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Does executive portfolio structure affect risk management? CEO risk-taking incentives and corporate derivatives usage

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Abstract

This paper extends the investigation of the effect of managerial motives on hedging policy. I utilize a proxy variable that incorporates CEO incentives to increase risk relative to incentives to increase stock price. The variable is directly measured using observed characteristics of CEO portfolios of stock and option holdings. Furthermore, CEO risk-taking incentives are modeled as a choice variable to eliminate the simultaneity bias of modeling risk-taking incentives as an exogenous variable. If modeled as a simultaneous system of equations, a strong negative link between CEO risk-taking incentives and the amount of derivative holdings exists. This result is consistent with the notion that derivatives are used for hedging purposes. Both the characteristics of stock and option holdings are important in determining cross-sectional differences in corporate derivative holdings. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Risk management theory provides several rationales as to why shareholders may view corporate hedging favorably. Tax incentives (Smith and Stulz, 1985; Leland, 1998) and reduction of underinvestment/distress costs (Smith and Stulz, 1985; Bessembinder, 1991; Froot et al., 1993) are commonly cited rationales for hedging by publicly held corporations. However, a firm's managers actually make the risk management decision, therefore the risk-taking incentives of managers may be an important determinant of corporate hedging policy (see Stulz, 1984; Smith and Stulz, 1985; Tufano, 1996).

This paper contributes to the corporate hedging literature by analyzing the risk-taking incentives of CEOs from stock and option holdings in relation to the derivative holdings of their firms. I frame the study in a setting in which risk-taking incentives are modeled as an endogenous variable. The modeling structure follows naturally from Smith and Stulz (1985) and Tufano (1996), who both recognize the nature of these two decisions. However, all prior empirical work in corporate hedging has modeled risk-taking incentives with exogenous variables. These works include Tufano (1996), Géczy et al. (1997), and Haushalter (2000).

Additionally, the analysis utilizes a more comprehensive measure of managerial risk-taking incentives than prior empirical studies of risk management. Core and Guay (2000) present a methodology for measuring the incentive effects arising from executive stock and option holdings. I use their methodology to estimate CEO incentives to increase equity risk and price.

In this paper, I examine the degree to which CEO risk-taking incentives are related to corporate derivatives usage. If CEO incentives are assumed to be exogenous, net derivative holdings are negatively related to risk-taking incentives at weak levels of statistical significance. This result is consistent with the notion that corporations hold derivatives for hedging purposes. Further, the lack of results suggesting managerial motives as a determinant of hedging in other cross-sectional studies (see Géczy et al., 1997; Gay and Nam, 1998; Allayannis and Ofek, 2001) may be a result of the use of less precise proxy variables.

The paper also examines CEO risk-taking incentives in models suggested by compensation literature. The predicted value from such models shows little significance in explaining differences in derivative holdings. Further analysis suggests that modeling of CEO risk-taking incentives should include the firm's derivatives choice as an explanatory variable. When a system of simultaneous equations is estimated, CEO incentives and derivatives hedging are negatively related to one another at strong levels of statistical significance.

The paper is organized as follows: Section 2 provides an overview of the basic relation between risk, risk-taking incentives, and derivatives usage. In Section 3, empirical models of corporate hedging and CEO risk-taking incentives are put forth, the dependent and explanatory variables are motivated, and the hypotheses are developed. Section 4 explains the sample construction. Section 5 explores the empirical relation between risk-taking incentives and corporate derivatives usage. Summarizing comments follow in Section 6.

2. Hedging and CEO risk-taking incentives

The nature of the relation between managerial incentives and risk management is complex. In the framework of prior empirical hedging studies, the manager's portfolio structure (stock and option holdings) is considered a determinant of the corporate risk management choice. For example, the commonly held view is that executive stock options provide the holder with a disincentive to hedge (i.e., Smith and Stulz, 1985). However, risk also impacts the compensation decision (i.e., how much equity-based compensation does the CEO receive?). The CEO of a riskier firm may require a higher risk premium (Stulz, 1996), as well as lower pay-performance sensitivity (Aggarwal and Samwick, 1999). Thus, an interdependent relation exists between risk management and executive compensation. In this section of the paper, I review the relations between compensation and risk management and also between risk and compensation structure.

