security by corporations. In this section, I develop hypotheses for why corporations or managers would prefer a linear or a nonlinear device.

2.3.1 Investment Opportunities

I argue that high-growth firms will use nonlinear hedging more extensively than will low-growth firms. Firms with more investment opportunities have substantial upside potential and thus have greater incentives to use nonlinear derivatives. Linear derivatives eliminate not only downside risk but also upside potential, resulting in the potential loss of positive gains derived from the investment opportunities. Thus, I expect that firms with greater investment opportunities adopt more nonlinear devices to take advantage of the substantial potential.

Alternatively, Adam (2003) extends Froot, et al.'s (1993) theory of risk management, and argues that firms with relatively large investment programs tend to engage in nonlinear instruments because they frequently face more complex hedging problems. He illustrates that complex hedging problems require hedge ratios to be "customized" on a state-by-state basis. Since high-growth firms often face more complex hedging problems, they are more inclined to use nonlinear derivatives to hedge the financing risk dynamically. Like Smith and Watts (1992), I use the ratio of the market value to the book value of total assets to proxy for growth opportunities.

2.3.2 Free Cash Flow

Financial slack is valuable to firms since it allows them to fund positive NPV projects without incurring the higher costs of external financing (Myers and Majluf, 1984). Thus, firms with free cash flow have the incentive to hedge with derivative contracts to protect this valuable asset. Relative to firm size, I expect both the use of linear and nonlinear contracts to increase with free cash flow. As free cash flow increases, firms are less likely to have to resort to costly external financing, which makes funds available to purchase nonlinear derivatives. Since these contracts preserve upside potential for investors, I expect that firms will use more nonlinear devices as the budget constraint is lessened. Therefore, I expect a positive relation between the proportion of nonlinear derivatives in the firm's portfolio and free cash flow.

Following Lehn and Poulsen (1989), I measure free cash flow before investment as operating income before depreciation less total income taxes plus changes in deferred taxes from the previous year to the current year less gross interest expense on short- and long-term debt less total amount of preferred dividend requirement on cumulative preferred stock and dividends paid on noncumulative preferred stock less total dollar amount of dividends on common stock.

2.3.3 Firm Size

The empirical literature documents that the likelihood of hedging increases with firm size. Dolde's (1993) survey data indicates that management's lack of familiarity with sophisticated financial instruments is a major impediment toward the hedging activities. Presumably, large firms can use their resources to attract employees who have the ability and knowledge required to manage derivative securities. Supporting this premise, researcher (Booth, et al. (1984), Block and Gallagher (1986), Nance, et al. (1993), Haushalter (2000)) find that larger firms tend to hedge more extensively.

I extend this logic to propose that larger firms are more likely to implement nonlinear strategies. These firms have more resources to invest in sophisticated control systems and more people with the ability to manage (more complex) nonlinear derivative portfolios. I measure firm size as the sum of the book value of the firm's debt and preferred stock plus the market value of common equity.

2.3.4 Tax Structure

Mayers and Smith (1982), and Smith and Stulz (1985) show that hedging increases the expected value of the firm when a progressive statutory tax schedule creates convexity in the taxable income. When the expected tax liability is an increasing and convex function of the firm's taxable income, the after-tax firm value is an increasing and concave function of the firm's taxable income. The corporate tax code stipulates that the firm with taxable income (0-$100k) is in the tax progressive region. In addition, tax preference items, such as tax loss carryforwards, investment tax credits, and foreign tax credits, extend the convex region. Therefore, the firm with more tax preference items is more likely to manage risks to preserve the tax benefit of hedging. Nance, et al. (1993) find evidence that firms that face more convex tax functions are more likely to hedge.

If the tax advantages are sufficiently large, firms in the progressive tax region have an incentive to forego upside potential to insure that they receive the tax advantages. I expect that firms with more tax preference items, which increase the likelihood that they fall in the progressive region, will use linear derivatives to preserve the tax shield. Since the convex region is small, these tax-induced benefits from the linear hedging are limited. Following Tufano (1996), I use the book value of tax loss carryforwards scaled by firm value to measure the firm's ability to extend the progressive tax region.

2.3.5 Capital Structure

As the likelihood of financial distress increases, firms have the incentives to forgo positive net present value projects since it becomes more likely that the gains from these projects will strictly accrue to bondholders (Myers, 1977). Firms can mitigate this underinvestment problem if they insure against these outcomes. However, if they use linear derivatives, they will lock in predetermined gains and shareholders will not benefit from upside potential. Thus, I expect that as the probability of financial distress increases, firms will be more likely to use nonlinear derivatives.

Alternatively, as leverage increases, shareholders have the incentive to engage in risky strategies that transfer wealth from debtholders to the shareholders (Galai and Masulis, 1976, Myers, 1977). Presumably, firms should not, cannot and do not perfectly hedge all uncertainties. If debt were impaired in certain states of the world, the use of nonlinear derivatives, which are costly, would reduce the assets available to debtholders but preserve upside potential for shareholders in other states of the world. Green (1984) shows that the substitution of convertible debt for straight debt mitigates such conflicts of interest between a firm's bondholders and its shareholders. Thus, if managers use nonlinear derivatives to pursue risk-shifting strategies, I expect a positive relation between nonlinear derivatives and financial leverage, but a negative relation with convertible debt.

In summary, my analysis allows us to shed light on the underinvestment hypothesis and the risk-shifting hypothesis. A positive relation between nonlinear derivative usage and measures of financial distress and no relation with convertible debt support the underinvestment hypothesis. A positive relation between nonlinear derivative usage and financial leverage combined with a negative relation with convertible debt supports the risk-shifting hypothesis, but does not rule out the underinvestment hypothesis.

To measure the probability of financial distress, I use four variables: the ratio of book value of long-term debt to firm size, an industry-adjusted-leverage indicator variable, Altman's (1993) Z-score, and the coverage ratio. I set the value of the indicator variable to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise. The Z-score measures the probability of bankruptcy. A Z-score that is less than 1.81 indicates that there is a high probability of bankruptcy, and a Z-score greater than 3.0 suggests that there is a low probability of bankruptcy. I define the coverage ratio as earnings before depreciation scaled by interest. I use convertible debt scaled by firm size to measure the level of convertible debt.

2.3.6 CEO Compensation Policy

Smith and Stulz (1985) argue that the form of managerial compensation contracts can influence a firm's hedging policies. I examine three components of executive compensation: annual bonus plans, stock option grants, and restricted stock plans. I predict that CEOs with greater stock option awards will implement nonlinear hedging strategies more extensively. In contrast, CEOs who receive more restricted stock grants have the incentives to adopt more linear derivative securities. I make no prediction for the relation between derivative choice and cash bonuses. I measure incentives provided by the form of the management compensation contract as one plus the logarithm of the value of the stock options awards, stock grants, or cash bonus awards, respectively.

CEOs who receive more stock option grants have greater incentives to use nonlinear instruments. The manager's compensation from stock options is a convex function of firm value. It follows that the expected payoff of managerial stock options is higher if the firm does not completely eliminate risk. Unlike linear devices, nonlinear derivatives reduce rather than eliminate volatilities of a firm's payoffs. Consequently, managers who receive more stock options have stronger incentives to administer nonlinear contracts to raise their expected compensation. Murphy (1998) documents that in 95% of stock option grants the exercise price equals the fair market value on date of grant. The "at-the-money" feature of stock option grants induces managers to execute nonlinear hedging strategy to increase the value of their options.

Restricted stock grants exacerbate a manager's risk aversion since restricting the manager to hold the firm's stock forces him to hold an undiversified portfolio. To the extent that the manager would have to bear the costs of a nonlinear hedge, he has the incentive to use linear derivatives and lock in the value of his stock grants. I expect that a CEO who receives greater compensation from restricted stocks will use more linear derivatives. However, the fact that the CEO bears only a small fraction of the costs of the nonlinear derivatives makes this a relatively weak hypothesis.

Smith and Stulz (1985) document that bonus payments are a convex function of accounting earnings. When the firm's accounting earnings exceed the target number, the CEO receives a bonus. However, when the accounting earnings are below the threshold, the manager receives no bonus payment. Since bonuses have option-like features, managers who have greater bonus compensation have the incentives to prefer nonlinear derivatives.

Murphy (1998) finds that bonus plans are generally capped and hence do not have unlimited upside potential. Bonus payments do not generally increase linearly with accounting earnings, but rather follow a "stair-step" function. This feature implies that managers whose bonus payments are at or near the cap have the incentives to use linear devices to lock in the bonus. In this case, the upside potential of accounting earnings would add little or no additional value to the bonus. As a result, I make no prediction for the relation between the derivative choice and bonus payments.

Due to the lack of data, this analysis does not include compensation variables. In a separate study, Huang, Ryan, and Wiggins (2002) find a positive relation between the use of nonlinear derivatives and compensation from stock options. In addition, they observe a negative relation between nonlinear derivative usage and bonus compensation. This result supports the argument that the feature of the limited upside potential in bonus compensation discourages managers from undertaking nonlinear hedging. They do not find any relation between restricted stock grants and the derivative choice.

2.3.7 CEO Tenure and Age

May (1995) argues that more tenured CEOs are more risk averse because their experiences and managerial skills are unique to a specific firm. Supporting his argument, May finds a negative and significant relation between CEO tenure and the variance of the firm's equity return and debt to equity ratio. Tufano (1996) argues that CEO age serves as a proxy for risk aversion because older managers prefer to reduce the variance of their portfolios. This line of reasoning suggests that older CEOs or more tenured CEOs are more likely to undertake linear derivatives to bear no risk. Older CEOs with more tenure are also more likely to have a short horizon since they are closer to retirement than younger CEOs. Thus, the older CEOs have less incentive to invest any effort to gain the necessary knowledge to understand the relatively more complex nonlinear derivatives.

Alternatively, if a CEO nearing retirement bears only a fraction of the cost of the nonlinear derivative, he has the incentive to choose nonlinear derivatives since they would guard against downside losses but preserve upside potential. In this case, the CEO potentially uses the firm' s resources to purchase nonlinear instruments as a "free" insurance policy.

2.3.8 Managerial Performance

Breeden and Viswanathan (1998) propose that managers with superior abilities are prone to hedge. They argue that hedging eliminates extraneous noise and thus improves the informativeness of management ability. Their model suggests that managers who have performed well in the past have the incentives to hedge so that the market can draw more precise inference about their abilities. Therefore, this argument suggests that managers with superior capabilities are more likely to use linear securities to completely hedge all uncertainties and exactly communicate their skills to the labor market. I measure managerial skill as the average of the firm's return on equity over a three-year period prior to the year when the firm undertakes particular instruments.

2.4 Sample Description and Dependent Variable

I obtain data on the use of derivatives by publicly traded firms in the United States for the fiscal years 1992–1996 from the Third Quarter 1997 Edition of Database of Users of Derivatives, published by Swaps Monitor Publications, Inc. The information contained in this database comes from annual reports or 10K statements. The data restrict this study to corporate uses of interest rate and currency derivatives. Many commodity financial instruments are not considered derivatives and are not disclosed under SFAS 119 because they could be physically delivered.

The database distinguishes hedging activities from trading purposes to a large degree because SFAS 119 requires firms to report detailed information on the notional position and purpose of derivative holdings. A random investigation of actual annual reports also reveals that my sample firms hold derivatives for hedging activities. I also randomly compare reported data on derivative positions to data in actual 10-k statements and find no discrepancies.

Table 2.1
Hypothesized Relations Between Firm Characteristics and Nonlinear Usage

Hypothesis	Variable	Sign	Data Description
Investment opportunities	Market-to-book Assets	+	The ratio of the market to the book value of total assets
Firm size	Log (Firm value)	+	Log of the sum of the book value of the firm's debt and preferred stock plus the market value of common equity
Free Cash Flows	Free Cash Flow	+	The value of (OIBDP – TXT + TXDITC – XINT - DVP – DVC) scaled by firm size
Tax Structure	Tax Loss Carryforwards	–	The book value of tax loss carryforwards scaled by firm size
Capital Structure	Leverage	+	Long-term debt scaled by firm size
Capital Structure	Leverage Indicator	+	I set the value of the indicator variable to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise.
Capital Structure	Coverage Ratio	–	Earnings before depreciation divided by interest expenses
Capital Structure	Z-score	–	Z-score is a measure of bankruptcy
Managerial Performance	Return on Equity	–	The average return on equity over a three-year period
CEO Tenure and Age	CEO Tenure	–	The number of years since the CEO has been in the position
CEO Tenure and Age	CEO Age	?	The CEO age

The Interest Rate and Currency Edition of the Database presents the notional positions of interest rate and currency derivatives used by 1,698 corporate firms, with 10,188 firm-year observations available. The observations that I include in the analysis must have positive notional amount of either interest rate or currency derivatives, and have filed a proxy statement for any year between 1991 and 1995. I exclude observations that have unavailable data from Standard and Poor's Research Insight database. Excluding the coverage ratio, Z-score, and CEO age in the analysis results in a sample of 382 firms and 920 firm-year observations. After eliminating observations that are missing CEO age, my sample consists of 259 firms and 584 firm-year observations.

Table 2.2 breaks down the frequency of various instruments that the sample firms use to manage interest rate and currency exposures across the years. The data indicate that some firms use more than one type of derivative instruments in their hedge portfolios. In results not reported in the table, I find that nearly 77% of the 382 firms in my sample use only linear derivatives, less than 6% use only nonlinear contracts, and approximately 18% use both linear and nonlinear derivative instruments in the hedge portfolio. Consistent with the Wharton/CIBC Survey (1995), my results suggest that a greater fraction of firms hedge interest rate exposures with swaps and manage currency risks with forward and futures contracts.

I construct the extent of linear and nonlinear hedging as the dependent variable in multivariate cross-sectional regressions. I measure the degree of linear and nonlinear hedging two ways. One measure is the total notional value of nonlinear (linear) derivatives scaled by the firm's total assets or firm size. This measure gauges the degree to which a firm hedges its total assets or market value with nonlinear or linear contracts. However, it would not serve well as an

Table 2.2
Derivative Instruments Firms Use to Manage Interest Rate and Currency Risks

This table presents the various types of financial instruments that the 382 sample firms (920 firm-year observations) use to manage interest rate and currency risks in the fiscal years 1992-1996. The data indicates that some firms use more than one type of financial instruments in their hedge portfolios. Interest rate options & others include caps, floors, collars, corridors, swaptions, and options on swap spreads. I report the fraction of firms that use particular derivatives by year.

Financial Instrument	1992	1993	1994	1995	1996
Interest Rate Derivatives					
Swaps	34.57%	49.46%	57.26%	62.20%	61.11%
Forwards & Futures	3.70%	1.63%	1.21%	1.91%	2.53%
Options & Others	7.41%	11.41%	15.73%	14.35%	16.67%
Currency Derivatives					
Swaps	22.22%	16.85%	19.76%	19.62%	15.66%
Forwards & Futures	75.31%	67.93%	65.32%	61.24%	59.09%
Options	13.58%	10.87%	16.53%	13.88%	12.63%
No. of Observations	81	184	248	209	198

estimate of the extent to which a firm uses linear and nonlinear derivatives in the composition of the hedge portfolio. This is important because a firm could demand linear and nonlinear hedging contracts simultaneously. For my second variable, I scale the total notional position of nonlinear derivatives by the total notional value of the hedge portfolio. I refer this measure to as the intensity of nonlinear usage. The intensity of nonlinear usage determines the component of nonlinear contracts in the hedge portfolio.

2.5 Univariate Results

Table 2.3 presents summary statistics for the variables that I use in the tests. The mean and median fractions of total assets hedged are 14.12% and 7.29%. Linear derivatives dominate nonlinear contracts in the composition of a typical hedge portfolio. On average, nonlinear derivatives account for less than 12% of the hedge portfolio. The average (median) debt ratio is 19.1% (15.6%) of firm value. The distribution of the coverage ratio is highly skewed. The average (median) coverage ratio is 81.5 (7.96) times. The median Z-score (3.2) is greater than 3.0, which indicates that the typical sample firm has a low probability of bankruptcy. There is a wide variation in firm value within the sample. Firm size ranges from $101.3 million to more than $106.3 billion. The ratio of the market value to the book value of total assets averages 1.35. The return on equity is less than 14% and appears to be slightly skewed. The firms in the sample typically do not have any tax loss carryforwards, or issue any convertible debts. The free cash flow in the median firm is more than 8% of firm value. The average (median) CEO has been in position for about 7.5 (5) years. The typical CEO is 56 years old.

Table 2.4 presents correlation coefficients for selected variables. I define these variables in Table 2.1. This table suggests that there is no strong correlation among the explanatory

Table 2.3
Descriptive Statistics of Firm Characteristics

The Fraction of Total Assets Hedged is defined as the total notional values of derivative contracts scaled by total assets. The Level of Nonlinear Hedging is the total notional amount of nonlinear derivatives scaled by the total notional amount of derivatives. Leverage is long-term debt scaled by firm size. I define Coverage Ratio as earnings before depreciation divided by interest. Z-score is a measure of bankruptcy. Firm Size is the market value of the firm. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Convertible Debt is convertible debt divided by firm size. Return on Equity is the average three-year return on equity prior to the decision year. Free Cash Flow is the ratio of free cash flow to firm size. CEO Tenure is the number of years since the CEO has been in position.

Variable	N	Mean	Median	Standard Deviation	Minimum	Maximum
Fraction of Total Assets Hedged	920	0.1412	0.0729	0.2494	0.0000	2.9533
Level of Nonlinear Hedging	920	0.1117	0.0000	0.2580	0.0000	1.0000
Leverage	920	0.1910	0.1563	0.1606	0.0000	0.7669
Coverage Ratio (times)	889	81.5876	7.96940	1,267	-572.60	27,160.8
Z-score	854	4.1137	3.2150	3.5356	-0.164	35.675
Firm Size ($US mil)	920	7,096.0698	2,616.6030	13,024.0909	101.3140	106,391.5320
Market-to-Book Assets	920	1.3525	1.0950	0.8619	0.1695	6.0903
Tax Loss Carryforwards	920	0.0213	0.0000	0.0818	0.0000	0.9743
Convertible Debt	920	0.0123	0.0000	0.0381	0.0000	0.5287
Return on Equity	920	0.1345	0.1229	0.2916	-0.9986	5.1032
Free Cash Flow	920	0.0960	0.0847	0.0586	-0.0675	0.3488
CEO Tenure	920	7.3978	5.0000	7.2169	0.0000	47.0000
CEO Age	584	56.0634	56.0000	6.6367	31.0000	82.0000

Table 2.4
Pearson Correlation Coefficients

This table presents correlation coefficients for variables of interest. The variables are defined in Table 2.1. ***, **, and * denote that the coefficient is significantly different from zero at 1%, 5%, and 10% level respectively.

Variable	Firm Size	Market-to-book	Leverage	Coverage Ratio	Z- score	Convertible Debt	Tax Loss Carryfor-wards	Free Cash Flows	Return on Equity	CEO Tenure	CEO Age
Firm Size	1.000	0.249***	0.116***	-0.055*	0.007	-0.136***	-0.102***	-0.002	0.075**	-0.048	0.131***
Market-to-book		1.000	0.495***	0.043	0.692***	-0.100***	-0.152***	-0.367***	0.257***	0.145***	-0.107***
Leverage			1.000	-0.071**	-0.494***	0.255***	0.154***	0.274***	0.181***	-0.093***	0.093***
Coverage Ratio				1.000	0.199***	-0.019	0.088***	-0.026	0.013	-0.011	-0.020
Z- score					1.000	-0.142***	-0.145***	-0.297***	0.139***	0.193***	-0.159***
Convertible Debt						1.000	0.088***	-0.020	-0.062*	0.002	0.051
Tax Loss Carryforwards							1.000	-0.038	-0.159***	-0.087***	0.008
Free Cash Flows								1.000	-0.051	-0.063*	-0.048
Return on Equity									1.000	0.040	-0.121***
CEO Tenure										1.000	0.267***
CEO Age											1.000

variables. Of all the variables, there is a relatively strong coefficient between the market-to-book ratio of total assets and Z-score. The coefficient is nearly 0.7. It is also interesting to note that the correlation coefficient between CEO age and CEO tenure are positively correlated but the correlation coefficient is less than 0.27.

Table 2.5 compares the means of firm characteristics by the level of nonlinear derivative usage. I classify a firm an extensive (minor) user of nonlinear vehicles if the total notional value of its nonlinear contracts account for more than (less than) 25% of its hedge portfolio. The results indicate that both minor nonlinear users and extensive nonlinear firms manage risks more extensively than firms that do not implement nonlinear strategies at all (p-values = 0.00). The finding is consistent with Adam's (2003) finding that gold mining firms that embrace risk management more extensively are more likely to face a complex hedging problem and thus undertake more nonlinear contracts.

The univariate results generally support my hypotheses. The results suggest that minor and extensive users of nonlinear instruments are larger than firms that do not implement a nonlinear strategy at all (p-values = 0.00 and 0.01, respectively). This finding supports the premise that large firms frequently have the resources to invest in sophisticated control systems and hire personnel who are capable of administering nonlinear portfolios. Consistent with the investment hypothesis, my results indicate that firms facing more investment opportunities are prone to use nonlinear derivatives (p-value = 0.01). I also find that extensive nonlinear users have a higher leverage level but a significantly lower coverage ratio than zero nonlinear firms.[3]

[3] Since the coverage ratio is highly skewed, I winsorize the sample at the 1% and 99% level and re-do the mean tests. In addition, I carry out a Wilcoxon Rank-Sum test. I find qualitatively similar results.

Table 2.5

Characteristics of US Corporate Firms by the Level of Nonlinear Derivative Usage, 1992 - 1996

This table presents characteristics of the sample firms by the degree of nonlinear derivative usage. I classify a firm an extensive (minor) user of nonlinear vehicles if the total notional value of its nonlinear contracts account for more than (less than) 25% of its hedge portfolio. I define the Fraction of Total Assets as the total notional position of all derivative contracts scaled by total assets. I define the other variables in Table 2.1. The sample size for Coverage Ratio is 666, 86, and 137 for zero nonlinear, minor nonlinear, and extensive nonlinear, respectively. The respective sample size for Z-score is 645, 84, and 125. For CEO Age, the respective sample size is 420, 64, and 100. I show variables whose p-values at the ten percent level or less in boldface type.

	Zero Nonlinear (N=691)	Minor Nonlinear (N=87)	Extensive Nonlinear (N=142)	P-Values Difference in Mean	
Variables	Mean	Mean	Mean	Minor Nonlinear Vs. Zero Nonlinear	Extensive Nonlinear Vs. Zero Nonlinear
Fraction of Total Assets Hedged	0.1096	0.2579	0.2241	**0.0001**	**<0.0001**
Level of Nonlinear Hedging	0.0000	0.1126	0.6545	**< 0.0001**	**< 0.0001**
Firm Size ($US mil)	5,510.8	15,538	9,638.3	**< 0.0001**	**0.0133**
Market-to-Book Assets	1.2907	1.5618	1.5251	**0.0117**	**0.0189**
Leverage	0.1857	0.1736	0.2280	0.5411	**0.0113**
Coverage Ratio	105.06	11.2290	11.648	0.1012	**0.1000**
Z-score	4.1056	4.2446	4.0680	0.6621	0.9155
Convertible Debt	0.0116	0.0126	0.0157	0.8235	0.1847
Tax Loss Carryforwards	0.0195	0.0281	0.0263	0.4355	0.4106
Free Cash Flows	0.0961	0.0914	0.0982	0.3988	0.7109
Return on Equity	0.1368	0.1226	0.1304	0.5311	0.7724
CEO Tenure	7.7844	6.0460	6.3451	**0.0071**	**0.0062**
CEO Age	55.83	57.125	56.350	0.1399	0.4912

The results support the underinvestment hypothesis that as the probability of financial distress increases, firms have greater incentives to hedge with nonlinear derivatives to mitigate the underinvestment problem but also benefit from upside potential for the shareholders. I do not observe any significant result on convertible debt. This finding lends no support to the risk-shifting hypothesis that firms use nonlinear derivative contracts at the expense of debtholders. In results that are not reported in the table, I find that firms that do not use nonlinear devices at all perform better in the past than do the minor users of nonlinear derivatives.[4] This result is consistent with the premise that managers with superior capabilities have the incentives to use linear securities to better communicate their skills to the labor market. As expected, CEOs with longer tenures are less likely to use nonlinear vehicles (p-value = 0.00).

2.6. Multivariate Analysis

2.6.1 Tobit Analysis

To investigate the determinants that affect the degree to which a firm uses linear and nonlinear derivatives, I estimate cross-sectional regressions using a Tobit model. This econometric model is appropriate because my dependent variable is censored at zero. I am interested in the level of linear and nonlinear hedging demanded. However, my measure only captures the actual level used because costs might prevent some firms from implementing either strategy. My dependent variable is censored at zero when the level demanded is transformed to the actual level used. I present the marginal effects defined as the partial derivative of the expected value of the dependent variable with

[4] The results from the Wilcoxon Rank-Sum test suggest that firms that do not adopt nonlinear contracts perform better in the past than do the minor users of nonlinear derivatives (p-value = 0.03). However, I do not find any significance when I winsorize the sample at the 1% and 99% level.

respect to the determinant. Similarly, Tobit analysis applies when I estimate the determinants of the extent of hedging.

Regressions 1 to 3 in Table 2.6 estimate the determinants of the extent of hedging, conditional on a firm hedging. Consistent with Froot, et al.'s (1993) prediction, I find that the extent of hedging increases with market-to-book assets (p-values = 0.09, 0.00, and 0.10, respectively). This relation suggests that hedging can reduce the underinvestment problem when access to external financing is costly. Leverage is positively related to the degree of hedging (significant at 10% in model 2). This finding supports Smith and Stulz's (1985) premise that risk management reduces the probability of incurring bankruptcy costs. The positive relation with return on equity is significant at the 5% level (model 2). This result is consistent with Breeden and Viswanathan's (1998) contention that managers who have superior abilities tend to hedge risks so that the market can draw more precise inference about their abilities. The relation with CEO age is negative and significant at the 5% level, consistent with the view that older CEOs are less likely to understand derivatives.

Table 2.7 reports Tobit regression results with the total notional value of nonlinear derivatives scaled by the book value of total assets as the dependent variable. I document a positive relation between firm size and the level of nonlinear hedging (significant at the 1% level). This evidence is consistent with the premise that larger firms have more resources to hire sophisticated employees who can manage more complex nonlinear derivatives. Confirming Adam's (2003) finding, I find that firms with greater investment opportunities undertake more nonlinear contracts to hedge their total

Table 2.6
Tobit Regression Results - Analysis of the Extent of Hedging

The table presents a Tobit analysis of the extent of hedging, conditional on a firm hedging. The dependent variable is the total notional amount of derivatives scaled by total assets. Coefficients represent marginal effects. Firm size is the log of the market value of the firm. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Leverage is long-term debt scaled by firm size. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. CEO Tenure is the number of years since the CEO has been in position. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	-0.0069 (0.24)	-0.0067 (0.12)	-0.0066 (0.26)
Market-to-Book Assets	**0.0196** **(0.09)**	**0.0236** **(0.00)**	**0.0191** **(0.10)**
Leverage	0.0705 (0.21)	**0.0734** **(0.09)**	0.0722 (0.20)
Convertible Debt	-0.0617 (0.76)	0.0153 (0.92)	-0.0670 (0.74)
Tax Loss Carryforwards	0.0800 (0.34)	0.0575 (0.43)	0.0824 (0.32)
Free Cash Flow	-0.1027 (0.50)	0.0603 (0.58)	-0.1024 (0.50)
Return on Equity	0.0329 (0.17)	**0.0410** **(0.04)**	0.0327 (0.18)
CEO Tenure	-0.0004 (0.70)	-0.0011 (0.16)	
CEO Age	**-0.0029** **(0.02)**		**-0.0031** **(0.01)**
Constant	**0.2616** **(0.00)**	0.0680 (0.13)	**0.2641** **(0.00)**
Year 1993 (0/1)	0.0018 (0.96)	0.0185 (0.43)	0.0018 (0.95)
Year 1994 (0/1)	0.0300 (0.40)	**0.0458** **(0.04)**	0.0299 (0.40)
Year 1995 (0/1)	0.0324 (0.37)	0.0374 (0.11)	0.0322 (0.37)
Year 1996 (0/1)	0.0577 (0.11)	**0.0543** **(0.02)**	0.0579 (0.10)
Number of Observations	584	920	584
Likelihood Ratio Index	0.1562	0.4475	0.1552

Table 2.7
Tobit Regression Results - Analysis of Nonlinear Derivative Usage (Asset Measure)

The dependent variable is the total notional amount of nonlinear derivatives scaled by total assets. Coefficients represent marginal effects. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Leverage is long-term debt scaled by firm size. Leverage Indicator is an indicator variable. The value of the indicator variable is set to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. CEO Tenure is the number of years since the CEO has been in position. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	**0.0314** **(0.00)**	**0.0190** **(0.00)**	**0.0343** **(0.00)**
Market-to-Book Assets	**0.0339** **(0.00)**	**0.0306** **(0.00)**	**0.0322** **(0.01)**
Leverage	0.0666 (0.39)	0.0368 (0.50)	0.0689 (0.37)
Leverage Indicator (0,1)	**0.0661** **(0.01)**	**0.0384** **(0.02)**	**0.0708** **(0.00)**
Convertible Debt	-0.1116 (0.67)	0.1247 (0.46)	-0.1511 (0.58)
Tax Loss Carryforwards	-0.0367 (0.70)	0.0354 (0.63)	-0.2242 (0.82)
Free Cash Flow	**0.3824** **(0.02)**	**0.2593** **(0.02)**	**0.3843** **(0.02)**
Return on Equity	-0.0248 (0.53)	-0.0260 (0.39)	-0.2711 (0.50)
CEO Tenure	**-0.0028** **(0.06)**	**-0.0028** **(0.00)**	
CEO Age	0.0013 (0.36)		0.0005 (0.69)
Constant	**-0.6433** **(0.00)**	**-0.3910** **(0.00)**	**-0.6400** **(0.00)**
Year 1993 (0/1)	0.0484 (0.33)	0.0209 (0.44)	0.0473 (0.34)
Year 1994 (0/1)	**0.0918** **(0.05)**	**0.0559** **(0.03)**	**0.0889** **(0.06)**
Year 1995 (0/1)	**0.0956** **(0.04)**	**0.0619** **(0.02)**	**0.0917** **(0.05)**
Year 1996 (0/1)	**0.0791** **(0.09)**	**0.0573** **(0.03)**	**0.0769** **(0.10)**
Number of Observations	584	920	584
Likelihood Ratio Index	0.0751	0.0539	0.0703

Table 2.8

Tobit Regression Results - Analysis of Nonlinear Derivative Usage (Size Measure)

The dependent variable is the total notional amount of nonlinear derivatives scaled by firm size. Coefficients represent marginal effects. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Leverage is long-term debt scaled by firm size. The value of the indicator variable is set to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	**0.0081**	**0.0061**	**0.0087**
	(0.00)	**(0.00)**	**(0.00)**
Market-to-Book Assets	**0.0071**	**0.0107**	**0.0066**
	(0.06)	**(0.00)**	**(0.07)**
Leverage	**0.0472**	0.0354	**0.0477**
	(0.03)	(0.12)	**(0.03)**
Leverage Indicator (0,1)	0.0108	0.0070	0.0117
	(0.16)	(0.33)	(0.13)
Convertible Debt	-0.0172	0.0616	-0.0244
	(0.81)	(0.37)	(0.74)
Tax Loss Carryforwards	-0.0059	0.0199	-0.0028
	(0.83)	(0.51)	(0.91)
Free Cash Flow	0.0460	**0.1061**	0.0461
	(0.36)	**(0.02)**	(0.36)
Return on Equity	-0.0056	-0.0083	-0.0060
	(0.59)	(0.48)	(0.57)
CEO Tenure	-0.0005	**-0.0012**	
	(0.17)	**(0.00)**	
CEO Age	0.0000		-0.0001
	(0.92)		(0.75)
Constant	**-0.1474**	**-0.1428**	**-0.1458**
	(0.00)	**(0.00)**	**(0.00)**
Year 1993 (0/1)	0.0123	0.0080	0.0121
	(0.39)	(0.47)	(0.39)
Year 1994 (0/1)	**0.0269**	**0.0269**	**0.0263**
	(0.04)	**(0.01)**	**(0.05)**
Year 1995 (0/1)	**0.0236**	**0.0235**	**0.0228**
	(0.08)	**(0.03)**	**(0.09)**
Year 1996 (0/1)	0.0215	**0.0222**	0.0211
	(0.11)	**(0.04)**	(0.12)
Number of Observations	584	920	584
Likelihood Ratio Index	0.1306	0.0747	0.1248

assets (significant at the 1% level). This evidence supports the premise that higher growth firms adopt more nonlinear derivatives to maintain a profit potential. I find that firms that use more debt than their industry norm also use more nonlinear derivatives (significant at 1%, 5%, and 1% respectively). I do not find any relation with convertible debt. Taken together, these relations support the underinvestment hypothesis. As expected, I also find that the extent of nonlinear hedging increases in the level of free cash flow (significant at 5%). My results also suggest that the CEOs who have held office longer use fewer nonlinear derivatives (significant at the 10% and 1% levels respectively). One interpretation of this finding is that these CEOs are closer to retirement and do not have the incentives to invest effort to learn about nonlinear devices. Table 2.8 provides qualitatively similar results when I define the dependent variable as the total notional amount of nonlinear instruments scaled by firm size.

I reestimate Tobit regressions with the total notional value of linear instruments scaled by the book value of total assets as the dependent variable. Table 2.9 identifies the determinants that affect the extent to which a firm hedges total assets with linear devices. The negative relation for leverage is significant at the 10% level in both model 1 and model 3, and the positive relation for free cash flow is significant at the 5% level in both models. I inspect Table 2.7 and Table 2.9 jointly and provide two interesting findings. First, firms with more risky debt tend to rely less on linear instruments. This evidence is consistent with the notion that firms with a higher probability of financial distress seek to increase nonlinear derivative usage to mitigate the underinvestment problem. Second, the uses of both linear and nonlinear derivatives increase with the level of free cash flow.

Table 2.9

Tobit Regression Results - Analysis of Linear Derivative Usage (Asset Measure)

The dependent variable is the notional amount of linear derivatives scaled by total assets. Coefficients represent marginal effects. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Leverage is long-term debt scaled by firm size. Leverage Indicator is an indicator variable. The value of the indicator variable is set to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. CEO Tenure is the number of years since the CEO has been in position. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	-0.0030 (0.89)	-0.0127 (0.55)	-0.0005 (0.98)
Market-to-Book Assets	0.0061 (0.89)	-0.0330 (0.42)	0.0035 (0.93)
Leverage	**-0.5120** **(0.06)**	-0.3239 (0.21)	**-0.5086** **(0.06)**
Leverage Indicator (0,1)	0.1208 (0.16)	0.0008 (0.99)	0.1249 (0.15)
Convertible Debt	-0.0099 (0.99)	-0.0382 (0.96)	-0.0473 (0.95)
Tax Loss Carryforwards	-0.0016 (0.99)	-0.0604 (0.86)	0.0136 (0.96)
Free Cash Flow	**1.3176** **(0.02)**	0.5109 (0.33)	**1.3179** **(0.02)**
Return on Equity	0.0262 (0.77)	0.0426 (0.66)	0.0243 (0.79)
CEO Tenure	-0.0028 (0.51)	-0.0000 (0.99)	
CEO Age	0.0036 (0.46)		0.0026 (0.57)
Constant	-0.2048 (0.53)	0.1972 (0.36)	-0.1877 (0.57)
Year 1993 (0/1)	0.0027 (0.98)	-0.0022 (0.98)	0.0029 (0.98)
Year 1994 (0/1)	0.0103 (0.93)	0.0859 (0.42)	0.0093 (0.94)
Year 1995 (0/1)	0.0514 (0.70)	0.0245 (0.82)	0.0501 (0.71)
Year 1996 (0/1)	0.1252 (0.35)	0.0957 (0.39)	0.1265 (0.34)
Number of Observations	584	920	584
Likelihood Ratio Index	0.0064	0.0019	0.0062

Table 2.10
Tobit Regression Results - Analysis of Linear Derivative Usage (Size Measure)

The dependent variable is the total notional amount of linear derivatives scaled by firm size. Coefficients represent marginal effects. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Leverage is long-term debt scaled by firm size. Leverage Indicator is an indicator variable. The value of the indicator variable is set to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. CEO Tenure is the number of years since the CEO has been in position. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	-0.0067 (0.13)	-0.0049 (0.16)	-0.0068 (0.12)
Market-to-Book Assets	**-0.0202** **(0.02)**	**-0.0191** **(0.00)**	**-0.0201** **(0.02)**
Leverage	0.0213 (0.69)	**0.0713** **(0.09)**	0.0211 (0.69)
Leverage Indicator (0,1)	0.0040 (0.81)	-0.0036 (0.78)	0.0038 (0.82)
Convertible Debt	-0.0800 (0.60)	0.0154 (0.90)	-0.0780 (0.61)
Tax Loss Carryforwards	0.0810 (0.19)	0.0416 (0.47)	0.0802 (0.20)
Free Cash Flow	-0.0882 (0.44)	-0.0579 (0.50)	-0.0882 (0.44)
Return on Equity	0.0193 (0.28)	**0.0272** **(0.09)**	0.0194 (0.28)
CEO Tenure	0.0001 (0.86)	-0.0001 (0.76)	
CEO Age	**-0.0020** **(0.03)**		**-0.0019** **(0.03)**
Constant	**0.2497** **(0.00)**	**0.1080** **(0.00)**	**0.2488** **(0.00)**
Year 1993 (0/1)	-0.0008 (0.97)	0.0094 (0.61)	-0.0008 (0.97)
Year 1994 (0/1)	0.0039 (0.88)	0.0189 (0.29)	0.0039 (0.88)
Year 1995 (0/1)	0.0155 (0.56)	0.0168 (0.36)	0.0155 (0.56)
Year 1996 (0/1)	0.0364 (0.17)	**0.0331** **(0.07)**	0.0363 (0.17)
Number of Observations	584	920	584
Likelihood Ratio Index	-0.2120	-0.1472	-0.2118

This finding supports the hypothesis that financial slack allows firms to use derivatives without incurring a higher cost of external financing.