2.1. Managerial incentives to manage risk

Two theoretical studies lay the groundwork for examining the link between risk management and executive compensation. Stulz (1984) and Smith and Stulz (1985) describe the nature of the relation. The empirical evidence from Tufano (1996) study of hedging by gold mining firms suggests that managerial risk aversion (primarily related to components of stock and option holdings) is a major determinant of risk management policy, however this relation has not been confirmed in broader-based samples.

Stulz (1984) models the currency hedging policy of a risk-averse manager in a perfect markets environment. The manager maximizes expected utility over his lifetime. The model assumes a compensation contract has been agreed upon, and furthermore, that the contract correctly aligns management incentives with those of shareholders. Because markets are perfect, shareholders are indifferent about hedging currency risk. However, fluctuations in currency values increase firm value volatility. The manager's risk aversion leads him to hedge because his compensation is a function of firm value.

Smith and Stulz (1985) suggest that shareholders can affect management's risk aversion through the design of compensation contracts. Given that a manager's utility function is concave in expected wealth, shareholders may structure compensation in a way to counteract the effects of risk aversion.

Specifically, compensation may be structured as a linear, concave, or convex function of firm value. A linear contract (i.e., the manager is paid in shares of stock) forces utility to be concave in firm value. The same result is obviously true of a concave compensation contract. If utility is concave in firm value, the manager possesses utility maximizing incentives to reduce risk. On the other hand, a convex compensation contract suggests that the manager's utility is less concave in firm value. Depending on the extent of convexity in the contract, the manager could be induced into less risk averse, risk-neutral, or even risk-seeking behavior.

Tufano (1996) provides the primary evidence that managerial motives are a determinant of hedging policy. However, Tufano's analysis is not consistent with his argument that compensation and hedging are simultaneously determined financial policies (see p. 1120). He assumes managers' stock and option holdings are exogenous, rather than choice, variables in tests of the determinants of risk management. Furthermore, Tufano's result that option holdings are negatively related to hedging is difficult to interpret. For example, deep in-the-money options provide weak risk-taking incentives, while out-of-the-money options provide far more. Guay (1999) illustrates that the number of options explains only a relatively small portion of the holder's incentives to alter risk.

Schrand and Unal (1998) examine the relation between risk management and managerial security holdings by managers of thrift institutions that convert from mutual to stock firms. They study the time series patterns of stock return volatility, interest rate risk (defined as the one-year gap), and credit risk (defined as the proportion of commercial loans). They find that firms with managers who are granted options at conversion experience significantly greater return volatility as opposed to firms whose managers receive no options. Additionally, lower total return volatility is experienced by firms whose managers purchase relatively more stock at the time of conversion.

Other empirical studies of hedging fail to find any significant evidence of managerial motives determining risk management. These studies include Géczy et al. (1997), Gay and Nam (1998), Allayannis and Ofek (2001), and Haushalter (2000). Like Tufano (1996), these studies utilize imprecise variables to proxy for managerial motives, and furthermore, treat compensation variables as exogenous.

2.2. Risk and stock-based compensation

Principal–agent theory (Grossman and Hart, 1983, for an example of a principal–agent model) provides a solid theoretic foundation for understanding the structure of managerial compensation. In the absence of unobservable action(s), shareholders optimally base some portion of the manager's compensation on a signal that is indicative of her productivity. Empirical studies of executive compensation (Jensen and Murphy, 1990) typically assume stock price is this signal, and as such, examine stock-based compensation.

The basic framework of principal–agent models assumes a risk-neutral principal (shareholders) and a risk-averse manager. The optimal contract in this setting typically includes a risk premium (above the first-best contract) to induce the correct action choice by the manager. Given the manager's risk aversion, a riskier firm (one whose signal is a relatively noisy proxy for the manager's action choice) will need to pay, not only a larger risk premium, but also a lesser proportion of stock-based compensation.