When the dependent variable is the total notional amount of linear securities scaled by firm size, the results are somewhat different. The results in Table 2.10 indicate that linear usage decreases with market-to-book assets (significant at the 5%, 1%, and 5% levels respectively), but increases with leverage and return on equity (significant at the 10% level in model 2). The positive coefficient on market-to-book assets is consistent with the argument that firms with greater investment opportunities are more likely to use nonlinear contracts to preserve the upside potential. In contrast, the positive signs on leverage and returns on equity do not support my hypotheses. A possible explanation for these results is that firms use derivatives to hedge total assets rather than the market value of total assets. This explanation suggests that the total notional value of linear securities scaled by total assets gauges the degree of linear hedging more accurately.

Regressions 1 to 3 in Table 2.11 provide some implications on the components of linear and nonlinear instruments in the hedge portfolio. I use the intensity of nonlinear usage as the dependent variable. Confirming my earlier findings from Table 2.7, I document positive relations between the component of nonlinear instruments in the hedge portfolio and firm size, market-to-book assets, and leverage indicator. The relations for firm size and market-to-book assets are significant at the 1% level, and the relation with the industry-adjusted-leverage indicator variable is significant at the 10%, 10%, and 5% levels, respectively. Also supporting my earlier results, I observe a negative relation between CEO tenure and the percentage of nonlinear instruments in the hedge portfolio

Table 2.11
Tobit Regression Results - Analysis of Intensity of Nonlinear Usage

The dependent variable is the total notional amount of nonlinear derivatives scaled by the total notional value of the hedge portfolio. Coefficients represent marginal effects. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Leverage is long-term debt scaled by firm size. The value of the indicator variable is set to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. CEO Tenure is the number of years since the CEO has been in position. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	**0.0296** **(0.00)**	**0.0190** **(0.00)**	**0.0320** **(0.00)**
Market-to-Book Assets	**0.0405** **(0.00)**	**0.0454** **(0.00)**	**0.0389** **(0.00)**
Leverage	**0.2239** **(0.00)**	**0.1545** **(0.01)**	**0.2263** **(0.00)**
Leverage Indicator	**0.0469** **(0.06)**	**0.0373** **(0.06)**	**0.0506** **(0.04)**
Convertible Debt	-0.0784 (0.73)	0.1934 (0.30)	-0.1075 (0.64)
Tax Loss Carryforwards	-0.0379 (0.68)	0.0615 (0.47)	-0.0251 (0.78)
Free Cash Flow	0.1596 (0.32)	0.1520 (0.25)	0.1606 (0.32)
Return on Equity	-0.0295 (0.41)	-0.0378 (0.29)	-0.0315 (0.38)
CEO Tenure	**-0.0024** **(0.07)**	**-0.0034** **(0.00)**	
CEO Age	-0.0000 (0.94)		-0.0008 (0.54)
Constant	**-0.5185** **(0.00)**	**-0.4177** **(0.00)**	**-0.5131** **(0.00)**
Year 1993 (0/1)	0.0575 (0.21)	0.0260 (0.40)	0.0568 (0.21)
Year 1994 (0/1)	**0.0990** **(0.02)**	**0.0646** **(0.02)**	**0.0968** **(0.02)**
Year 1995 (0/1)	**0.0889** **(0.04)**	**0.0644** **(0.03)**	**0.0858** **(0.05)**
Year 1996 (0/1)	**0.0763** **(0.08)**	**0.0623** **(0.04)**	**0.0748** **(0.09)**
Number of Observations	584	920	584
Likelihood Ratio Index	0.0943	0.0593	0.0899

(significant at the 10% and 1% levels respectively). In general, the results in Table 2.11 suggest that larger firms, firms with greater investment opportunities, and firms that have more risky debts than their industry norm use more nonlinear derivatives in their hedge portfolios. CEOs who have held office longer implement nonlinear strategies less extensively.

Unlike the results in Table 2.7, those in Table 2.11 show that the variables pertaining to leverage are statistically significant at the 1% level but those related to free cash flows are not significant. The differences in these two results suggest that a test using the extent of nonlinear hedging in total assets might not identify the determinants that affect the component of nonlinear contracts in the hedge portfolio.

2.6.2 Sensitivity Analysis

In this section I explore the robustness of my results to alternative measures of leverage ratio and to alternative samples. I find that the general results in Table 2.11 are not sensitive to alternative measures of leverage-related variables or to the subsamples of major and minor hedgers. I also document that the relation with leverage-related factors is not restricted to the subsample of interest rate hedgers.

I use alternative measures of leverage ratio to inspect the robustness of the results in Table 2.11. In particular, I use coverage ratio and Z-score to further examine the capital structure hypothesis, and find similar results. Table 2.12 shows that firms with lower coverage ratios are inclined to manage risk with nonlinear derivatives (significant at the 1% level). The results in Table 2.13 report that the extent of nonlinear derivative usage is negatively associated with the firm's Z-score (significant at 5% only in model 2)

Table 2.12
Tobit Results - Analysis of Intensity of Nonlinear Usage (Coverage Ratio)

The dependent variable is the total notional value of nonlinear derivatives scaled by the total notional value of the hedge portfolio. Coefficients represent marginal effects. Firm size is the log of the market value of the firm. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Coverage Ratio is defined as earnings before depreciation scaled by interest. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. CEO Tenure is the number of years since the CEO has been in position. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	**0.0200** **(0.00)**	**0.0099** **(0.02)**	**0.0213** **(0.00)**
Market-to-Book Assets	**0.0218** **(0.04)**	**0.0295** **(0.00)**	**0.0204** **(0.05)**
Coverage Ratio	**-0.0004** **(0.01)**	**-0.0004** **(0.00)**	**-0.0004** **(0.00)**
Convertible Debt	0.1237 (0.52)	0.2223 (0.11)	0.1025 (0.59)
Tax Loss Carryforwards	0.0031 (0.96)	0.0601 (0.34)	0.0142 (0.85)
Free Cash Flow	0.1608 (0.26)	0.1479 (0.14)	0.1596 (0.26)
Return on Equity	-0.0512 (0.24)	-0.0438 (0.16)	-0.0542 (0.22)
CEO Tenure	**-0.0020** **(0.09)**	**-0.0022** **(0.01)**	
CEO Age	-0.0000 (0.98)		-0.0006 (0.59)
Constant	**-0.3540** **(0.00)**	**-0.2353** **(0.00)**	**-0.3404** **(0.00)**
Year 1993 (0/1)	**0.0709** **(0.09)**	0.0247 (0.29)	**0.0700** **(0.09)**
Year 1994 (0/1)	**0.1082** **(0.00)**	**0.0526** **(0.02)**	**0.1061** **(0.01)**
Year 1995 (0/1)	**0.1060** **(0.01)**	**0.0563** **(0.01)**	**0.1034** **(0.01)**
Year 1996 (0/1)	**0.0956** **(0.02)**	**0.0527** **(0.02)**	**0.0944** **(0.02)**
Number of Observations	568	889	568
Likelihood Ratio Index	0.0597	0.0494	0.0555

Table 2.13

Tobit Results - Analysis of Intensity of Nonlinear Usage (Z-score Measure)

The dependent variable is the total notional value of nonlinear derivatives scaled by the total notional value of the hedge portfolio. Coefficients represent marginal effects. Firm size is the log of the market value of the firm. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Z-score is a measure of bankruptcy. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. CEO Tenure is the number of years since the CEO has been in position. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	**0.0211** **(0.00)**	**0.0126** **(0.02)**	**0.0231** **(0.00)**
Market-to-Book Assets	**0.0391** **(0.00)**	**0.0515** **(0.00)**	**0.0392** **(0.00)**
Z-score	-0.0035 (0.27)	**-0.0063** **(0.04)**	-0.0044 (0.17)
Convertible Debt	0.2444 (0.26)	**0.3398** **(0.06)**	0.2118 (0.34)
Tax Loss Carryforwards	-0.0366 (0.72)	0.0596 (0.52)	-0.0225 (0.83)
Free Cash Flow	**0.4702** **(0.00)**	**0.3904** **(0.00)**	**0.4706** **(0.00)**
Return on Equity	-0.0450 (0.31)	-0.0510 (0.20)	-0.0501 (0.28)
CEO Tenure	**-0.0030** **(0.02)**	**-0.0037** **(0.00)**	
CEO Age	0.0005 (0.69)		-0.0003 (0.82)
Constant	**-0.4548** **(0.00)**	**-0.3200** **(0.00)**	**-0.4403** **(0.00)**
Year 1993 (0/1)	**0.0808** **(0.08)**	0.0309 (0.33)	**0.0812** **(0.08)**
Year 1994 (0/1)	**0.1126** **(0.01)**	**0.0575** **(0.06)**	**0.1117** **(0.01)**
Year 1995 (0/1)	**0.1072** **(0.01)**	**0.0623** **(0.04)**	**0.1056** **(0.02)**
Year 1996 (0/1)	**0.0965** **(0.03)**	**0.0575** **(0.06)**	**0.0977** **(0.03)**
Number of Observations	547	854	547
Likelihood Ratio Index	0.0687	0.0493	0.0610

but positively related to convertible debt (significant at the 10% level in specification 2). Supporting the underinvestment hypothesis, I find that there is a positive relation between the intensity of nonlinear usage and the probability of financial distress. The positive relation with convertible debt, however, is not consistent with the risk-shifting hypothesis. Table 2.13 also presents evidence that firms carrying more free cash flow incorporate more nonlinear instruments in their hedge portfolio (significant at the 1% level). This evidence is consistent with the notion that firms will use more nonlinear devices as the budget constraint is lessened.

To address the concern that firms engaging in extensive risk management might differ from those embracing moderate levels of risk management, I reestimate cross-sectional regressions using the tobit for the two subsamples: major and minor hedgers. I classify a firm as a major hedger if the fraction of its total assets hedged exceeds the sample median (i.e. 0.07) and a minor hedger otherwise. I document that the results are qualitatively similar when I consider each subsample. I also find similar results when I winsorize the sample at the ninety-ninth percentile and first percentile, respectively, of the fraction of total assets hedged.

All the specifications in Table 2.14 use a Tobit model to estimate the determinants of the extent to which a major hedger uses nonlinear instruments. I use the intensity of nonlinear usage as the dependent variable. I examine Table 2.11 and Table 2.14 jointly and find that the results from the sample of major hedgers are comparable to those from the full sample. In particular, the extent of nonlinear hedging is positively related to firm size, market-to-book assets, and leverage (model 1 and 3), but is negatively related to

Table 2.14
Tobit Regression Results - Analysis of Hedging Strategies, among Major Hedgers

The firm is considered a major hedger if the fraction of its total assets hedged exceeds the median (0.07) of the 382 sample firms. The dependent variable is the total notional value of nonlinear derivatives scaled by the total notional value of the hedge portfolio. Coefficients represent marginal effects. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Leverage is long-term debt scaled by firm size. The value of the indicator variable is set to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. CEO Tenure is the number of years since the CEO has been in position. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	**0.0310** **(0.00)**	**0.0210** **(0.01)**	**0.0347** **(0.00)**
Market-to-Book Assets	**0.0507** **(0.00)**	**0.0482** **(0.00)**	**0.0487** **(0.01)**
Leverage	**0.2302** **(0.04)**	0.1576 (0.12)	**0.2204** **(0.05)**
Leverage Indicator (0,1)	0.0146 (0.73)	0.0192 (0.57)	0.0204 (0.63)
Convertible Debt	0.2274 (0.59)	0.5107 (0.14)	0.2243 (0.59)
Tax Loss Carryforwards	-0.0654 (0.70)	0.0894 (0.55)	-0.0479 (0.78)
Free Cash Flow	**0.6994** **(0.01)**	**0.3715** **(0.09)**	**0.7388** **(0.00)**
Return on Equity	-0.0331 (0.46)	-0.0494 (0.29)	-0.0344 (0.44)
CEO Tenure	-0.0037 (0.13)	**-0.0050** **(0.00)**	
CEO Age	0.0014 (0.52)		0.0007 (0.73)
Constant	**-0.6298** **(0.00)**	**-0.4145** **(0.00)**	**-0.6382** **(0.00)**
Year 1993 (0/1)	0.0764 (0.31)	0.0331 (0.52)	0.0711 (0.34)
Year 1994 (0/1)	0.1157 (0.11)	**0.0832** **(0.09)**	0.1053 (0.14)
Year 1995 (0/1)	0.0826 (0.26)	0.0627 (0.21)	0.0702 (0.33)
Year 1996 (0/1)	0.0701 (0.33)	0.0630 (0.21)	0.0597 (0.41)
Number of Observations	299	460	299
Likelihood Ratio Index	0.0926	0.0555	0.0871

Table 2.15

Tobit Regression Results - Analysis of Hedging Strategies, among Minor Hedgers

The firm is considered a minor hedger if the fraction of its total assets hedged is less than the median (0.07) of the 382 sample firms. The dependent variable is the total notional value of nonlinear derivatives scaled by the notional amount of the hedge portfolio. Coefficients represent marginal effects. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Leverage is long-term debt scaled by firm size. The value of the indicator variable is set to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. CEO Tenure is the number of years since the CEO has been in position. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	**0.0227** **(0.00)**	0.0102 (0.14)	**0.0224** **(0.00)**
Market-to-Book Assets	0.0114 (0.46)	**0.0281** **(0.04)**	0.0122 (0.42)
Leverage	**0.1596** **(0.08)**	**0.1387** **(0.08)**	**0.1590** **(0.07)**
Leverage Indicator (0,1)	0.0427 (0.11)	0.0364 (0.11)	0.0423 (0.11)
Convertible Debt	-0.2720 (0.34)	-0.1281 (0.55)	-0.2588 (0.34)
Tax Loss Carryforwards	-0.0577 (0.60)	0.0338 (0.73)	-0.0586 (0.60)
Free Cash Flow	-0.1336 (0.46)	-0.0172 (0.91)	-0.1300 (0.47)
Return on Equity	-0.0595 (0.48)	-0.0437 (0.51)	-0.0575 (0.49)
CEO Tenure	0.0004 (0.77)	-0.0006 (0.65)	
CEO Age	-0.0008 (0.63)		-0.0006 (0.68)
Constant	**-0.3307** **(0.00)**	**-0.3346** **(0.00)**	**-0.3362** **(0.00)**
Year 1993 (0/1)	0.0086 (0.86)	-0.0016 (0.96)	0.0086 (0.86)
Year 1994 (0/1)	0.0592 (0.20)	0.0204 (0.54)	0.0593 (0.20)
Year 1995 (0/1)	0.0568 (0.23)	0.0336 (0.33)	0.0570 (0.23)
Year 1996 (0/1)	0.0527 (0.26)	0.0269 (0.44)	0.0523 (0.26)
Number of Observations	285	460	285
Likelihood Ratio Index	0.1019	0.0623	0.1016

CEO tenure (model 2). The relations for firm size, market-to-book assets, and CEOtenure are significant at the 1% level, and the relation with leverage is significant at the 5% level.

However, the results on the subsample of major hedgers do not suggest that a firm whose leverage is above its industry average uses more nonlinear instruments. In addition, the results show a strong and positive relation between the extent to which a major hedger uses nonlinear contracts and free cash flow (significant at the 1%, 10%, and 1% levels, respectively). This evidence supports the prediction that firms with more financial slack are less likely to resort to external financing and thus find it more cost effective to fund the premiums on nonlinear devices.

Table 2.15 presents Tobit regression results for minor hedgers. The signs for the coefficients in the data are similar to those when I consider the subsample of major hedgers. The results from minor hedgers suggest that the intensity of nonlinear usage increases with firm size (significant at 1% in model 1 and 3), market-to-book assets (significant at 5% in model 2), and leverage (significant at 10%). Nevertheless, the magnitudes of the coefficients and the levels, and the number of significances for minor hedgers are generally smaller than those for major hedgers. For example, for major hedgers, the coefficients on market-to-book assets range from 0.04 to 0.05 and are significant at the 1% level. For minor hedgers, the coefficient of 0.02 on the same determinant is only significant in model 2 at the 5% percent level.

There could be a possibility that the interest rate derivatives drive any relation with leverage because the firm that has a higher leverage is more likely to undertake

Table 2.16
Tobit Regression Results - Interest Rate Derivative Usage

The dependent variable is the total notional value of interest rate nonlinear derivatives scaled by the total notional value of the interest rate derivatives. Coefficients represent marginal effects. Firm size is the log of the market value of the firm. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Leverage is long-term debt scaled by firm size. The value of the indicator variable is set to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	0.0071 (0.51)	-0.0073 (0.44)	0.0106 (0.34)
Market-to-Book Assets	**0.0424** **(0.07)**	**0.0656** **(0.00)**	**0.0387** **(0.10)**
Leverage	**0.3209** **(0.00)**	**0.1781** **(0.07)**	**0.3203** **(0.00)**
Leverage Indicator	0.0432 (0.28)	0.0426 (0.20)	0.0472 (0.24)
Convertible Debt	-0.4756 (0.21)	-0.3342 (0.32)	-0.5226 (0.18)
Tax Loss Carryforwards	-0.0696 (0.60)	-0.0049 (0.97)	-0.0463 (0.73)
Free Cash Flow	0.0859 (0.71)	0.1657 (0.42)	0.0992 (0.68)
Return on Equity	-0.0255 (0.57)	-0.0612 (0.25)	-0.0288 (0.53)
CEO Tenure	**-0.0045** **(0.06)**	**-0.0061** **(0.00)**	
CEO Age	0.0001 (0.94)		-0.0011 (0.60)
Constant	**-0.4728** **(0.01)**	**-0.2527** **(0.01)**	**-0.4527** **(0.01)**
Year 1993 (0/1)	0.1353 (0.21)	0.0196 (0.75)	0.1352 (0.21)
Year 1994 (0/1)	0.1599 (0.13)	0.0515 (0.39)	0.1564 (0.14)
Year 1995 (0/1)	0.1353 (0.20)	0.0337 (0.58)	0.1298 (0.22)
Year 1996 (0/1)	0.1214 (0.25)	0.0459 (0.45)	0.1193 (0.26)
Number of Observations	378	572	378
Likelihood Ratio Index	0.1224	0.0923	0.1153

Table 2.17
Tobit Regression Results - Currency Derivative Usage

The dependent variable is the total notional value of currency nonlinear derivatives scaled by the total notional amount of the currency derivatives. Coefficients represent marginal effects. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Leverage is long-term debt scaled by firm size. The value of the indicator variable is set to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	**0.0259**	**0.0225**	**0.0268**
	(0.00)	**(0.00)**	**(0.00)**
Market-to-Book Assets	**0.0264**	**0.0201**	**0.0260**
	(0.00)	**(0.01)**	**(0.00)**
Leverage	-0.0663	-0.0537	-0.0626
	(0.40)	(0.42)	(0.42)
Leverage Indicator	**0.0402**	0.0229	**0.0415**
	(0.05)	(0.20)	**(0.05)**
Convertible Debt	0.2721	**0.7041**	0.2347
	(0.25)	**(0.00)**	(0.31)
Tax Loss Carryforwards	0.0704	0.1188	0.0747
	(0.41)	(0.14)	(0.38)
Free Cash Flow	0.2185	0.1045	0.2152
	(0.16)	(0.41)	(0.17)
Return on Equity	0.0011	0.0281	-0.0002
	(0.97)	(0.49)	(0.99)
CEO Tenure	-0.0008	-0.0013	
	(0.43)	(0.13)	
CEO Age	0.0018		0.0016
	(0.11)		(0.14)
Constant	**-0.4775**	**-0.3490**	**-0.4775**
	(0.00)	**(0.00)**	**(0.00)**
Year 1993 (0/1)	-0.0030	0.0023	-0.0036
	(0.92)	(0.92)	(0.90)
Year 1994 (0/1)	0.0352	**0.0423**	0.0337
	(0.23)	**(0.06)**	(0.25)
Year 1995 (0/1)	0.0250	0.0355	0.0233
	(0.40)	(0.13)	(0.43)
Year 1996 (0/1)	0.0076	0.0207	0.0062
	(0.79)	(0.38)	(0.83)
Number of Observations	396	637	396
Likelihood Ratio Index	0.2285	0.1703	0.2271

nonlinear devices to benefit from favorable changes in interest rates. To investigate the robustness of my results to the potential impact of debt ratio on the interest rate derivatives, I partition the full sample into two subsamples: interest rate and currency hedgers. The results in Table 2.16 indicate that the positive relation between interest rate nonlinear usage and leverage is significant at the 1%, 10%, and 1% levels, respectively. Table 2.17 presents evidence that the use of currency nonlinear derivatives increases with industry-adjusted leverage (significant at 5% level in model 1 and 3). Thus, the relation between nonlinear derivative usage and leverage is not restricted to the subsample of interest rate hedgers.

2.6.3 McDonald and Moffit's Decomposition

McDonald and Moffit (1980) show that I can use the estimates from a Tobit analysis to determine both the changes in the probability that the dependent variable will be above the limit and the changes in the value of the dependent variable if the dependent variable is already above the limit. I apply McDonald and Moffit's decomposition to further analyze my Tobit results. I decompose the change in any derivative usage into two components: (1) the marginal change in the positive expenditures on the derivative, and (2) the marginal change in the probability that the firm will use the derivative at all.

Table 2.18 shows that 28.08% of the firm-year observations in model 1 of Table 2.7 have nonzero expenditures on nonlinear derivatives. Evaluating my data at this point, I find that a correspondingly lower percentage (23.02%) of any total changes in nonlinear derivative usage arise from the marginal changes in the positive expenditures on nonlinear instruments. However, 76.98% of the incremental usage in nonlinear devices

Table 2.18
Decomposition of Tobit Effects

The table illustrates the application of McDonald and Moffitt's (1980) decomposition to the Tobit analyses in this chapter. The fractions of mean total response due to response above limit are reported. The fractions of sample above limit are in parentheses.

		Fraction of Mean Total Response Due to Response above Limit (%)		
Tobit Analysis	Dependent Variable	Model 1	Model 2	Model 3
All Hedgers (Table 2.7)	The notional value of nonlinear derivatives scaled by the firm's total asset	23.02 (28.08)	22.02 (24.89)	23.09 (28.08)
All Hedgers (Table 2.8)	The notional value of nonlinear derivatives scaled by firm size	27.56 (28.08)	25.98 (24.89)	27.61 (28.08)
All Hedgers (Table 2.9)	The notional value of linear derivatives divided by the firm's total asset	49.78 (96.57)	40.57 (95.97)	49.78 (96.57)
All Hedgers (Table 2.10)	The notional value of linear derivatives scaled by firm size	54.51 (96.57)	54.52 (95.97)	54.51 (96.57)
All Hedgers (Table 2.11)	The notional value of nonlinear derivatives scaled by the total notional amount of derivatives	24.52 (28.08)	23.45 (24.89)	24.59 (28.08)
Major Hedgers (Table 2.14)	The notional value of nonlinear derivatives scaled by the total notional amount of derivatives	30.48 (40.46)	28.69 (36.30)	30.74 (40.46)
Minor Hedgers (Table 2.15)	The notional value of nonlinear derivatives scaled by the total notional amount of derivatives	18.37 (15.08)	18.00 (13.47)	18.37 (15.08)

results from the changes in the probability of using nonlinear derivatives at all. In model 2 of Table 2.7, 24.89% of the observations undertake nonlinear derivative. Most of any changes (77.98%) in nonlinear derivative usage take the form of the changes in the probability of using nonlinear instruments at all. In addition, most of the changes in the position of nonlinear derivatives in model 3 are from the changes in the probability of adopting nonlinear devices at all (76.91%).

Table 2.18 also indicates that most of the total changes in any derivative usage in Tables 2.8, 2.9, 2.11, 2.14 and 2.15 result from the changes in the probability of using the derivative at all. Nearly 75% of the changes in nonlinear usages in Table 2.8 are from the changes in the probability that the firm will engage in nonlinear derivatives at all. In Table 2.9, nearly 51 % to 60% of the total changes in linear hedging are from the marginal changes in the likelihood that the firm will use linear contracts at all. More than 75% of the changes in Table 2.11 come from the changes in the probability that a firm will adopt nonlinear vehicles. In addition, most of the changes in Table 2.14 (70%) and Table 2.15 (80%) take the form of the changes in the likelihood of using nonlinear mechanism. However, less than 50% of the total changes in the degree of linear hedging in Table 2.10 arise from the changes in the probability of using linear securities at all.

2.6.4 Probit Model Results

As I discussed above, most of the total changes in any derivative usage result from the changes in the probability of using the derivative at all. In order to shed light on the marginal change in the likelihood that a firm will use any particular derivative, I use (ordered) Probit model. Table 2.19 presents the multivariate results of ordered Probit

Table 2.19
Ordered Probit Regression Results - Analysis of the Derivative Users

The dependent variable is coded zero if the firm uses linear derivative instruments only. It is one if the firm uses both linear and nonlinear derivatives. It is coded two if the firm uses only nonlinear devices. Firm size is the log of the market value of the firm. Market-to-Book Assets is the ratio of the market value to total assets. Leverage is long-term debt scaled by firm size. The value of the indicator variable is set to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. CEO Tenure is the number of years since the CEO has been in position. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	**0.2378** **(0.00)**	**0.1445** **(0.00)**	**0.2510** **(0.00)**
Market-to-Book Assets	**0.2681** **(0.00)**	**0.2910** **(0.00)**	**0.2545** **(0.00)**
Leverage	**1.2878** **(0.00)**	**0.8766** **(0.02)**	**1.2892** **(0.00)**
Leverage Indicator (0/1)	**0.3593** **(0.02)**	**0.2623** **(0.04)**	**0.3800** **(0.01)**
Convertible Debt	-0.6932 (0.68)	1.0106 (0.39)	-0.8854 (0.60)
Tax Loss Carryforwards	-0.1956 (0.78)	0.3645 (0.58)	-0.1105 (0.87)
Free Cash Flow	1.0746 (0.27)	0.8706 (0.28)	1.0750 (0.27)
Return on Equity	-0.2029 (0.57)	-0.2530 (0.40)	-0.2137 (0.56)
CEO Tenure	-0.0159 (0.11)	**-0.0216** **(0.00)**	
CEO Age	-0.0014 (0.89)		-0.0058 (0.52)
Constant	**-3.7221** **(0.00)**	**-2.8045** **(0.00)**	**-3.6547** **(0.00)**
Year 1993 (0/1)	0.4118 (0.21)	0.1929 (0.35)	0.4039 (0.20)
Year 1994 (0/1)	**0.7033** **(0.02)**	**0.4127** **(0.04)**	**0.6844** **(0.02)**
Year 1995 (0/1)	**0.5982** **(0.06)**	**0.4154** **(0.04)**	**0.5746** **(0.06)**
Year 1996 (0/1)	**0.5253** **(0.10)**	**0.3990** **(0.05)**	**0.5125** **(0.10)**
Number of Observations	584	920	584
Likelihood Ratio Index	0.0980	0.0581	0.0940

regressions of the choice of hedging strategies. The dependent variable is zero, one, or two, which corresponds to the extent of nonlinear hedging. I code the dependent variable zero if the firm uses only linear derivatives. The dependent variable is one if the firm adopts both linear and nonlinear contracts. It equals two if the firm undertakes only nonlinear derivatives.

The results from ordered Probit regressions identify several factors that change the probability that a firm will include nonlinear derivatives in the hedge portfolio. Examining the results from the Tobit and the ordered Probit regressions, I find that the determinants that affect the extent of nonlinear hedging significantly change the likelihood of undertaking nonlinear derivatives. The results in Table 2.19 indicate positive coefficients on firm size, market-to-book assets, leverage, and leverage indicator. The relations for firm size and market-to-book assets are significant at the 1% level. The relation with leverage is significant at the 1%, 5%, and 1% levels respectively. The coefficient on industry-adjusted leverage is significant at the 5%, 5%, and 1% levels, respectively. These findings suggest that larger firms, firms with enhanced investment opportunities, or firms facing a higher probability of financial distress are more likely to use nonlinear instruments. I find an inverse relation between nonlinear usage and CEO tenure (significant at 1% in model 2).

The findings are generally consistent with my hypotheses. The results for firm size supports the notion that larger firms have more resources to employ sophisticated personnel and thus are more likely to administer sophisticated devices. The results for the variable market-to-book assets suggest that higher growth firms are more likely to use

Table 2.20
Probit Regression Results – The Likelihood of Nonlinear Usage

The dependent variable corresponds to zero if a firm does not use nonlinear vehicles at all and one otherwise. Coefficients represent marginal effects. Firm size is the log of the market value of the firm. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Leverage is long-term debt scaled by firm size. Leverage Indicator is an indicator variable. The value of the indicator variable is set to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	**0.0886** **(0.00)**	**0.0606** **(0.00)**	**0.0934** **(0.00)**
Market-to-Book Assets	**0.1033** **(0.00)**	**0.0990** **(0.00)**	**0.0989** **(0.00)**
Leverage	**0.3892** **(0.01)**	**0.2571** **(0.04)**	**0.3902** **(0.01)**
Leverage Indicator (0/1)	**0.0976** **(0.07)**	**0.0660** **(0.09)**	**0.1055** **(0.05)**
Convertible Debt	-0.1470 (0.76)	0.3957 (0.28)	-0.2151 (0.66)
Tax Loss Carryforwards	0.0270 (0.89)	0.2116 (0.21)	0.0566 (0.77)
Free Cash Flow	0.4572 (0.20)	0.2358 (0.37)	0.4624 (0.19)
Return on Equity	-0.0597 (0.45)	-0.0707 (0.31)	-0.0633 (0.42)
CEO Tenure	**-0.0053** **(0.06)**	**-0.0066** **(0.00)**	
CEO Age	0.0024 (0.42)		0.0008 (0.77)
Constant	**-1.4757** **(0.00)**	**-0.9928** **(0.00)**	**-1.4567** **(0.00)**
Year 1993 (0/1)	0.1296 (0.18)	0.0520 (0.39)	0.1277 (0.19)
Year 1994 (0/1)	**0.2327** **(0.01)**	**0.1380** **(0.01)**	**0.2281** **(0.01)**
Year 1995 (0/1)	**0.1976** **(0.03)**	**0.1240** **(0.03)**	**0.1914** **(0.04)**
Year 1996 (0/1)	**0.1638** **(0.08)**	**0.1164** **(0.05)**	**0.1614** **(0.08)**
Number of Observations	584	920	584
Likelihood Ratio Index	0.1273	0.0826	0.1224

nonlinear hedging to take advantage of the upside potential. The results for leverage and leverage indicator indicate that firms with more risky debt have stronger incentives to adopt nonlinear instruments to lower the costs of underinvestment. A possible explanation for the negative sign on CEO tenure is that more tenured CEOs are less likely to invest any effort to understand more complex nonlinear derivative contracts. I also estimate binominal Probit models to provide additional evidence on the relation between the likelihood of nonlinear hedging and firm characteristics. The dependent variable corresponds to zero if a firm does not use nonlinear vehicles at all and one otherwise.

Table 2.20 shows that the binomial results are consistent with those from ordered Probit regressions. I find that the likelihood of undertaking nonlinear instruments increases with firm size (significant at 1%), market-to-book assets (significant at 1%), leverage (significant at 1%, 5%, and 1% respectively), and leverage indicator (significant at 10%, 10%, and 5% respectively). Moreover, the results on CEO tenure from binominal Probit regressions (significant at the 10% and 1% levels in models 1 and 2) are similar to but more significant than those from ordered Probit models (significant at the level in model 2).

Table 2.21 and Table 2.22 provide additional support for the underinvestment hypothesis. Regressions 2 and 3 in Table 2.21 provide evidence that the likelihood that a firm will use nonlinear contracts is decreasing in the level of coverage ratio (significant at the 1% and 10% levels respectively) but increasing in that of convertible debt (significant at 1%). Table 2.22 (model 2) suggests that the negative relation with Z-score is significant at the 1% level and the positive relation with convertible debt is significant at

Table 2.21
Ordered Probit Results - Analysis of the Derivative Users (Coverage Measure)

The dependent variable is coded zero if the firm uses linear derivative instruments only. It is one if the firm uses both linear and nonlinear derivatives. It is two if the firm uses only nonlinear devices. Firm size is the log of the market value of the firm. Market-to-Book Assets is the ratio of the market value to total assets. Leverage is long-term debt scaled by firm size. Coverage ratio is defined as earnings before depreciation scaled by interest. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. CEO Tenure is the number of years since the CEO has been in position. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	**0.1931** **(0.00)**	**0.1093** **(0.00)**	**0.2043** **(0.00)**
Market-to-Book Assets	**0.1823** **(0.08)**	**0.2702** **(0.00)**	**0.1716** **(0.09)**
Coverage Ratio	-0.0032 (0.15)	**-0.0041** **(0.00)**	**-0.0034** **(0.09)**
Convertible Debt	0.8114 (0.61)	**0.2702** **(0.00)**	0.6449 (0.69)
Tax Loss Carryforwards	0.0490 (0.94)	0.4819 (0.45)	0.1349 (0.84)
Free Cash Flow	1.3478 (0.14)	1.2246 (0.12)	1.3468 (0.14)
Return on Equity	-0.4088 (0.30)	-0.4013 (0.20)	-0.4360 (0.26)
CEO Tenure	-0.0157 (0.12)	**-0.0192** **(0.01)**	
CEO Age	-0.0005 (0.95)		-0.0051 (0.55)
Constant	**-2.9808** **(0.00)**	**-2.1953** **(0.00)**	**-2.8904** **(0.00)**
Year 1993 (0/1)	0.5313 (0.13)	0.2326 (0.28)	0.5279 (0.12)
Year 1994 (0/1)	**0.8356** **(0.01)**	**0.4474** **(0.03)**	**0.8246** **(0.01)**
Year 1995 (0/1)	**0.7671** **(0.02)**	**0.4779** **(0.02)**	**0.7535** **(0.02)**
Year 1996 (0/1)	**0.6951** **(0.04)**	**0.4422** **(0.03)**	**0.6922** **(0.03)**
Number of Observations	568	889	568
Likelihood Ratio Index	0.0675	0.0500	0.0634

Table 2.22

Ordered Probit Regression - Analysis of the Derivative Users (Z-score Measure)

The dependent variable is coded zero if the firm uses linear derivative instruments only. It is one if the firm uses both linear and nonlinear derivatives. It is two if the firm uses only nonlinear devices. Firm size is the log of the market value of the firm. Market-to-Book Assets is the ratio of the market value to total assets. Leverage is long-term debt scaled by firm size. Z-score is a probability of bankruptcy. Convertible Debt is convertible debt scaled by firm size. Tax Loss Carryforwards is the book value of tax loss carryforwards divided by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. CEO Tenure is the number of years since the CEO has been in position. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	**0.1966** **(0.00)**	**0.1117** **(0.00)**	**0.2072** **(0.00)**
Market-to-Book Assets	**0.2554** **(0.02)**	**0.3341** **(0.00)**	**0.2527** **(0.02)**
Z-score	-0.0257 (0.25)	**-0.0442** **(0.01)**	-0.0315 (0.14)
Convertible Debt	1.4182 (0.38)	**1.9775** **(0.09)**	1.1744 (0.48)
Tax Loss Carryforwards	-0.0906 (0.90)	0.4064 (0.54)	0.0043 (0.99)
Free Cash Flow	**3.0347** **(0.00)**	**2.2856** **(0.01)**	**2.9993** **(0.00)**
Return on Equity	-0.3116 (0.41)	-0.3524 (0.25)	-0.3419 (0.37)
CEO Tenure	**-0.0199** **(0.09)**	**-0.0235** **(0.01)**	
CEO Age	0.0036 (0.68)		-0.0020 (0.82)
Constant	**-3.4255** **(0.00)**	**-2.2430** **(0.00)**	**-3.2832** **(0.00)**
Year 1993 (0/1)	0.5362 (0.14)	0.2171 (0.33)	0.5319 (0.13)
Year 1994 (0/1)	**0.7726** **(0.03)**	**0.3691** **(0.08)**	**0.7584** **(0.02)**
Year 1995 (0/1)	**0.6861** **(0.08)**	**0.3981** **(0.07)**	**0.6690** **(0.05)**
Year 1996 (0/1)	**0.6152** **(0.08)**	**0.3561** **(0.10)**	**0.6168** **(0.07)**
Number of Observations	547	854	547
Likelihood Ratio Index	0.075	0.050	0.070

the 10% level. Taken together, these findings are consistent with the underinvestment hypotheses but inconsistent with the risk- shifting notion.

Table 2.23 and Table 2.24 present ordered Probit regressions results on the subsample of major and minor hedgers, respectively. Compared with those in Table 2.19, the results provide several interesting observations. First, both the major hedger and the typical hedger that have large total assets, or greater investment opportunities are more likely to include nonlinear derivatives in their hedge portfolios. Second, the likelihood that both the major hedger and the typical hedger adopt nonlinear instruments is decreasing in CEO's tenure. Third, unlike the typical firm, the major hedger that has more free cash flow is more likely to undertake nonlinear devices. Finally, both the minor hedger and the typical hedger that have higher financial leverage or larger total assets are more likely to use nonlinear contracts.

Although the data limit analysis on the firms that use only interest rate or currency derivatives, I have no reason to believe that the results for firms that use commodity derivatives would be different. Like commodity price movements, the exchange rate or interest rate behavior over time will alter a company's future revenues and costs, and therefore affect a firm's production or investment decisions. In fact, corporate use of interest rate and currency derivatives is significantly greater than that of commodity derivative contracts. For example, Geczy, et al. (1995) find that during 1993, 52.1% of Fortunate 500 non-financial firms use currency derivatives, 44.2% use interest rate derivatives, and only 11.3% use commodity derivatives. Thus, my sample represents the majority of corporate hedging decisions.