Two studies address the relation between risk and pay-performance sensitivity. Garen (1994) examines the relation between CEO pay-performance sensitivity and different risk measures. He finds negative relations between proxies for risk (R&D expenditures and standard deviations of the residuals from market model regressions interacted with firm size) and pay-performance sensitivity. However, the statistical significance of Garen's tests is typically weak. Aggarwal and Samwick (1999) test the relation between the variation of stock return volatility and pay-performance sensitivity. They find that pay-performance sensitivity declines in the level of stock return variance. The basic results from these studies suggest that equity-based compensation may be a decreasing function of risk.

However, given that option-based incentives become more valuable with increases in risk, it seems conceivable that executives at risky firms may desire option compensation. Guay (1999) finds that stock return volatility is a positive function of CEO incentives to increase risk (as measured by their stock and option portfolios). While this evidence runs in the opposite direction (i.e., higher incentives to increase risk are associated with higher risk levels), it suggests that high ex ante risk levels may be attractive for less risk averse executives. In turn, these executives may desire riskier pay packages. In such a scenario, risk-taking incentives associated with compensation may be a positive function of ex ante risk level.

3. Hypothesis development and variables

The basic purpose of this paper is to examine the relation between risk-taking incentives and corporate risk management choices. The structure of the test may be expressed by the following system:

$$\text{CEO risk-taking incentives}_t = f(\text{ex ante risk, control variables}), \tag{1}$$

$$\text{Extent of risk management}_t = f(\text{risk-taking incentives, control variables}). \tag{2}$$

Eq. (1) provides a specification for measuring the amount of risk-taking incentives as a function of the risk faced by the CEO. Eq. (2) specifies the manager's choice of risk management given the CEO's risk-taking incentives determined in Eq. (1). The dependent and explanatory variables utilized in each model are discussed in detail in Section 3.1.

3.1. Definition of variables – risk management model

3.1.1. Extent of risk management

Theoretical work in risk management suggests that corporate taxes, costs of underinvestment and financial distress, managerial motives, and information asymmetry may provide a value-maximizing corporation with rationales to alter risk. [1] Based on prior theoretical and empirical work in risk management, I model risk management with derivatives as a function of the following measures: (1) managerial motive proxies, (2) growth opportunity proxies, (3) financial distress cost proxies, (4) information asymmetry proxies, and (5) firm size. [2]

The prior empirical work in risk management makes use of several different proxies to measure risk management. I consider three proxies from prior cross-sectional work: (1) a binary variable indicating interest rate (IR) or foreign currency (FX) derivatives use, (2) total notional value of IR and FX derivative contracts scaled by book value of assets, and (3) net notional value of IR and FX derivative contracts scaled by book value of assets. [3] The net derivatives variable is determined by taking absolute differences between the notional values of derivative holdings of the same category (i.e., IR, British pound, etc.), but that will experience opposite value changes as the value of the underlying asset changes.

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[1] Stulz (1984), Smith and Stulz (1985), DeMarzo and Duffie (1991), Bessembinder (1991), Froot et al. (1993), and Leland (1998) provide models of optimal risk management.

[2] The reader may note that we do not discuss tax convexity motives for hedging. Graham and Rogers (2001) found, using a precise measure of tax function convexity on the same sample of firms used in this study, that this rationale is not an empirically important determinant of corporate derivative holdings. All of the reported tests were run with the tax convexity measure used in Graham and Rogers (2001) included. The inclusion does not alter reported results, but does decrease the number of observations significantly. Thus, I choose to report results excluding the tax convexity variable.

[3] The binary variable approach is used exclusively in Nance et al. (1993), Mian (1996), and Géczy et al. (1997). Gay and Nam (1998) and Allayannis and Ofek (2001) use total notional values in their studies. Graham and Rogers (2001) construct measures of net notional values to allow for the possibility of offsetting contracts.