Table 2.23
Ordered Probit Results - Analysis of Hedging Strategies, among Major Hedgers

The firm is considered a major hedger if the fraction of its total assets hedged exceeds the median (0.07) of the 382 sample firms. The dependent variable is zero if the firm uses linear derivative instruments only. It is one if the firm uses both linear and nonlinear derivatives. The dependent variable is two if the firm uses only nonlinear devices. Firm size is the log of the market value of the firm. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Leverage is long-term debt scaled by firm size. The value of the indicator variable is set to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise. Convertible Debt is convertible debt scaled by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. CEO Tenure is the number of years since the CEO has been in position. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	**0.2458** **(0.00)**	**0.1545** **(0.00)**	**0.2660** **(0.00)**
Market-to-Book Assets	**0.3318** **(0.00)**	**0.2786** **(0.00)**	**0.3193** **(0.00)**
Leverage	0.9373 (0.13)	0.6013 (0.26)	0.8789 (0.16)
Leverage Indicator (0,1)	0.1909 (0.44)	0.1644 (0.37)	0.2216 (0.36)
Convertible Debt	0.8014 (0.71)	2.2097 (0.22)	0.7749 (0.72)
Tax Loss Carryforwards	0.2448 (0.83)	0.6517 (0.51)	0.3516 (0.76)
Free Cash Flow	**4.4789** **(0.00)**	**2.0167** **(0.09)**	**4.7142** **(0.00)**
Return on Equity	-0.2666 (0.57)	-0.3319 (0.37)	-0.2711 (0.56)
CEO Tenure	-0.0211 (0.12)	**-0.0278** **(0.00)**	
CEO Age	0.0054 (0.64)		0.0016 (0.88)
Constant	**-4.2179** **(0.00)**	**-2.5740** **(0.00)**	**-4.2604** **(0.00)**
Year 1993 (0/1)	0.6454 (0.16)	0.2600 (0.37)	0.6092 (0.17)
Year 1994 (0/1)	**0.8755** **(0.05)**	**0.4884** **(0.08)**	**0.8123** **(0.06)**
Year 1995 (0/1)	0.6669 (0.14)	0.4027 (0.16)	0.5939 (0.18)
Year 1996 (0/1)	0.5731 (0.20)	0.3829 (0.18)	0.5126 (0.23)
Number of Observations	299	460	299
Likelihood Ratio Index	0.1203	0.0623	0.1145

Table 2.24

Ordered Probit Results - Analysis of Hedging Strategies, among Minor Hedgers

The firm is considered a minor hedger if the fraction of its total assets hedged is less than the median (0.07) of the 382 sample firms. The dependent variable is zero if the firm uses linear derivative instruments only. It is one if the firm uses both linear and nonlinear derivatives. The dependent variable is two if the firm uses only nonlinear devices. Firm size is the log of the market value of the firm. Market-to-Book Assets is the ratio of the market value to the book value of total assets. Leverage is long-term debt scaled by firm size. The value of the indicator variable is set to one if the firm's leverage ratio is greater than the average of its two-digit SIC code industry, and zero otherwise. Convertible Debt is convertible debt scaled by firm size. Free Cash Flow is the ratio of free cash flow to firm size. Return on Equity is the average of three-year return on equity prior to the decision year. CEO Tenure is the number of years since the CEO has been in position. P-values are in parentheses. Results significant at the ten percent level or less are in bold.

Independent Variables	Model 1	Model 2	Model 3
Firm Size	**0.2303** **(0.01)**	**0.1243** **(0.07)**	**0.2275** **(0.01)**
Market-to-Book Assets	0.0721 (0.70)	0.2344 (0.11)	0.0801 (0.67)
Leverage	**1.6091** **(0.08)**	1.0542 (0.11)	**1.6028** **(0.08)**
Leverage Indicator (0,1)	0.4038 (0.15)	0.3247 (0.11)	0.3993 (0.15)
Convertible Debt	-2.5341 (0.50)	-0.5203 (0.83)	-2.4038 (0.51)
Tax Loss Carryforwards	-0.6049 (0.66)	0.1601 (0.88)	-0.6164 (0.65)
Free Cash Flow	-1.6253 (0.45)	0.0443 (0.97)	-1.5880 (0.45)
Return on Equity	-0.3576 (0.77)	-0.2858 (0.71)	-0.3402 (0.78)
CEO Tenure	0.0041 (0.81)	-0.0087 (0.54)	
CEO Age	-0.0063 (0.77)		-0.0045 (0.83)
Constant	**-3.2288** **(0.05)**	**-2.9012** **(0.00)**	**-3.2874** **(0.05)**
Year 1993 (0/1)	-0.0132 (0.97)	0.0395 (0.90)	-0.0130 (0.97)
Year 1994 (0/1)	0.5057 (0.29)	0.2455 (0.45)	0.5062 (0.29)
Year 1995 (0/1)	0.4206 (0.41)	0.3379 (0.32)	0.4234 (0.40)
Year 1996 (0/1)	0.4198 (0.41)	0.3652 (0.27)	0.4154 (0.41)
Number of Observations	285	460	285
Likelihood Ratio Index	0.0934	0.0469	0.0931

Table 2.25
Summary of the Empirical Results

The table summaries selected multivariate results. The method column indicates the type of multivariate analysis that I perform. Sample identifies the population from which I draw the sample. Dependent Variable identifies the variable that I use to quantify the extent of nonlinear/linear hedging. The other columns summarize the variables, and the predicted signs. Results that are consistent with the hypotheses are in parentheses.

Method	Sample	Dependent Variable	Investment		Size		Free Cash Flow		CEO Tenure and Age		Capital Structure	
Tobit	All	Nonlinear/asset	Market/Book	(+)	Ln (size)	(+)	Free cash flow	(+)	CEO Tenure	(–)	Leverage	+
									CEO Age	+/–	Leverage (0/1)	(+)
Tobit	All	Nonlinear/size	Market/Book	(+)	Ln (size)	(+)	Free cash flow	(+)	CEO Tenure	(–)	Leverage	(+)
									CEO Age	+/–	Leverage (0/1)	+
Tobit	All	Linear/asset	Market/Book	–	Ln (size)	–	Free cash flow	(+)	CEO Tenure	+	Leverage	(–)
									CEO Age	+/–	Leverage (0/1)	–
Tobit	All	Linear/size	Market/Book	(–)	Ln (size)	–	Free cash flow	+	CEO Tenure	+	Leverage	–
									CEO Age	(+/–)	Leverage (0/1)	–
Tobit	All	Intensity Nonlinear	Market/Book	(+)	Ln (size)	(+)	Free cash flow	+	CEO Tenure	(–)	Leverage	(+)
									CEO Age	+/–	Leverage (0/1)	(+)
											Coverage	(–)
											Z-score	(–)
Tobit	Major Hedger	Intensity Nonlinear	Market/Book	(+)	Ln (size)	(+)	Free cash flow	(+)	CEO Tenure	(–)	Leverage	(+)
									CEO Age	+/–	Leverage (0/1)	+

(Table 2.25 Continued)

Method	Sample	Dependent Variable	Investment		Size		Free Cash Flow		CEO Tenure and Age		Capital Structure	
Tobit	Minor Hedger	Intensity Nonlinear	Market/Book	(+)	Ln (size)	(+)	Free cash flow	+	CEO Tenure CEO Age	– +/–	Leverage Leverage (0/1)	(+) +
Ordered Probit	All	Intensity Nonlinear	Market/Book	(+)	Ln (size)	(+)	Free cash flow	+	CEO Tenure CEO Age	(–) +/–	Leverage Leverage (0/1) Coverage Z-score	(+) (+) (–) (–)
Ordered Probit	Major Hedger	Intensity Nonlinear	Market/Book	(+)	Ln (size)	(+)	Free cash flow	(+)	CEO Tenure CEO Age	(–) +/–	Leverage Leverage (0/1)	+ +
Ordered Probit	Minor Hedger	Intensity Nonlinear	Market/Book	+	Ln (size)	(+)	Free cash flow	+	CEO Tenure CEO Age	– +/–	Leverage Leverage (0/1)	(+) +

2.6.5 Summaries of Multivariate Results

Table 2.25 summaries the multivariate results. It summarizes the method, the sample, the dependent variable, and the predicted signs of the explanatory variables. The results that are consistent with the hypotheses are in parentheses.

2.7 Conclusions

In this chapter, I examine the determinants of corporate use of linear and nonlinear derivatives from the perspective of managers and shareholders. The results of cross-sectional regressions using Tobit and Probit models indicate that both managerial incentives and value maximization explain why firms use linear or nonlinear derivatives. In particular, I find that nonlinear usage is positively related to investment opportunity, free cash flow, firm size, stock option grants, and the prospect of financial distress. I document a negative relation between the use of nonlinear derivatives and bonus plan and CEO tenure. My empirical analysis is partly exploratory due to the lack of a specific theoretical framework.

Supporting the notion that managerial incentives influence the choice of derivative instruments, I document a positive relation between nonlinear derivative usage and stock option grants, but a negative relation between the use of nonlinear derivative contracts and bonus compensation. These results are consistent with the hypothesis that managers with more option grants have greater incentives to use derivatives that have nonlinear payoffs to raise their expected compensation. The "stair-step" function of bonus payments discourages managers whose bonus payments are adjacent to the cap from undertaking nonlinear derivatives. These findings suggest that hedging policies reflect the incentives provided in compensation contracts. Inefficient contracts lead to inefficient policies.

I document a negative relation between the use of nonlinear devices and CEO tenure. One interpretation of this result is that more tenure CEOs are more risk averse and thus have greater incentives to use linear derivative instruments to eliminate the variation in cash flows or earnings. Alternatively, managers with longer tenures are closer to retirement and thus possibly lack the incentives to understand the more sophisticated derivatives that have nonlinear payoffs. This result suggests that managerial risk aversion or management's lack of famility with sophisticated financial instrument impedes nonlinear derivative usage.

My evidence indicates that the use of nonlinear hedging is positively related to investment opportunity. This evidence suggests that firms with more investment opportunities have greater incentives to use derivatives that can preserve upside potential for shareholders. Linear derivative securities eliminate downside risk but also upside potential, resulting in the potential loss of growth opportunities.

Additionally, my results provide evidence that nonlinear usage increases with firm size. This evidence supports the concept that larger firms have more resources to invest in complex control systems and personnel capable of administering more sophisticated nonlinear instruments. This evidence suggests that corporations facing more financial constraints are less likely to use nonlinear derivative instruments.

My results also shed light on the relation between the use of nonlinear vehicles and internal capital. I document that the notional values of both linear and nonlinear derivative contracts and the component of nonlinear devices in the firm's hedge portfolio increase in the level of free cash flow. These results suggest that a substantial cost differential between internal cash and external capital precludes firms lacking financial slack from undertaking derivatives or using nonlinear devices.

Finally, I provide evidence on the relation between capital structure and nonlinear derivative usage. I document a positive relation between nonlinear usage and the likelihood of financial distress, measured as leverage, industry-adjusted leverage, Z-score, and coverage ratio. These findings support the premise that firms use nonlinear derivative contracts to mitigate the underinvestment problem but also preserve upside potential for shareholders. I do not observe an inverse relation between the use of nonlinear devices and convertible debt. The evidence is not consistent with the notion that firms use nonlinear instruments to engage in risk-shifting behavior.

My findings have several implications for corporate policy. At the most basic level, the results suggest that firms with larger growth opportunities should use nonlinear derivatives to protect against downside losses but preserve growth potential for shareholders. However, managers establish hedging policies to protect the values of their own wealth. Compensation committees should take care that managers' incentive compensation contracts are also in the best interests of shareholders. Additionally, CEOs who have been in their position for a long time become entrenched and potentially too risk averse. As these CEOs approach retirement, they also face shorter horizons. Thus, long-tenured CEOs have the incentives to engage in sub-optimal hedging policies. Firms should be aware of this problem and possibly use incentive compensation or monitoring mechanisms to mitigate these potential conflicts of interests between shareholders and managers.

The data also suggests that firms can protect valuable financial slack with derivatives, which should lower their cost of capital by limiting the need to raise external funds. As financial slack increases, firms should consider using some of these internal funds to purchase nonlinear derivatives, which can preserve both financial slack and upside potential for shareholders. Finally, firms that face the prospect of financial distress can use nonlinear derivatives to mitigate the underinvestment problem associated with a debt overhang. All in all, the results suggest that an effective corporate hedging policy, combined with a proper incentive compensation system, can increase firm value by mitigating agency problems and lowering the cost of capital for the firm.

CHAPTER 3

A THEORETICAL AND EMPIRICAL ANALYSIS OF THE STACKED HEDGE HEDGING FLOWS IN COMMERCIAL AND INVESTMENT ASSETS

3.1 Introduction

MG Refining & Marketing (MGRM), the U.S. subsidiary of a German industrial giant Metallgesellschaft A. G. (MG), reported its derivatives-related losses of \$1.3 billion in late 1993 and early 1994. MGRM's derivatives activities were in fact part of its marketing/hedging program sometime referred to as "synthetic storage." MGRM committed itself to supply gasoline and heating oil to end-users over the next ten years at fixed prices. In order to insulate the profit margins in its fixed-price commitment from its exposure to spot price increases, MGRM took long positions in derivatives contracts. During 1993, MGRM established very large derivative positions in crude oil, heating oil, and gasoline that were roughly 80 times the daily output of Kuwait.

The most efficient way for MGRM to eliminate all risks was to buy a strip of forward contracts corresponding to the maturity of a delivery date and the quantity of gasoline and oil scheduled for delivery on that date. If MGRM had implemented a strip hedge, it would have had no exposure to oil prices. Nevertheless, a strip hedge may have been prohibitively expensive to execute. A strip hedge requires using contracts from over-the-counter markets characterized by limited liquidity. Since most contracts tended to be of short maturity, MGRM hedged its long-term exposures by sequentially stacking nearby futures contracts until the end of its hedging horizon.

MGRM suffered tremendous losses in its derivatives position in the autumn of 1993 when oil prices declined. Since it was unable to meet maintenance margins, the paper losses have to be realized.

The purpose of this chapter is to evaluate how well a long-term exposure to asset prices can be neutralized using a stacked hedge rather than a strip hedge. This chapter examines the hedging problem facing the agent as discussed in Hilliard (1999). The agent has long-term deterministic commodity supply commitments and wishes to hedge those long-term exposures by repeatedly rolling nearby futures contracts until settlement. This issue has been addressed theoretically in the literature. A collection of articles may be found in Culp and Miller (1999). The approach here is to examine competing models and to test their predictions using empirical data on both investment and commercial assets.

Commercial commodities are those held for use in production processes or for ultimate consumption. They include, for example, agricultural, metal, and energy commodities. Investment assets are held solely for investment purposes and include stocks, fixed income securities and money market securities. Convenience yield is a type of yield found in commercial assets but not in investments. Marginal convenience yield is the benefit which one derives from holding the commodity physically. It reflects the market's expectations regarding the future availability of the commodity. Low inventories tend to contribute to high convenience yields. On the other hand, the expectation of a surplus of the commodity tends to lead to low convenience yields. Fama and French (1987) find that the marginal convenience yields of most agricultural and animal products vary seasonally. Fama and French (1988) examine the metals futures contracts traded on the London Metals Exchange and provide empirical evidence that the convenience yield of metals follows a mean-reverting process. Gibson and Schwartz (1990) develop a two-factor model to value oil-linked assets under the assumption that the cash price of oil and the convenience yield of oil follow a joint stochastic process. Their empirical results demonstrate that the model performs well in valuing short-term contracts such as futures. Schwartz (1997) reveals that there is strong mean reversion of convenience yield for copper and oil, but not for gold, which Hull (2000) considers an investment asset.

This chapter develops and tests the hypothesis that stacked hedges perform better with investment assets than with commercial commodities. The effectiveness of the stacked-hedge depends on hedged assets obeying spot-futures parity. Investment assets closely obey spot-futures parity. Commercial commodities do not. Deviations from spot-futures parity are a result of stochastic net convenience yields. Since investment assets have little or no convenience yields while commercial commodities have non-trivial convenience yields, stacked hedges should perform better with investment assets than with commercial commodities.

The strip hedge is used as a benchmark of multi-period hedging accuracy. The strip hedge uses a portfolio of futures contracts of different maturities to match required outflows or inflows. Under price convergence and liquidation of contracts at maturity, future cash flows will be completely determined. This is assumed to be the optimal hedging strategy, net of liquidity and transaction cost considerations. While not specifically matching maturities, Neuberger (1999) shows that hedging of commercial contracts can be greatly improved by using futures contracts of several maturities simultaneously. He studies the crude oil contracts traded on the New York Mercantile Exchange (NYSE) and finds that the quality of the hedge is improved if contracts of more maturities are used.

Three commercial commodities and three investment assets are examined. The commercial commodities, presumably with non-trivial convenience yield, are heating oil, light crude oil, and unleaded gasoline. The investment assets are the British Pound, Deutsche Mark, and Swiss Franc. My empirical evidence is consistent with the hypothesis that stacked hedges perform better with investment assets than with commercial commodities. The stacked hedge produces an R^2 of at least 0.98 for investment assets. However, the mean hedge performance for commercial commodities range from less than 0.83 for heating oil to 0.96 for unleaded gasoline. I also document that the significant differences in hedge performance between the two classes of assets are attributed to the stochastic nature of marginal convenience yields of commercial commodities.

The remainder of the chapter is organized as follows. Section 3.2 develops five candidate hedging models for implementing the stacked hedge. Section 3.3 describes techniques used to estimate the parameters of hedging models. Section 3.4 describes the data and presents empirical evidence. Section 3.5 concludes the chapter.

3.2 Hedging Models

This section derives and/or reviews the path of hedge ratios and hedged cash flows for each of the five models. The first model follows from Hilliard's (1999) setup. The second model extends the first model by allowing for variable but non-stochastic instantaneous net convenience yield. The third model imposes additional assumptions on the first model and develops the framework for investigating the sources of errors in the stacked hedge. The fourth model uses time-series regression to derive the new hedge path and the last model is the naïve scheme used by MGRM.

3.2.1 Model 1

Hilliard (1999) posits an agent who has long-term deterministic flow commitments and who wishes to hedge those long-term exposures by repeatedly rolling short-dated futures contracts of the same maturity until the hedging horizon ends. The hedging problem is as follows: an agent sells or buys the underlying commodity in each of the *n*-periods at the prevailing spot price and wishes to hedge his flows using traded futures contracts. Hilliard (1999) derives the optimal hedging path for the agent.

The model is set in discrete time. The agent faces an n-period hedging horizon with deterministic product flow m_i, at times t_i, $i = 1, 2, \ldots, n$. At the beginning of each period a new futures contract starts trading and it matures exactly one period later. When one futures contract matures, another is introduced; this process continues until the end of the multi-period hedge. At the end of each period, futures positions are unwound and the generated cash from spot and futures positions is deposited into an account at the riskless interest rate until the end of the hedge period. $P(t)$ is the spot price at time t and $F(t, T)$ is the price at time t of the futures contract that settles at time T. For simplicity, the price of the contract at initiation is denoted as F_i and the price at maturity as $F_{i,i}$. The change in the futures price is $\Delta F_i = F_{i,i} - F_i$ and $\Delta P_i = P_{i+1} - P_i$ is the change in spot price. For convenience, let $t_0 = 0$ and $t_i = i * \Delta$ where Δ is time between flow events. The problem facing an agent is to find the optimal hedging path x_i, $i = 0, 1, 2, \ldots$, n-1 so that $Var(V_k)$ is minimized, where V_k is the accumulated cash flow, computed as

$$(1) \quad V_k = \sum_{i=k+1}^{n} \exp(r\Delta \cdot (n-i)) \cdot (m_i P_i + x_{i-1} \Delta F_{i-1}),\ k = 0,1,2,\ldots,n-1.$$

The following assumptions are made implicitly and explicitly in the model:

Assumption 1. The market is frictionless, i.e., there are no transaction costs or taxes, information is freely available and participants are price takers. Futures contracts are cash settled and no margins are required.