I utilize net notional values in all regression specifications as the proxy of derivatives hedging. [4] Unlike a binary variable, the use of the net notional variable allows for cross-sectional variation in the amount of risk management. Net notional values may provide a less noisy proxy than total notional values because this variable takes into account the effect of holding both "long" and "short" positions in similar derivative contracts.

3.1.2. Managerial motives

Prior research in risk management has utilized relatively simple proxies of managerial motives. For example, Tufano (1996) finds that hedging by gold mining firms is positively related to the value of executive stock holdings and negatively related to the number of stock options held by managers. Other studies have utilized these types of variables in cross-sectional studies (Géczy et al., 1997), and find no relation between managerial motives and hedging. However, as illustrated by Guay (1999), these simple proxies provide relatively weak explanations for the risk-taking incentives of managers. Core and Guay (2000) develop a methodology for measuring managerial incentives to increase volatility and stock price using stock and option holdings given one year of proxy (or Execucomp) data, and show that these measures are highly correlated with the full-information measures computed in Guay (1999). Core and Guay (2000) provide a purely methodological study (i.e., they do not use the incentive measures in any applied empirical setting). They suggest that the measures would be useful in a study of risk management. I adopt the Core and Guay methodology for measuring CEO incentives to increase risk and stock price. This methodology is explained further in Appendix A. [5]

The measure of CEO incentives to increase risk is referred to as *vega*. This variable is the based upon the partial derivative of the dividend-adjusted Black–Scholes equation with respect to the annual standard deviation of stock returns. The partial derivative is then multiplied by 0.01 to represent the dollar change in option value from a 1% change in standard deviation. [6] The CEO's

[4] Much of the subsequent analysis has also been conducted using the binary and total notional value variables. This variable choice does not materially affect the conclusions of the paper with respect to the relation between CEO risk-taking incentives and derivatives usage.

[5] The methodology is based on risk-neutral valuation. To the degree that the risk aversion of CEOs decreases their personal valuation of stock options, the methodology may yield inaccurate estimates. For a discussion of the valuation of equity-based compensation from a risk averse manager's perspective, see Lambert et al. (1991). However, readers should note that executives have the capability to hedge their option holdings with instruments such as "zero-cost" collars (Bettis et al., 2001). Thus, criticisms of risk-neutral valuation of executive stock options may be increasingly irrelevant as these hedging instruments become more commonplace.

[6] Guay (1999) also calculates vega for CEO stock holdings. However, he finds that stockholdings provide essentially no risk-taking incentives. Throughout this paper, I assume shares of stock have a vega value of zero.

incentive to increase risk (in total dollar terms) is calculated by multiplying the generated value by the number of stock options.

Incentives to increase stock price are also of interest in the risk management decision. This incentive is measured by *delta*, which is based on the partial derivative of the Black–Scholes equation with respect to stock price. The per-share dollar magnitude of this incentive is obtained by multiplying the partial derivative by 1% of stock price, and is then converted to a total dollar amount by multiplying by the number of options. The dollar incentives provided by actual stock holdings are, by definition, 1% of stock price multiplied by number of shares. Thus, the total delta reflects the sum of the deltas of options and stock holdings.

The relative risk-taking incentives of CEOs are measured with the ratio of vega-to-delta. This ratio provides a measure of CEO risk-taking incentives per dollar of value-increasing incentives from stock and option holdings. Using the ratio in the analysis offers two advantages over examining vega and delta separately. First, the use of the ratio implies that only one model of CEO incentives needs to be specified (as opposed to separate models for risk-taking and value-increasing incentives). Second, both vega and delta are largely functions of firm size. Therefore, given that derivative holdings are also a function of firm size, it may be difficult to observe any relation between risk management and vega if firm size is also an explanatory variable. However, using a ratio of vega-to-size seems to offer less economic meaning than vega-to-delta.

Besides executive risk aversion, other issues may create errors in the valuation of executive stock options with the Black–Scholes model. Lack of trading and early exercise may cause significant errors in option valuation. However, if the Black–Scholes valuation model biases both vega and delta in the same direction, the use of vega-to-delta will yield a less inaccurate estimate of risk-taking incentives.