Assumption 2. The interest rates and the instantaneous net convenience yields are known and constant over time.

Assumption 3. The hedge path $x_k, x_{k+1}, \ldots, x_{n-1}$, is independent of past hedge parameters $x_0, x_1, \ldots, x_{k-1}$.

Assumption 4. The agent can borrow or lend at the riskless rate.

Assumption 5. The cost-of-carry model in the form $F_i = P_i \exp(b\Delta)$ holds, where the cost of carry b equals the riskless interest rate γ minus the instantaneous net convenience yield δ.

Assumption 6. Price convergence in the form of $F_{i,i} = P_{i+1}$ holds.

Under the above assumptions, the hedge ratio

(2) $$x_k^* = -\sum_{j=k}^{n-1} m_{j+1} \exp((b-r)\cdot(j-k)\Delta),\ k = 0,1,\ldots,\ n-1,$$

gives risk-free cash flows at the end of period n. Neglecting compounding terms, notice that this is the same result as the naïve stacked hedge since x_k^* at period k is the sum of remaining commitments. The compounded value of these flows is

(3) $$V_0^* = \sum_{j=0}^{n-1} m_{j+1} F_0 \exp(b\cdot j\Delta)\cdot\exp(r\cdot(n-1-j)\Delta).$$

3.2.2 Model 2

The hedge path derived in Hilliard (1999) is based on an assumption that instantaneous net convenience yields are known and constant over time. The theory of storage of Brennan (1958), Telser (1958), and Working (1949) posits that marginal convenience yield is a decreasing function of the level of inventories of the commodity. Marginal convenience yield is a measure of the benefits that may include the ability to keep production running. It reflects the market's expectations regarding the future availability of the commodity. Low stocks held tend to contribute to high convenience yields. On the other hand, the expectation of a surplus of the commodity tends to lead to low convenience yields. More recent papers including Fama and French (1987, 1988), Gibson and Schwartz (1989, 1990), and Schwartz (1997), and Hilliard and Reis (1998) also note that convenience yield follows a mean-reverting process.

Model 2 relaxes the assumption that instantaneous net convenience yield remains constant over time. Instead, I allow for an arbitrary term structure. The spot price and the nearby futures price of the underlying asset are used to derive the forward cost-of-carry. However, I must assume that the cost-of-carry for a given calendar date remains constant, else future hedge ratios are random and the variance calculations become intractable.

The new hedge path when cost-of-carry is a deterministic function of instantaneous net convenience yield follows the setup of Hilliard (1999).

Using equation (1), the one-period model facing the agent becomes:

$$(4) \quad L_{n-1} = Var(V_{n-1}) = Var(m_n P_n + x_{n-1}\Delta F_{n-1}).$$

Differentiating L_{n-1} solving for the critical point gives

$$(5) \quad x^*_{n-1} = -m_n.$$

Similarly, the two-period problem is

$$(6) \quad L_{n-2} = Var(V_{n-2}) = Var[(m_{n-1}P_{n-1} + x_{n-2}\Delta F_{n-2})\exp(r\Delta) + (m_n P_n + x^*_{n-1}\Delta F_{n-1})].$$

Using equation (5) in equation (6) and take the derivative of equation (6) with respect to x_{n-2} giving the critical point

$$(7) \quad x^*_{n-2} = -m_{n-1} - m_n \exp[(b_n - r)\Delta],$$

where b_n *is the one − period forward rate beginning at period − i*. The one-period rate is computed from i-period rates by recursion as

$$(8) \ b_n = nB_n - (n-1)B_{n-1}, \ where \ B_n = \ln\left(\frac{F(0,n\Delta)}{n\Delta}\right) \forall n.$$

The three-period problem is as follows:

$$(9)\quad L_{n-3} = Var[(m_{n-2}P_{n-2} + x_{n-3}\Delta F_{n-3})\exp((n-(n-2))r\Delta) + (m_{n-1}p_{n-1} + x^*_{n-2}\Delta F_{n-2})\cdot$$

$$\exp((n-(n-1))r\Delta) + m_n P_n + x^*_{n-1}\Delta F_{n-1}].$$

Using equation (5), (7) in equation (9) and solving the first order condition gives the critical point

$$(10)\quad x^*_{n-3} = -m_{n-2} - m_{n-1}\exp[(b_{n-1} - r)\Delta] - m_n \exp[(b_{n-1} + b_n - (n-1-(n-3))r)\Delta],$$

where

$$(11)\quad b_n = nB_n - (n-1)B_{n-1},\ and\ B_i = \frac{\ln(\frac{F_0}{S_0})}{i\Delta}\ \forall\ i.$$

Repeated iteration gives the new hedge path:

$$(12)\quad x^*_k = -m_{k+1} - \sum_{j=k+1}^{n-1} m_{j+1} \exp[(\sum_{l=k+1}^{j} b_{l+1} - (j-k)r)\Delta],\ k = 0,1,2,...,n-2.$$

$$(13)\quad x^*_{n-1} = -m_n.$$

3.2.3 Model 3

Models 1 and 2 assume that interest rates are constant. If short-term interest rates are not constant, the optimal hedge path and terminal cash flows are impacted. The third model extends the first one by allowing for both convenience yield and interest rates to be stochastic. By imposing additional covariance assumptions from the first model, a tractable closed form solution is obtained for the optimal hedge path and hedged cash flows. More importantly, this model gives us insights into why the stacked hedges perform better with investment assets than with commercial commodities.

Assumption 7. Cross-covariances are stationary, i.e.,

$$(14)\ \frac{Cov(F_i, P_i)}{Var(P_i)} = \frac{Cov(F_j, P_j)}{Var(P_j)} = \beta \ \ \forall\ i, j.$$

Assumption 8. Prices are orthogonal to residuals from the cost-of-carry model. That is, $Cov(F_i - \beta P_i, P_j) = 0\ \forall\ i,\ j.$

All covariance expressions are conditioned on information available at prior periods k < j. Hedged cash flows forthcoming from period *k+1* through period *n* can then be expressed as:

$$(15)\ \ V_k = \sum_{i=k+1}^{n} \exp(f_{i,n-i}\Delta \cdot (n-i)) \cdot (m_i P_i + x_{i-1}\Delta F_{i-1}),$$

$where\ f_{i,n-i} = \dfrac{n\,r_{0,n} - i\,r_{0,i}}{n-i}, and\ k = 0,1,2,...,n-1.$ The *n-i* period forward rate beginning at time $i\Delta$ is $f_{i,n-i}$ and $r_{0,n}$ is the current yield to maturity of n-period Treasury-Bills. Minimizing *Var*(V_k) gives the hedge ratio

$$(16)\ \ x_k^* = -m_{k+1} - [\sum_{i=k+2}^{n} m_i \exp(f_{i,n-i}\Delta \cdot (n-i))\,\beta^{i-(k+1)}]\exp(-f_{k+1,n-k-1}\Delta \cdot (n-k-1)),$$

$$k = 0,1,2,...,n-2,$$

and

$$(17)\ \ x_{n-1}^* = -m_n.$$

The terminal cash flows at the end of period n are:

$$(18)\quad V_0^* = F_0\Big(\sum_{i=1}^{n} m_i \exp(f_{i,n-i}\Delta\cdot(n-i))\,\beta^{i-1}\Big) - \sum_{i=1}^{n-1}(F_i - \beta\,P_i)\exp(f_{i+1,\,n-i-1}\,\Delta\cdot(n-i-1))\,x_i^* .$$

The first part of equation (18) is deterministic while the second part contains random terms. Stacked hedges are therefore effective when the second part of the equation is vanishingly small. If the second term vanishes completely, the stacked hedge is equivalent to the strip hedge. Commercial commodities generally have positive convenience yields. The convenience yields, as discussed above, have a mean-reverting tendency and in any event requires a stochastic representation. This implies that assumption 7 does not necessarily hold and that some or all terms containing $(F_i - \beta\,P_i)$ are non-zero. More specifically, $(F_i - \beta\,P_i)$ captures the stochastic nature of the marginal convenience yield. As a result, stacked hedges with commercial commodities would not perform as well as strip hedges. On the other hand, investment assets have little or no convenience yield. This implies that the assumptions of model 3 generally remain valid and therefore stacked hedges with investment assets perform almost as well as strip hedges. In fact, if the assumptions hold perfectly, the stacked hedge results in completely hedged future cash flows.

3.2.4 Model 4

Model 4 is a one-period, myopic model. Therefore, interest rates and convenience yields are of no consequence so long as there is price convergence. However, applying this model in a multi-period context requires the assumption that the hedge ratio is invariant over time. Previous research on the derivation of the optimal hedge ratio and hedging effectiveness of futures contracts is largely related to the covariance between the changes in spot and futures prices and the variances of futures price changes (Ederington, 1979, and Hill and Schneeweis, 1981 and 1982). However, these studies are restricted to a one-period world. More realistically, hedging strategy should be implemented dynamically so that the agent has to roll the hedge as old futures contracts mature and new futures contracts are available. The purpose of this model is to apply the optimal hedge ratio derived from a one-period world to a multi-period world.

Following the terminology and approach of Ederington (1979), consider an agent who wishes to minimize the variance of portfolio return. In this context, an agent who enters the market in one period to buy is "short". The portfolio return is written

$$(19) \quad R = X_S \Delta P + X_F \Delta F,$$

where $X_S = \text{-}m \text{ and } X_F$ are units held in the spot and futures market, respectively. In order to maximize expected quadratic utility, the agent minimizes return variance, written as:

$$(20) \quad Var(R) = X_S{}^2\, Var(\Delta P) + X_F{}^2\, Var(\Delta F) + 2\, X_S X_F Cov(\Delta P, \Delta F)$$

The first order condition with respect to the futures position, X_F, is

$$(21) \quad X_F^* = -X_S \frac{Cov(\Delta P, \Delta F)}{Var(\Delta F)} = -ma_1.$$

The hedge ratio (a_1) is typically estimated by ordinary least squares (OLS) method. Three theoretical specifications of the cash and futures prices are used to estimate the hedge ratio. First, the price level model regresses the spot price on the futures price to estimate for the hedge ratio. Witt, Schroeder, and Hayenga (1987) provide empirical support for this specification. Second, the price change model regresses the change in the spot price against the change in the futures price. Hill and Schneeweis (1981, 1982) and others use this specification. Finally, the percentage change in the spot price is regressed on the percentage change in the futures price.

Based on the setup of Ederington (1979), I use the price change model to estimate the optimal hedge ratio in a one-period world. The value of x^* is equivalent to the slope coefficient of a time-series regression of spot price changes on futures price changes. Specifically, the following time-series regression is considered:

$$(22)\quad P_i - P_{i-1} = a_0 + a_1(F_i - F_{i-1}) + \varepsilon_i .$$

The optimal hedge position in a one-period world is used in the multi-period stacked hedge strategy assuming that the hedge ratio a_1 remains constant. When m_k is negative, the agent goes long $a_1 \sum_{k=i+1}^{n}(-m_k)$ units in nearby futures contracts at the beginning of time period *i*. At the end of the period, the agent reverses the futures position. This process is continued throughout the agent's hedging horizon.

3.2.5 Model 5

This model is based on the naïve scheme used by MGRM. The agent enters positions in the nearby futures contracts that equal the sum of the remaining flow commitments. As time evolves, the agent rebalances the hedging portfolio and rolls forward in a similar fashion until the end of the hedging horizon.

3.3 Parameter Estimation

The state variables, or factors, in the empirical implementation of Model 3 are frequently not directly observable. For example, the instantaneous interest rate is not directly observed. In the absence of arbitrage, forward interest rates can be derived from the yield curve of Treasury Bills. The parameter β can be estimated by time-series regression of the form

(23) $F_i = \alpha + \beta P_i + e_i$.

Classical statistical inference is valid if both $\{F_i\}$ and $\{P_i\}$ are stationary. However, most financial time series such as price series are non-stationary. To examine stationarity, the augmented Dicky-Fuller (ADF) procedure is used to test for the presence of unit roots. The equations are:

(24) $$\Delta F_i = a_0 + \gamma F_{i-1} + \sum_{j=2}^{n} \beta_j \Delta F_{i-j+1} + \varepsilon_i,$$

(25) $$\Delta P_i = a_0 + \gamma P_{i-1} + \sum_{j=2}^{n} \beta_j \Delta P_{i-j+1} + \eta_i,$$

where $\gamma = -1 - \sum_{j=1}^{n} a_j$, $\beta_j = \sum_{k=1}^{n} a_k$, and ε, γ are well-behaved residuals. The appropriate lag length *n* is selected by starting with a maximum lag of 12 and the model is pared down by the usual t-test and F-tests. Once a tentative lag length has been determined, we ensure that the Ljung-Box Q-statistic reveals no significant autocorrelations among residuals. When testing for unit root, the null hypothesis is that if γ = 0, the system has a unit root. If the null hypothesis is rejected, there is sufficient evidence to conclude that the series are stationary.

If both price series are stationary, the parameter β is estimated directly. When both series are non-stationary and is integrated of order 1, Engle and Granger's (1987) method is used to test whether they are cointegrated. If the two series are cointegrated, $e_i = F_i - \alpha - \beta P_i$ must be stationary. A Dickey-Fuller test is performed on the residual

$$(26)\ \ \Delta \hat{e}_i = a \hat{e}_{i-1} + \varepsilon_{i.}$$

If the null hypothesis $a = 0$ is accepted, the $\{F_i\}$ and $\{P_i\}$ sequences are analyzed as if they are not cointegrated and the first difference of equation (23) is used to estimate β:

$$(27)\ \ \Delta F_i = a + \beta \Delta P_i + \Delta e_i .$$

If the residuals of (26) appear not to be white noise, the ADF test is performed on the estimated residual:

$$(28)\ \ \Delta \hat{e}_i = a \hat{e}_{i-1} + \sum_{j=1}^{n} a_{j+1} \Delta \hat{e}_{i-j} + \varepsilon_{i.}$$

As before, the appropriate lag length is selected by starting with a maximum lag of 12 and the model is pared down by the usual t-test and F-tests. Once a tentative lag length has been determined, we ensure that the Ljung-Box Q-statistic reveals no significant autocorrelations among residuals. If $-2 < a < 0$, I conclude that the residual sequence is stationary and $\{F_i\}$ and $\{P_i\}$ are CI (1,1).

Engle and Granger (1987) show that if the series are cointegrated, there exists an error correction representation of the series. Specifically, if $\{F_i\}$ and $\{P_i\}$ are CI (1,1), the series have the error-correction form:

$$(29)\quad \Delta F_i = \alpha_1 + \alpha_2 (F_{i-1} - b\,P_{i-1}) + \beta\,\Delta P_i + \sum_{j=1}^{m} \gamma_j \Delta F_{i-j} + \sum_{k=1}^{n} \delta_k \Delta P_{i-k} + \varepsilon_{i.}$$

Lag lengths are determined using an F test that all $\gamma_j = 0$ and $\delta_k = 0$. The parameter β is then estimated.

3.4 Data and Empirical Results

Data was obtained from Futures Industry Institute. The data consist of observations of settlement and cash prices for three commercial commodities and three investment assets. The commercial commodities are heating oil, light crude oil, and unleaded gasoline. The investment assets include the British Pound, Deutsche Mark, and Swiss Franc. Monthly observations are available for heating oil, light crude oil, and unleaded gasoline. Quarterly observations are available for the British Pound, Deutsche Mark, and Swiss Franc. The heating oil, light crude oil, and unleaded gasoline futures contracts are traded on the New York Mercantile Exchange (NYME). The British Pound, Deutsche Mark, and Swiss Franc futures contracts are traded on the Chicago Mercantile Exchange (CME).

In general, available data series for futures contracts is comparatively recent and therefore short. The data on heating oil futures contracts consist of the period November 1979 - May 2001. The light crude oil data is available for the period November 1983 - May 2001. The sample period for unleaded gasoline is January

1985 - April 2001. The Deutsche Mark data covers the period December 1975 - September 1999. The data are available from December 1975 - June 2001 for the British Pound and Swiss Franc.

Table 3.1 presents summary statistics for the spot prices series and the futures prices series. This table reports sample sizes, mean prices, standard deviations of prices, skewness, and kurtosis. The volatility of spot prices appears to be quite similar to the futures series. For example, the standard deviation of spot prices for light crude oil is 5.459 and that of futures prices for light crude oil is only 5.195. The standard deviation of heating oil, the British Pound, the Deutsche Mark and Swiss Franc differ in only the third significant place. Although test statistics are not computed, the distributions are noticeably non-normal. Skewness and kurtosis of the normal is 0 and 3, respectively. Distributions of all prices series are positively skewed except for the series of the Deutsche Mark and the Swiss Franc. The sample kurtosis coefficients never exceed one and indicate that both the spot prices and the futures prices are not normally distributed. Most notable is the similarity in all of the statistics between spot and future prices.

Table 3.2 reports the results of Augmented Dickey-Fuller tests for unit root. The parameters of model 1 and model 2 are estimated for the spot price series and the futures price series, respectively. The numbers of observations are reported in the column labeled T. The chosen lag lengths are reported in the column *n*. The estimated values a_0, t(a_0), γ, and t(γ) are reported in columns 4, 5, 6, and 7, respectively. Under the null of nonstationary, I use the MacKinnon critical values.

Table 3.1
Sampling Distributions for the series

Series	Sample Size	Mean	Standard Deviation	Skewness	Kurtosis
Spot Prices					
Heating Oil	258	0.641	0.178	0.436	-0.845
Light Crude Oil	210	21.121	5.459	0.626	-0.280
Unleaded Gasoline	195	0.601	0.144	0.876	0.820
British Pound	102	1.685	0.242	0.708	0.859
Deutsche Mark	95	0.525	0.103	-0.291	-0.895
Swiss Franc	102	0.608	0.128	-0.151	-0.755
Futures Prices					
Heating Oil	258	0.634	0.176	0.491	-0.771
Light Crude Oil	210	20.918	5.195	0.622	-0.311
Unleaded Gasoline	195	0.594	0.133	0.815	0.679
British Pound	102	1.677	0.240	0.741	0.922
Deutsche Mark	95	0.527	0.102	-0.315	-0.843
Swiss Franc	102	0.613	0.127	-0.163	-0.663

The data on heating oil futures contracts are available from the period November 1979 - May 2001. The light crude oil data consists of the period November 1983 - May 2001. The sample period for unleaded gasoline is January 1985 – April 2001. The Deutsche Mark data cover the period December 1975 - September 1999. The data are available from December 1975 – June 2001 for both the British Pound and the Swiss Franc.