A negative relation is predicted between the vega-to-delta ratio and derivative holdings if the principal purpose of derivatives usage is to reduce risk (i.e., hedge). [7] If derivatives are regularly used to increase risk, then this would drive the relation towards zero or positive values.

[7] A positive relation between delta and derivatives could also create a negative relation between the vega-to-delta ratio and hedging. If hedging is associated with higher valuations, all else equal, then this mechanical relation could bias the results. However, several features of the data suggest that a potential relation between delta and hedging is not driving the results. First, vega-to-delta is more positively correlated with vega (38%) than negatively correlated with delta (−13%). Second, both vega and delta are positively correlated with net derivative holdings, but the correlation is higher on vega than delta. Finally, when vega-to-delta is considered an endogenous variable, the stock return over the last five years is included as a determinant. This should control for positive stock price effects on delta.

3.1.3. Other hedging incentives

Smith and Stulz (1985) and Froot et al. (1993) suggest that a firm with greater growth opportunities will derive greater benefits from hedging (because of the reduction in underinvestment costs). I control for growth options with (1) book-to-market value of assets and (2) research and development (R&D) expenditures scaled by book value of assets. Because these ratios may be impacted by current expenditures, I also include capital expenditures scaled by book value of assets as an additional control variable.

The same set of theories argues that firms facing higher expected costs of financial distress possess larger hedging incentives. I control for distress costs with the ratio of total debt to book value of assets. Firms with lower profitability may face higher inherent probabilities of encountering distress. To control for profitability, I include the ratio of operating income scaled by book value of assets. Net operating loss (NOL) carryforwards may be indicative of current or recent financial distress. A firm in (or close to) financial distress may desire to increase the option value of its equity by increasing risk. Thus, I also include the ratio of NOL carryforwards to book value of assets.

DeMarzo and Duffie (1991) argue that, if managers possess superior information about the firm's risk exposures (relative to shareholders), then shareholders will approve of corporate hedging. Candidate variables to measure the amount of information asymmetry faced by firms include (1) percentage of shares owned by institutional investors and (2) firm size (measured as the natural logarithm of book value of total assets).

3.2. Definition of variables – risk-taking incentives model

3.2.1. CEO risk-taking incentives

The primary variable measuring CEO risk-taking incentives is the vega-to-delta ratio discussed in Section 3.1.1. Vega is calculated for the CEO's current year option grants as of fiscal year-end (to reflect risk-taking incentives as of the point in time when risk management is measured), and estimated with the Core and Guay (2000) algorithm for options granted in prior years. Delta is measured for the CEO's current year option grants and existing holdings of common stock, and estimated for options granted in prior years. The sum of the vega values divided by the sum of the deltas equals the ratio for all holdings. I also decompose this ratio into two parts: (1) the ratio attributable to current option grants, and (2) the ratio attributable to prior holdings. In this manner, flow and stock variables are developed as suggested by Core and Guay (1999).

3.2.2. Determinants of CEO risk-taking incentives

CEO risk-taking incentives depend crucially on the firm's decision to compensate him or her with equity-based awards. The literature on equity-based compensation suggests that such pay is dependent on several factors including (1) risk, (2) growth opportunities, (3) leverage, (4) marginal tax rate, (5) firm size, and (6) regulation.

The amount of risk facing a firm should impact the risk-taking incentives provided to the CEO. In one respect, greater risk may prompt a decrease in the pay-performance sensitivity (Aggarwal and Samwick, 1999). On the other hand, less risk-averse executives may self-select into high-risk firms. If this is true, higher risk firms may provide greater risk-taking incentives. As a proxy for the total risk of the firm, I calculate each firm's standard deviation of monthly stock returns using a minimum of 12 and a maximum of 60 months of data prior to the date of hedging measurement (December 1994–October 1995).

Guay (1999) shows directly that proxies for growth opportunities (book market of assets, R&D expenditures, and capital expenditures) are positively related to CEO risk-taking incentives. Smith and Watts (1992) also show a positive relation between growth opportunity proxies and the existence of stock option plans. To control for growth opportunities, I utilize the book market of assets ratio and the ratio of R&D expense-to-assets.

John and John (1993) show that financial leverage creates a disincentive for shareholders to pay the agent with compensation tied to stock price. Furthermore, as financial leverage increases, there is lesser need to supply the agent with risk-taking incentives as explained by Garvey and Mawani (1999). The debt ratio as discussed in the prior section is used as our proxy of leverage.

Because the cost of stock option awards is not deducted from revenues at the time of the grant, the cost of options does not provide a tax shield to the corporation (Matsunaga, 1995), while cash compensation does. Because CEO risk-taking incentives are created through the use of such non-cash compensation, the vega-to-delta ratio should be related to marginal tax rates in a similar manner. I utilize the marginal tax rate estimates developed by Graham et al. (1998).

Guay (1999) finds a positive association between firm size and CEO risk-taking incentives. I measure firm size as the book value of total assets.

Regulated firms are subject to greater monitoring, and thus it may be less necessary to provide these firms with equity-based compensation. As in Smith and Watts (1992), I define regulated firms as those in the utility, banking, and insurance industries.

3.2.3. Other control variables

The firm's stock return performance should play a role in determining CEO incentives as of fiscal year end. A CEO's vega-to-delta ratio is mechanically altered by changes in the firm's stock price. As stock price increases away from the strike price, vega of option holdings decrease while delta increases. Furthermore, grants of restricted stock and options may be a reward for good performance as pointed out by Yermack (1995). To control for performance effects, I include an average monthly stock return in all CEO incentive regressions. The average of monthly returns over the prior five years is used in the model for the vega-to-delta of all holdings, while a six-month stock return is utilized in the model of current incentives.

Incentives from an executive's existing holdings of options and stock may impact the current compensation structure decision. Core and Guay (1999) show that the residual from a model of optimal current compensation incentives is negatively related to incentives granted to CEOs in the current time period. To control for existing incentives in the models of current incentives, I utilize the vega-to-delta ratio of stock and options held prior to the current fiscal year end.

The percentage of equity-based compensation may be related to cash compensation. Beginning with 1994, US federal tax rules limit the deductibility of executive compensation to $1 million (per executive) unless the excess qualifies as performance-based pay. Therefore, CEOs with higher levels of cash compensation may be paid in the form of options because the value of option grants is not deducted for tax purposes. On the other hand, equity-based compensation may be a substitute for cash compensation. I measure cash compensation as the natural logarithm of the sum of salary and bonus. [8]

4. Sample

A random sample of 850 firms is generated from the population of 10-K filings (approximately 3200) in the SEC's EDGAR database (http://www.sec.gov.edgarp.htm). From this set, I apply the following selection criteria: (1) fiscal year ends December 15, 1994 through October 31, 1995, (2) the firm is not a subsidiary of another firm in the sample, (3) the firm is listed on the Compustat annual database, and (4) the firm discloses the notional value of its derivative holdings, if any. These screens leave 569 eligible firms for the sample.

I gather detailed data regarding the notional values of IR and FX derivative holdings from financial statement footnotes and management's discussion from the 10-K filings. I utilize only derivatives disclosed as being used for non-trading purposes. This distinction is required by SFAS 119. Most firms disclose explicitly that these derivatives are held for risk management purposes. For each disclosure, I attempt to classify derivative holdings as long or short. Net holdings are calculated as the sum of absolute values of the differences in

[8] I exclude long-term incentive payouts as this compensation relates to the executive's past performance over several years. Therefore, inclusion of this variable may add noise to current cash compensation.

notional values between long and short positions across IR derivatives and individual currency contracts. [9]

Compensation data for the sample firms are taken from proxy statements. Financial statement data are from Compustat. Stock price data are from CRSP. Institutional ownership data are from CDA Spectrum. Marginal tax rates are provided by John Graham.