As can been seen from inspection of Table 3.2, the estimated values of γ for both the spot series and the futures series of heating oil, unleaded gasoline, the British Pound, the Deutsche Mark, and the Swiss Franc are not statistically different from zero at the 5% level. Only the spot prices and the futures series of light crude oil have an estimated value of γ that is significant different from zero at the 5% level. This suggest that both $\{P_i\}$ and $\{F_i\}$ of only light crude oil are stationary.

Table 3.3 reports the results of the Augmented Dickey-Fuller tests for unit root in the autoregressive representations of the first difference of the series data of heating oil, unleaded gasoline, the British Pound, the Deutsche Mark, and the Swiss Franc. The estimated values of γ in all series data are statistically different from zero at the 5% level. This evidence suggests that $\{P_i\}$ and $\{F_i\}$ of heating oil, unleaded gasoline, the British Pound, the Deutsche Mark, and the Swiss Franc are integrated of order 1 (i.e. $I(1)$).

Table 3.4 summarizes the estimation of the parameter β for light crude oil. Since both $\{P_i\}$ and $\{F_i\}$ of light crude oil are respectively stationary, the standard regression, $F_i = \alpha + \beta\, P_i + e_i$, is used to estimate the parameter β. The estimated coefficient β of P_i equals 0.944. The adjusted R^2 of the model is approximately 98.5%.

Table 3.5 presents the results of Augmented Dickey-Fuller tests of the Residuals for Cointegration. Table 3.3 indicated that both $\{P_i\}$ and $\{F_i\}$ of heating oil, unleaded gasoline, the British Pound, the Deutsche Mark, and the Swiss Franc are integrated of order one. Therefore, it is imperative to investigate whether $\{P_i\}$ and $\{F_i\}$ are cointegrated of order (1,1). The column labeled T displays the numbers of observations. The chosen lag lengths are reported in the column n. The estimated values and t(a) are

Table 3.2
Augmented Dickey-Fuller tests for autoregressive unit roots

$$Model\ 1:\ \Delta P_i = a_0 + \gamma P_{i-1} + \sum_{j=1}^{n} \beta_j \Delta P_{i-j} + \eta_i .$$

Series (Spot Price)	T	n	a_0	t(a_0)	γ	t(γ)
Heating Oil	247	10	0.036	2.032	-0.058	-2.078
Light Crude Oil	208	1	1.674	2.819	-0.079	-2.919*
Unleaded Gasoline	191	3	0.061	2.625	-0.101	-2.668
British Pound	97	4	0.139	1.975	-0.084	-2.026
Deutsche Mark	86	8	0.030	1.691	-0.056	-1.695
Swiss Franc	97	4	0.050	2.377	-0.079	-2.357

$$Model\ 2:\ \Delta F_i = a_0 + \gamma F_{i-1} + \sum_{j=1}^{n} \beta_j \Delta F_{i-j} + \varepsilon_i .$$

Series (Futures Price)	T	n	a_0	t(a_0)	γ	t(γ)
Heating Oil	249	8	0.023	1.568	-0.036	-1.599
Light Crude Oil	208	1	1.505	2.811	-0.072	-2.897*
Unleaded Gasoline	182	12	0.068	2.334	-0.115	-2.285
British Pound	97	4	0.135	1.982	-0.082	-2.029
Deutsche Mark	86	8	0.031	1.733	-0.058	-1.740
Swiss Franc	97	4	0.053	2.465	-0.083	-2.448

T is the number of observations. n is the chosen lag length. t(a_0) and t(γ) are the ratios of the OLS estimates of a_0 and γ to their respective standard errors. Under the null of nonstationary, we use MacKinnon critical values. The value of t(γ) denoted by an (*) is smaller than the 5% one tail critical value of the distribution of t(γ).

Table 3.3
Augmented Dickey-Fuller tests for unit roots in the autoregressive representations of the first difference of the series data

$$Model\ 1:\ \Delta^2 P_i = a_0 + \gamma \Delta P_{i-1} + \sum_{j=1}^{n} \beta_j \Delta^2 P_{i-j} + \eta_i .$$

Series (Spot Price)	T	n	a_0	t(a_0)	γ	t(γ)
Heating Oil	246	10	0.000	0.007	-1.476	-4.741*
Unleaded Gasoline	190	3	0.000	0.127	-1.460	-8.475*
British Pound	96	4	-0.003	-0.373	-0.991	-4.733*
Deutsche Mark	85	8	0.000	0.095	-0.833	-2.915*
Swiss Franc	96	4	0.001	0.426	-0.890	-4.070*

$$Model\ 2:\ \Delta^2 F_i = a_0 + \gamma \Delta F_{i-1} + \sum_{j=1}^{n} \beta_j \Delta^2 F_{i-j} + \varepsilon_i .$$

Series (Futures Price)	T	n	a_0	t(a_0)	γ	t(γ)
Heating Oil	248	8	0.000	0.122	-1.459	-6.422*
Unleaded Gasoline	181	12	0.003	0.721	-1.278	-4.088*
British Pound	96	4	-0.003	-0.355	-0.958	-4.678*
Deutsche Mark	85	8	0.000	0.081	-0.803	-2.907*
Swiss Franc	96	4	0.001	0.416	-0.870	-4.051*

T is the number of observations. n is the chosen lag length. t(a_0) and t(γ) are the ratios of the OLS estimates of a_0 and γ to their respective standard errors. Under the null of nonstationary, we use MacKinnon critical values. The value of t(γ) denoted by an (*) are smaller than the 5% one tail critical value of the distribution of t(γ).

Table 3.4
Estimation of the parameter β for Light Crude Oil

$Model: F_i = \alpha + \beta\ P_i + e_i.$						
Series	T	α	t(α)	β	t(β)	$adj-R^2$
Crude Oil	210	0.976	5.433	0.944	114.633	0.984

T is the number of observations. t(α) and t(β) are the ratios of the OLS estimates of α and β to their respective standard errors.

Table 3.5
Augmented Dickey-Fuller tests of the Residuals for Cointegration

$$Model: \Delta e_i = a\, e_{i-1} + \sum_{j=1}^{n} a_{j+1}\, \Delta e_{i-j} + \varepsilon_i.$$

					Critical		Values
Series	T	n	a	t(a)	1%	5%	10%
Heating Oil	245	12	-0.567	-3.765*	-2.574	-1.940	-1.616
Unleaded Gasoline	182	12	-0.534	-2.487*	-2.576	-1.941	-1.616
British Pound	100	1	-0.345	-3.852*	-2.586	-1.943	-1.617
Deutsche Mark	90	4	-0.162	-2.427*	-2.588	-1.943	-1.617
Swiss Franc	93	8	-0.189	-2.498*	-2.588	-1.943	-1.617

T is the number of observations. n is the chosen lag length. t(a) is the ratio of the OLS estimates of a to its standard error. Under the null of nonstationary, we use MacKinnon critical values. The value of t(a) denoted by an (*) are smaller than the 5% one tail critical value of the distribution of t(a).

demonstrated in columns 4, and 5, respectively. The MacKinnon critical values for heating oil, unleaded gasoline, the British Pound, the Deutsche Mark, and the Swiss Franc at the 1%, 5%, and 10% levels are reported. All the deviations from long-run equilibrium are found to be stationary. That is, the $\{P_i\}$ and $\{F_i\}$ sequences of heating oil, unleaded gasoline, the British Pound, the Deutsche Mark, and the Swiss Franc are cointegrated of order (1,1).

Table 3.6 displays the estimation of the parameter β for heating oil, unleaded gasoline, the British Pound, the Deutsche Mark, and the Swiss Franc in an error correction system. The parameter β in model 3 is estimated for each of the series. They are 0.740, 0.957, 0.990, 0.835, and 1.014 for heating oil, the British Pound, the Deutsche Mark, unleaded gasoline, and the Swiss Franc, respectively.

Because of data limitations, a three-period version of Hilliard's (1999) general multi-period model is analyzed. Specifically, the agent wishes to hedge three-period supply commitments with the flow of one unit of commodity per period to maximize quadratic utility. In fact, longer-dated supply commitments are of most interest. However, the nature of the dataset imposes limitations on the types of studies that are possible. Ideally, a very long series would be available for testing each hedge path. The performance measurement from each path would constitute one observation. Repeating this procedure for a series of observations would generate sufficient statistics to critically evaluate the stacked hedge. However, a multi-period hedging horizon extending over several periods would require several decades of data to obtain a sufficient number of independent observations. In consideration of datasets available, I choose to evaluate the three-period hedging performance of the stacked strategy. With a period being three

Table 3.6
Estimation of the parameter β for Heating Oil, the British Pound, the Deutsche Mark, Unleaded Gasoline, and the Swiss Franc

$$Model: \Delta F_i = \alpha_1 + \alpha_2 e_{i-1} + \beta \Delta P_i + \sum_{j=1}^{m} \gamma_j \Delta F_{i-j} + \sum_{k=1}^{n} \delta_k \Delta P_{i-k} + \varepsilon_i .$$

Series:	Heating Oil	British Pound	Deutsche Mark
CONST	-0.000 (-0.46)	0.000 (0.76)	0.000 (0.17)
e_{i-1}	-0.454 (-3.44)	-0.413 (-3.78)	-0.147 (-2.08)
ΔP_i	0.740 (28.07)	0.957 (77.54)	0.990 (96.71)
ΔF_{i-1}	-0.016 (-0.12)	-0.230 (-1.84)	-0.301 (-2.45)
ΔF_{i-2}	0.013 (0.10)	-0.193 (-1.57)	-0.159 (-1.21)
ΔF_{i-3}	0.024 (0.20)	-0.008 (-0.06)	0.272 (2.15)
ΔF_{i-4}	-0.072 (-0.63)	0.027 (0.27)	0.056 (0.47)
ΔF_{i-5}	-0.200 (-1.84)		
ΔF_{i-6}	-0.088 (-0.84)		
ΔF_{i-7}	-0.271 (-2.68)		
ΔF_{i-8}	-0.153 (-1.64)		
ΔF_{i-9}	-0.297 (-3.30)		
ΔF_{i-10}	-0.224 (-2.62)		
ΔF_{i-11}	-0.021 (-0.26)		
ΔF_{i-12}	-0.071 (-1.02)		
ΔP_{i-1}	0.040 (0.32)	0.229 (1.86)	0.303 (2.48)
ΔP_{i-2}	-0.015 (-0.12)	0.188 (1.53)	0.160 (1.21)
ΔP_{i-3}	-0.016 (-0.13)	0.010 (0.09)	-0.268 (-2.12)
ΔP_{i-4}	0.003 (0.03)	-0.030 (-0.30)	-0.058 (-0.50)
ΔP_{i-5}	0.101 (0.96)		
ΔP_{i-6}	0.066 (0.66)		
ΔP_{i-7}	0.200 (2.12)		
ΔP_{i-8}	0.203 (2.31)		
ΔP_{i-9}	0.278 (3.32)		
ΔP_{i-10}	0.170 (2.15)		
ΔP_{i-11}	0.064 (0.91)		
ΔP_{i-12}	0.032 (0.56)		
T	245	97	90
$adj-R^2$	0.829	0.986	0.992

(Table 3.6 Continued)

$$Model: \Delta F_i = \alpha_1 + \alpha_2 e_{i-1} + \beta \Delta P_i + \sum_{j=1}^{m} \gamma_j \Delta F_{i-j} + \sum_{k=1}^{n} \delta_k \Delta P_{i-k} + \varepsilon_i .$$

Series:	Unleaded Gasoline	Swiss Franc
CONST	0.002 (1.11)	-0.000 (-0.84)
e_{i-1}	-0.332 (-1.97)	0.151 (2.19)
ΔP_i	0.835 (26.97)	1.014 (95.06)
ΔF_{i-1}	-0.447 (-2.59)	-0.647 (-5.39)
ΔF_{i-2}	-0.257 (-1.50)	-0.440 (-3.26)
ΔF_{i-3}	-0.099 (-0.59)	0.038 (0.26)
ΔF_{i-4}	-0.258 (-1.63)	0.220 (1.49)
ΔF_{i-5}	-0.327 (-2.16)	0.063 (0.42)
ΔF_{i-6}	-0.279 (-1.93)	0.084 (0.57)
ΔF_{i-7}	-0.329 (-2.41)	-0.180 (-1.24)
ΔF_{i-8}	-0.329 (-2.57)	-0.265 (-1.82)
ΔF_{i-9}	-0.217 (-1.82)	-0.388 (-2.66)
ΔF_{i-10}	-0.089 (-0.76)	-0.164 (-1.09)
ΔF_{i-11}	-0.263 (-2.49)	0.095 (0.60)
ΔF_{i-12}	-0.055 (-0.58)	0.239 (1.78)
ΔP_{i-1}	0.382 (2.34)	0.670 (5.50)
ΔP_{i-2}	0.229 (1.42)	0.443 (3.21)
ΔP_{i-3}	0.110 (0.71)	-0.053 (-0.35)
ΔP_{i-4}	0.222 (1.48)	-0.221 (-1.47)
ΔP_{i-5}	0.223 (1.57)	-0.061 (-0.40)
ΔP_{i-6}	0.241 (1.79)	-0.073 (-0.49)
ΔP_{i-7}	0.273 (2.14)	0.182 (1.24)
ΔP_{i-8}	0.257 (2.20)	0.268 (1.81)
ΔP_{i-9}	0.214 (1.95)	0.391 (2.65)
ΔP_{i-10}	0.134 (1.27)	0.167 (1.10)
ΔP_{i-11}	0.215 (2.30)	-0.093 (-0.58)
ΔP_{i-12}	0.059 (0.73)	-0.242 (-1.78)
T	182	89
$adj-R^2$	0.823	0.995

months, this gives four independent observations per year. For my dataset of heating oil, this procedure produces about 86 independent observations.

Five alternative models for choosing hedge ratios are considered to evaluate how well a long-term exposure to asset prices can be hedged using a stacked hedge. The first model follows from Hilliard's (1999) setup. The second model extends the first model by allowing for variable instantaneous net convenience yield. The third model extends the first model by allowing for both interest rates and convenience yields to be stochastic. The fourth model uses time-series regression to derive the new hedge path. The last model is known as the naïve strategy apparently used by MGRM.

3.4.1 The Hedging Portfolio

Hedging portfolios are formed assuming that a unit flow of the asset is to be hedged at the end of each of the next three periods, e.g. one barrel of crude oil is to be bought at the end of each period. The strip hedge is used as a benchmark. With the strip hedge, three units of flow are purchased in the futures market with contracts of length one, two, and three periods. Each contract is for one unit of product. Thus, under price convergence, future cash flows are completely determined. The hedge error (HE) for model *i* is defined as the absolute value of the difference in percentage cumulative future cash flows between the candidate strategy (CF_i) and the benchmark (CF_b).

$$(30)\quad HE = \left| \frac{CF_i - CF_b}{CF_b} \right| x100.$$

Hedge performance (HP) is defined as follows:

$$(31)\quad HP = 1 - \frac{Var(HE_{Candidate\ Model})}{Var(HE_{Unhedged})}.$$

Table 3.7 presents the three-period hedging performance for heating oil. The volatility of the percentage difference in cash flows between the unhedged position and the strip hedge portfolio equals 7.4185%. Model 1 requires a total trading of 5.9571 units. Under this model, 80.76% of the spot price risk is reduced. Model 2 performs slightly worse. The risk reduction is 79.64%. This strategy requires an overall trading of 5.9788 units. Model 3 needs much less trading (4.8857 units are traded) and has the best performance with a 92.15% reduction. Model 4 has a risk reduction of 81.38% and the overall position to be initiated is 5.8551 units. Model 5 requires the most intensive trading and has the lowest hedging performance. Overall, Model 3 performs best as it requires the smallest position, and has the lowest standard deviation of hedging error.

Table 3.8 displays the hedging performance for light crude oil. Each of the five models has comparable trading positions and similar hedge performances. The average hedge performance of the models is 0.9576. Model 3 has the smallest standard deviation of hedge errors. Table 3.9 provides similar implications. Model 3 has the best performance and requires minimum hedging positions. The mean of hedge performances for the five models equals 0.9651.

Table 3.10 reports the hedging effectiveness for the British Pound. The five models show a nearly perfect hedge. The risk reduction ranges from 0.9783 to 0.9815. The average risk reduction of the five models is approximately 98 percent. In addition, the hedge positions across these models do not differ significantly.

Table 3.11 reports the hedging performance for the Deutsche Mark. The results are similar to but than better those for the British Pound. All of the five models have

Table 3.7
Comparison of Three-Period Hedging Performance for Heating Oil

Period No.	Unhedged	Stacked Hedge Model 1	2	3	4	5	Strip Hedge
1	0	2.9684	2.9841	2.1869	2.9276	3	3
2	0	1.9888	1.9947	1.6988	1.9517	2	0
3	0	1.0000	1.0000	1.0000	0.9759	1	0
Gross Position	0	5.9571	5.9788	4.8857	5.8551	6	3
SD of HE (%)	7.4185	3.2538	3.3471	2.0509	3.2015	3.3816	0
HP	0	0.8076	0.7964	0.9215	0.8138	0.7922	1
No. of Observations	86	86	86	86	86	86	86

The stack hedge consists of a single one-period contract that is rolled every period. Model 1 follows from Hilliard's (1999) setup. Model 2 extends Model 1 by allowing for variable instantaneous net convenience yield. Model 3 extends Model 1 by allowing for both interest rates and convenience yields to be stochastic. Model 4 uses time-series regression to derive the new hedge path. Model 5 is known as the naïve strategy used by MGRM. The strip hedge uses one-, two-, and three-period contracts simultaneously.

The hedge is executed from November 1979 to May 2001. I assume that the supply flow commitment of one unit of commodity per period occurs. For each strategy the average positions in futures contracts, the Standard Deviation of the Hedge Error (SD of HE), and Hedging Performance (HP) are reported. The hedge error is defined as the absolute value of the difference in percentage cumulative future cash flows between the candidate strategy and the benchmark strip hedge. $HP = 1 - \frac{Var(HE_{Candidate\ Strategy})}{Var(HE_{Unhedged})}$.

Table 3.8
Comparison of Three-Period Hedging Performance for Light Crude Oil

Period No.	Unhedged	Stacked Hedge Model 1	2	3	4	5	Strip Hedge
1	0	2.9777	2.9870	2.8222	2.9029	3	3
2	0	1.9922	1.9957	1.9395	1.9353	2	0
3	0	1.0000	1.0000	1.0000	0.9676	1	0
Gross Position	0	5.9700	5.9827	5.7617	5.8059	6	3
SD of HE (%)	8.0781	1.5614	1.7917	1.5053	1.6122	1.8216	0
HP	0	0.9626	0.9508	0.9653	0.9602	0.9492	1
No. of Observations	70	70	70	70	70	70	70

The stack hedge consists of a single one-period contract that is rolled every period. Model 1 follows from Hilliard's (1999) setup. Model 2 extends Model 1 by allowing for variable instantaneous net convenience yield. Model 3 extends Model 1 by allowing for both interest rates and convenience yields to be stochastic. Model 4 uses time-series regression to derive the new hedge path. Model 5 is known as the naïve strategy used by MGRM. The strip hedge uses one-, two-, and three-period contracts simultaneously.