Many firms do not use derivatives. For example, Bodnar et al. (1998) report 50% of their survey respondents use derivatives. One explanation for the large number of firms not using derivatives is that they do not face a significant risk exposure hedgeable with existing derivative contracts. [10] If the lack of exposure is the reason for a lack of derivatives use, tests including such firms lose relevance. Thus, I further limit the sample to include firms identified as facing ex ante exposure to either IR or FX risk. [11]

Similar to previous research (see Géczy et al., 1997), I define firms to face ex ante FX risk if they disclose foreign assets, sales, or income in the Compustat Geographic segment file, or disclose positive values of foreign currency adjustment, exchange rate effect, foreign income taxes, or deferred foreign taxes in the annual Compustat files. I identify 242 firms in the sample as being exposed to FX risk.

The definition of ex ante IR risk is based in part on the sensitivity of operating income to interest rates. Specifically, changes in quarterly operating income are regressed on changes in the six-month LIBOR rate over the 1988–1994 time period. Based on the sign of the regression coefficient, firms are classified as having positive, negative, or zero operating exposure to interest rates. Zero exposure occurs when the regression coefficient is not significant at the 10% level. A firm faces ex ante IR risk if it meets any of the following criteria:

1. Zero operating exposure to IR changes, and positive amounts of floating debt (i.e., short-term and/or floating-rate debt): This categorization captures the risk of volatile interest expense. This category includes almost all of the IR risk firms (95.4%).
2. Negative operating exposure to IR changes (applies to 2.2% of the IR risk firms), or

[9] For example, suppose a firm discloses the following notional values of its derivative holdings: \$100 million long IR derivatives, \$50 million short IR derivatives, \$10 million long British pounds, \$30 million short British pounds, and \$20 million long German marks. This firm would have \$90 million in net derivative holdings $[(100-50)+(30-10)+20]$. Notional values are used in all calculations, regardless of derivative type (i.e., swap, forward, futures, or option).

[10] Bodnar et al. (1998) find that 118 of 198 non-derivative-using firms listed "insufficient exposure to financial or commodity prices" as the most important reason for not using derivatives.

[11] This sampling procedure is also used in Graham and Rogers (2001).

3. Positive operating exposure to IR changes, and less than 50% of debt is floating (applies to 2.4% of the IR risk firms). [12]

This definition of IR risk includes 502 firms. Sixty-seven of the sample firms do not face IR risk; however, 22 of these 67 firms face ex ante currency risk. On net, 45 firms are deleted because they face neither FX nor IR risk.

The resulting sample consists of 524 firms from various industries and of varying sizes. [13] Table 1 presents summary statistics of the distributions of variables utilized throughout the analysis. Approximately 38% of the sample firms are classified as derivative hedgers. The average (median) firm owns \$4.8 (\$0.58) billion in assets. Average (median) total CEO compensation is valued at \$1.8 (\$0.85) million. Equity compensation consists primarily of option grants. The value of stock options comprises an average of 20% of total compensation in the current period. The average ratio of equity-based compensation is 23.7%. Risk-taking incentives are only 20%, on average, of value-maximizing incentives for the CEO's entire portfolio of stock and options. [14] Current compensation provides risk-taking incentives of 43% of those to increase stock price.

5. Analysis of the relation between CEO incentives and risk management

The analysis is conducted entirely in a multivariate framework. Relations between the variables are difficult to interpret in univariate analysis. For example, firm size is highly positively correlated with both derivatives usage and with CEO risk-taking incentives. Additionally, one expects interrelations between some of the independent variables (such as debt ratios vs. R&D expenditures).

The general framework of the multivariate analysis consists of two equations. In Section 5.1., I conduct tests of Eq. (2) in a one-stage Tobit framework (assuming that CEO risk-taking incentives are exogenous). In Section 5.2., the predicted level of CEO risk-taking incentives (Eq. (1)) is estimated, and incorporated as an explanatory variable in Eq. (2). In Section 5.3., the two equations are estimated jointly in a simultaneous system.

[12] The 50% floating rate debt figure is arbitrary. The results are not sensitive to changing the percentage of floating rate debt.