The hedge is executed from November 1983 to May 2001. I assume that the supply flow commitment of one unit of commodity per period occurs. For each strategy the average positions in futures contracts, the Standard Deviation of the Hedge Error (SD of HE), and Hedging Performance (HP) are reported. The hedge error is defined as the absolute value of the difference in percentage cumulative future cash flows between the candidate strategy and the benchmark strip hedge. $HP = 1 - \frac{Var(HE_{Candidate\ Strategy})}{Var(HE_{Unhedged})}$.

Table 3.9
Comparison of Three-Period Hedging Performance for Unleaded Gasoline

Period No.	Unhedged	Stacked Hedge Model 1	2	3	4	5	Strip Hedge
1	0	2.9920	2.9872	2.5235	2.9276	3	3
2	0	1.9963	1.9957	1.8317	1.9517	2	0
3	0	1.0000	1.0000	1.0000	0.9759	1	0
Gross Position	0	5.9883	5.9830	5.3551	5.8552	6	3
SD of HE (%)	9.5405	1.7832	1.9349	1.3819	1.9775	0	0
HP	0	0.9651	0.9589	0.9790	0.9655	0.9570	1
No. of Observations	65	65	65	65	65	65	65

The stack hedge consists of a single one-period contract that is rolled every period. Model 1 follows from Hilliard's (1999) setup. Model 2 extends Model 1 by allowing for variable instantaneous net convenience yield. Model 3 extends Model 1 by allowing for both interest rates and convenience yields to be stochastic. Model 4 uses time-series regression to derive the new hedge path. Model 5 is known as the naïve strategy used by MGRM. The strip hedge uses one-, two-, and three-period contracts simultaneously.

The hedge is executed from January 1985 to April 2001. I assume that the supply flow commitment of one unit of commodity per period occurs. For each strategy the average positions in futures contracts, the Standard Deviation of the Hedge Error (SD of HE), and Hedging Performance (HP) are reported. The hedge error is defined as the absolute value of the difference in percentage cumulative future cash flows between the candidate strategy and the benchmark strip hedge. $HP = 1 - \frac{Var(HE_{Candidate\ Strategy})}{Var(HE_{Unhedged})}$.

Table 3.10
Comparison of Three-Period Hedging Performance for the British Pound

Period No.	Unhedged	Stacked Hedge Model 1	2	3	4	5	Strip Hedge
1	0	2.9343	2.8661	2.8263	2.9227	3	3
2	0	1.9779	1.9835	1.9411	1.9484	2	0
3	0	1.0000	1.0000	1.0000	0.9742	1	0
Gross Position	0	5.9122	5.8496	5.7674	5.8453	6	3
SD of HE (%)	4.2493	0.5774	0.5901	0.6259	0.5773	0.5931	0
HP	0	0.9815	0.9807	0.9783	0.9815	0.9805	1
No. of Observations	34	34	34	34	34	34	34

The stack hedge consists of a single one-period contract that is rolled every period. Model 1 follows from Hilliard's (1999) setup. Model 2 extends Model 1 by allowing for variable instantaneous net convenience yield. Model 3 extends Model 1 by allowing for both interest rates and convenience yields to be stochastic. Model 4 uses time-series regression to derive the new hedge path. Model 5 is known as the naïve strategy used by MGRM. The strip hedge uses one-, two-, and three-period contracts simultaneously.

The hedge is executed from December 1975 to June 2001. I assume that the supply flow commitment of one unit of commodity per period occurs. For each strategy the average positions in futures contracts, the Standard Deviation of the Hedge Error (SD of HE), and Hedging Performance (HP) are reported. The hedge error is defined as the absolute value of the difference in percentage cumulative future cash flows between the candidate strategy and the benchmark strip hedge. $HP = 1 - \frac{Var(HE_{Candidate\ Strategy})}{Var(HE_{Unhedged})}$.

Table 3.11
Comparison of Three-Period Hedging Performance for the Deutsche Mark

Period No.	Unhedged	Stacked Hedge Model 1	2	3	4	5	Strip Hedge
1	0	2.9650	3.0301	2.9179	2.9484	3	3
2	0	1.9883	1.9836	1.9720	1.9656	2	0
3	0	1.0000	1.0000	1.0000	0.9828	1	0
Gross Position	0	5.9533	6.0136	5.8899	5.8969	6	3
SD of HE (%)	4.5127	0.2732	0.3037	0.3531	0.2708	0.3319	0
HP	0	0.9963	0.9955	0.9939	0.9964	0.9946	1
No. of Observations	32	32	32	32	32	32	32

The stack hedge consists of a single one-period contract that is rolled every period. Model 1 follows from Hilliard's (1999) setup. Model 2 extends Model 1 by allowing for variable instantaneous net convenience yield. Model 3 extends Model 1 by allowing for both interest rates and convenience yields to be stochastic. Model 4 uses time-series regression to derive the new hedge path. Model 5 is known as the naïve strategy used by MGRM. The strip hedge uses one-, two-, and three-period contracts simultaneously.

The hedge is executed from November 1979 to May 2001. I assume that the supply flow commitment of one unit of commodity per period occurs. For each strategy the average positions in futures contracts, the Standard Deviation of the Hedge Error (SD of HE), and Hedging Performance (HP) are reported. The hedge error is defined as the absolute value of the difference in percentage cumulative future cash flows between the candidate strategy and the benchmark strip hedge. $HP = 1 - \frac{Var(HE_{Candidate\ Strategy})}{Var(HE_{Unhedged})}$.

nearly perfect performance – the hedge performance, on average, is higher than 0.99. Table 3.12 provides additional and stronger evidence that stacked hedges with investment assets perform nearly as well as strip hedges.

Table 3.13 demonstrates the relation between average deviation from the cost-of-carry (CC) model and hedging performance (HP) for three commercial commodities and three investment assets. The commercial commodities are heating oil, light crude oil, and unleaded gasoline. The investment assets include the British Pound, the Deutsche Mark, and the Swiss Franc. The deviation from the cost-of-carry model is defined as follows:

$$(32)\ \ d = \left| \frac{\sum_{i=1}^{n-1} (F_i - \beta\, P_i) \exp(f_{i+1,n-i-1} \Delta \cdot (n-1-1)) x_i^*}{V_0^*} \right|,$$

where

$$(33)\ \ V_0^* = F_0 \Big(\sum_{i=1}^{n} m_i \exp(f_{i,n-i} \Delta \cdot (n-i)) \beta^{i-1}\Big) - \sum_{i=1}^{n-1} (F_i - \beta\, P_i) \exp(f_{i+1,n-i-1} \Delta \cdot (n-i-1) x_i^* .$$

I report hedge performance for each of the five stacked hedge models. The evidence suggests that stacked hedges perform better with investment assets than with commercial commodities. The investment assets have better hedge performance: 0.9805 for the British Pound, 0.9953 for the Deutsche Mark, and 0.9937 for the Swiss Franc. The commercial commodities have lower hedge performance. The mean hedge performance for commercial commodities range from 0.8263 for heating oil to 0.9651 for unleaded gasoline.

My analysis indicates that the average deviation from the cost-of-carry model for commercial commodities is higher than the corresponding measure for investments assets. The average deviation from cost of carry for heating oil is 23.1504 percent, which

Table 3.12
Comparison of Three-Period Hedging Performance for the Swiss Franc

Period No.	Unhedged	Stacked Hedge Model 1	2	3	4	5	Strip Hedge
1	0	2.9769	3.0984	2.9899	2.9227	3	3
2	0	1.9923	1.9835	1.9968	1.9484	2	0
3	0	1.0000	1.0000	1.0000	0.9742	1	0
Gross Position	0	5.9692	6.0819	5.9867	5.8453	6	3
SD of HE (%)	4.5562	0.3376	0.3817	0.3937	0.3219	0.3631	0
HP	0	0.9945	0.9930	0.9925	0.9950	0.9936	1
No. of Observations	34	34	34	34	34	34	34

The stack hedge consists of a single one-period contract that is rolled every period. Model 1 follows from Hilliard's (1999) setup. Model 2 extends Model 1 by allowing for variable instantaneous net convenience yield. Model 3 extends Model 1 by allowing for both interest rates and convenience yields to be stochastic. Model 4 uses time-series regression to derive the new hedge path. Model 5 is known as the naïve strategy used by MGRM. The strip hedge uses one-, two-, and three-period contracts simultaneously.

The hedge is executed from December 1975 to June 2001. I assume that the supply flow commitment of one unit of commodity per period occurs. For each strategy the average positions in futures contracts, the Standard Deviation of the Hedge Error (SD of HE), and Hedging Performance (HP) are reported. The hedge error is defined as the absolute value of the difference in percentage cumulative future cash flows between the candidate strategy and the benchmark strip hedge. $HP = 1 - \frac{Var(HE_{Candidate\ Strategy})}{Var(HE_{Unhedged})}$.

Table 3.13
Average Deviation from the CC Model and Hedge Performance

Assets	β	Average Deviation (%)	Stacked Hedge Model 1	2	3	4	5	Mean of HP
Commercial Commodity								
Heating Oil	0.7402	23.1504	0.8076	0.7964	0.9215	0.8138	0.7922	0.8263
Light Crude Oil	0.9442	4.7492	0.9626	0.9508	0.9653	0.9602	0.9492	0.9576
Unleaded Gasoline	0.8358	14.5539	0.9651	0.9589	0.9790	0.9655	0.9570	0.9651
Investment Asset								
British Pound	0.9578	3.7139	0.9815	0.9807	0.9783	0.9815	0.9805	0.9805
Deutsche Mark	0.9904	1.6163	0.9963	0.9955	0.9939	0.9964	0.9946	0.9953
Swiss Franc	1.0145	0.8255	0.9945	0.9930	0.9925	0.9950	0.9936	0.9937

This table reports β, Hedge Performance (HP), and the mean deviation (d) from the cost-of-carry (CC) model for three commercial commodities and three investment assets. The commercial commodities are heating oil, light crude oil, and unleaded gasoline. The investment assets include British Pound, Deutsche Mark, and Swiss Franc. β is the estimated parameter from Model 3. Mean Deviation from CC is the average deviation of futures prices from that predicted by the cost-of-carry model.

Specifically, $d = \left| \dfrac{\sum_{i=1}^{n-1} (F_i - \beta P_i) \exp(f_{i+1,n-i-1} \Delta \cdot (n-i-1)) x_i^*}{V_0^*} \right|$, where V_0^* is the terminal cash flows at the end of period n.

$$HP = 1 - \frac{Var(HE_{Candidate\ Strategy})}{Var(HE_{Unhedged})}.$$

Table 3.14
Hedge Error and Average Deviation from the CC Model

		$Model: HE_t = \alpha + \lambda d_t^* + \varepsilon_t$.			
Assets	T	α	t(α)	λ	t(λ)
Heating Oil	86	0.009	2.574*	0.097	3.679*
Light Crude Oil	70	0.003	1.908	0.010	8.481*
Unleaded Gasoline	65	0.011	4.833*	0.091	2.437*
British Pound	34	0.004	3.019*	0.014	0.395
Deutsche Mark	32	0.003	4.222*	0.035	0.520
Swiss Franc	34	0.004	4.019*	0.028	0.522

T is the number of observations. t(α) is the ratio of the OLS estimates of α to its standard error. The value of t(α) denoted by an (*) are smaller than the 5% one tail critical value of the distribution of t(α).

$$d_t^* = \left| \sum_{i=1}^{n-1} (F_i - \beta P_i) \exp(f_{i+1,n-i-1} \Delta \cdot (n-i-1)) x_i^* - \bar{d} \right|,$$

where

$$\bar{d} = \frac{\sum_{t=1}^{T} d_t}{T} \text{ and } d_t = \sum_{i=1}^{n-1} (F_i - \beta P_i) \exp(f_{i+1,n-i-1} \Delta \cdot (n-i-1)) x_i^* .$$

is followed by 14.5539 percent for unleaded gasoline, 4.7492 percent for light crude oil, 3.7139 percent for the British Pound, 1.6163 percent for the Deutsche Mark, and 0.8255percent for the Swiss Franc.

To formally test my hypothesis that the significant differences in hedging performance between commercial commodities and investment assets are attributed to the stochastic nature of instantaneous net convenience yields, I test the regression model as follows:

(34) $HE_t = \alpha + \lambda d_t^* + \varepsilon_t$,

where $d_t^* = \left| d_t - \bar{d} \right|,\ \bar{d} = \frac{\sum_{t=1}^{T} d_t}{T}$, *and* T is the number of hedging observations.

The null hypothesis is $H_0 : \lambda \leq 0$. If the null hypothesis is rejected, there is sufficient evidence to conclude that assets with high convenience yields yield larger hedge errors in the multi-period stacked hedge.

As can been see from inspection of Table 3.14, the estimated values of λ for heating oil, light crude oil, and unleaded gasoline are positive and statistically different from zero. This evidence is consistent with my hypothesis that a stochastic representation of instantaneous net convenience yields results in pronounced deviations from the theoretical spot-futures parity resulting in non-trivial hedge errors. Since investment assets have little or no convenience yields while commercial commodities have non-trivial convenience yields, stacked hedges perform better with investment assets than with commercial commodities. However, the estimated values of λ for the British Pound, Deutsche Mark, and Swiss Franc are not statistically different from zero. A possible explanation of these results is that investment assets have little or no convenience yields so that they do not retain sufficient time-serial variation in the deviation term, which is predicted to be positively related to hedge error. Caution is also needed in interpreting the estimated values of λ for the Deutsche Mark and Swiss Franc because their series of $\{HE_t\}$ and $\{d_t\}$ are integrated of different orders. These results suggest that their residual sequences in the regression model contain a stochastic trend and thus those estimated values of λ are not consistent.

3.5 Conclusions

The strip hedge strategy provides a perfect hedge under price convergence. However, there is not always sufficient volume and liquidity in distant contracts to make the strip hedge economically feasible. This chapter compares different versions of the stacked hedge with the strip hedge. Empirical evidence suggests that stacked hedges perform better with investment assets than with commercial commodities. For investment assets, the hedging performance of the stacked hedge approaches that of the strip hedge. Empirical evidence shows that a stochastic representation of convenience yields result in pronounced deviations from the spot-futures parity resulting in non-trivial hedge errors.

This study also sheds light on the MGRM controversy. The press and the financial economics literature have discussed extensively the debacle of MGRM. One of the main problems is that because MGRM was unable to meet maintenance margins, the tremendous paper losses became realized. My study suggests that MGRM's tremendous losses were also related to an ineffective hedging strategy. Since most contracts tended to be of short maturity, MGRM hedged its long-term exposures to the prices of crude oil, heating oil, and gasoline by sequentially stacking nearby futures contracts until the end of its hedging horizon. My results suggest that rolling short-term futures contracts exposes MGRM to substantial rollover risk.

In summary, the stacked hedge is effective when the spot-futures relationship depends on no additional state variables. If other state variables are present, the stacked hedge can generally produce some risk reduction, but more effective strategies might require multiple contracts of different maturities as suggested by Neuberger (1999) and Schwartz (1997).

CHAPTER 4

CONCLUSIONS

This dissertation contributes to the corporate hedging literature along two dimensions. First, it empirically analyzes the determinants of corporate use of linear and nonlinear hedging instruments. Second, it evaluates how well long-term exposures to assets prices can be neutralized using a stacked hedge with applications to three commercial commodities and to three investment assets.

It presents an exploratory study on why firms use linear or nonlinear derivative contracts. This study answers two main questions. First, what induces firms to adopt nonlinear derivatives or linear securities? Second, what determines the extent of linear and nonlinear hedging by corporations that undertake linear and nonlinear devices? The results of cross-sectional regression using Tobit and Probit models indicate that the determinants that motivate firms to use linear and nonlinear derivative instruments significant affect the extent to which firms use linear and nonlinear derivative vehicles. Overall, my evidence is consistent with the previous studies that both value maximization and personal incentives affect corporate hedging policy.

I find several interesting results that support the shareholder-value-maximization paradigm. First, I document that nonlinear derivative usage is positively related to investment opportunity. This finding suggests that firms with greater investment opportunities use nonlinear devices to reduce downside risk but also preserve positive gains derived from the enhanced investment opportunity sets. Second, the use of nonlinear derivatives increases with firm size. This evidence is consistent with the notion that larger corporations have more resources to invest in sophisticated systems and personnel required to manage more complex nonlinear derivatives. Third, free cash flow is positive related with the notional values of both linear and nonlinear contracts and the proportion of nonlinear derivative contracts in the hedge portfolio. These results suggest that internal cash allows firms to use nonlinear derivatives to maintain upside potential for shareholders without incurring the higher costs of external financing. Finally, I find a positive relation between the use of nonlinear hedging and the prospect of financial distress, measured as leverage, industry-adjusted leverage, Z-score, and coverage ratio. This evidence suggests that firms facing the prospect of financial distress attempt to mitigate the underinvestment problem by using derivatives that can maintain upside potential for shareholders. The absence of a negative relation between the use of a nonlinear strategy and convertible debt lends no support to the hypothesis that firms use nonlinear contracts at the expense of debtholders.

Additionally, I document results that are consistent with the agency theory. I find a positive relation between the use of nonlinear mechanism and stock option awards, but a negative relation between bonus plans and nonlinear usage. The positive relation with stock option awards suggests that managers who receive more compensation from stock options have greater incentives to implement a nonlinear strategy to raise the value of their stock options. The negative relation with bonus plans suggests that managers are less likely to use nonlinear financial instruments when his bonus payments are at or near the cap. Overall, these findings suggest that the incentive compensation structure affects the hedging decision. Inefficient contracts lead to inefficient policies. I find a negative relation between CEO tenure and the use of nonlinear hedging. This result suggests that managerial risk aversion or management's lack of familiarity with sophisticated derivatives reduces nonlinear usage.

This dissertation also sheds light on the effectiveness of stacked hedges, which Metallgesellsahft Refining & Marketing (MGRM) used to manage its exposures to oil prices.

Empirical evidence indicates that stacked hedges perform better with investment assets than with commercial commodities. For investment assets, the hedging performance of stacked hedge approaches that of strip hedge. The stacked hedge produces R^2 of at least 0.98 for investment assets while it produces R^2 of less than 0.83 for heating oil. These results are consistent with my hypothesis that two classes of assets are attributed to the stochastic nature of marginal convenience yields of commercial commodities.

My results provide some implications for the MGRM controversy. One of the main problems is that because MGRM was unable to meet maintenance margins, the tremendous paper losses in derivative contracts became realized. My evidence suggests that MGRM's losses were also related to an ineffective hedging strategy. If MGRM had implemented a strip hedge, it would have had no exposures to oil prices. Instead, it sequentially stacked nearby futures contracts until the end of the hedging problem to insulate the profit margins in its fixed-price commitment from its exposure to spot price increases. Rolling short-term futures contracts exposed MGRM to substantial roller risk.

In summary, this dissertation provides evidence that value maximization and managerial incentives motivate the use of linear and nonlinear derivatives by corporations. It also presents evidence that the stacked hedge is effective when hedges assets obey the spot-futures parity. If other state variables such as convenience yields are present, the stacked hedge can generally reduce some risks, but more effective strategies require a strip of derivative contracts corresponding to the maturity of a delivery date.

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