[13] The analysis is also conducted using only nonfinancial firms from the sample. The qualitative conclusions of the analysis are unchanged. In general, the relation between CEO risk-taking incentives and derivative holdings is not as strong if financial firms are excluded. This result suggests that the risk-taking incentives of CEOs are especially important in determining the cross-sectional variation in net derivatives held by financial firms for risk management purposes.

[14] A significant number (145 out of 475) of CEOs have no risk-taking incentives (i.e., vega $= 0$). Given that these firms are typically small, they may be expected to use no derivatives. To the degree that this is true, the results may be biased towards finding no relation between CEO risk-taking incentives and risk management. An analysis of only firms in which CEOs have positive values of vega shows no significant changes in results presented.

Table 1
Summary statistics for derivatives, compensation, and control variables

Variable	*N*	Mean	Median	Std Dev	1st %ile	99th %ile
Derivative variables						
Net derivatives – scaled by assets	497	0.0318	0	0.0716	0	0.3523
Binary derivatives variables	524	0.3798	0	0.4858	0	1
Total derivatives – scaled by assets	524	0.0605	0	0.2279	0	0.5189
Compensation variables						
Value of total compensation (mil)	475	$1.7580	$0.8451	$3.8131	$0.1019	$16.13
Value of equity-based compensation (mil)	475	$0.9272	$0.0935	$3.4891	$–	$14.09
Equity compensation – % of total	475	23.70%	15.54%	27.29%	0.00%	94.19%
Value of current option compensation (mil)	475	$0.7798	$0.0259	$3.0857	$–	$14.09
Option compensation – % of total	473	19.98%	6.39%	25.86%	0.00%	93.85%
Delta of option and stock holdings (mil)	475	$0.2343	$0.0546	$0.6761	$–	$3.68
Delta of current compensation (mil)	475	$0.0139	$0.0012	$0.0471	$–	$0.24
Vega of option and stock holdings (mil)	475	$0.0250	$0.0050	$0.0536	$–	$0.26
Vega of current compensation (mil)	475	$0.0085	$0.0003	$0.0257	$–	$0.12
Vega-to-delta of option and stock holdings	475	0.1961	0.1070	0.2329	0	0.8722
Vega-to-delta of current compensation	475	0.4268	0.1994	0.5811	0	2.5305
Control variables						
Book value of total assets (mil)	524	$4829	$575	$17,883	$6.25	$198,938
Book-to-market value of assets	497	0.7864	0.8325	0.2549	0.1544	1.5084
R&D expense – scaled by assets	508	0.0234	0	0.1101	0	0.2459
Capital expenditures – scaled by assets	507	0.0585	0.0478	0.0600	0	0.2728
Debt-to-assets ratio	524	0.2840	0.2556	0.2290	0	0.9944
Return on assets (pre-tax)	524	0.0488	0.0558	0.1327	−0.4366	0.2732
NOL carryforwards – scaled by assets	524	0.0376	0	0.2235	0	0.9498
Institutional ownership – % of shares	474	40.79%	40.26%	23.48%	0.70%	86.29%
Std deviation of monthly stock returns	390	0.1094	0.0963	0.0584	0.0406	0.3504
Marginal tax rate	491	0.2332	0.3371	0.1513	0	0.3780

Table 1 shows descriptive statistics of variables used in the analysis. Net derivatives are the difference between long and short positions summed across IR and individual currency derivatives (in notional values). The binary derivatives variable is set to 1 if a firm uses interest rate or currency derivatives. Total derivatives are total notional values of IR and currency contracts. Total compensation is defined as salary, bonus, option, and restricted stock grants. Equity compensation is the sum of the values of restricted stock and option grants. Delta and vega values are calculated as in Core and Guay (2000).

5.1. One-stage tests of derivatives risk management

In this section, I examine the relation between several alternative proxies for managerial risk-taking incentives in one-stage Tobit regressions. Table 2 shows the results of these multivariate tests. In column (1) of Table 2, CEO risk-taking incentives are measured with simple stock and option variables utilized in Tufano (1996) and Géczy et al. (1997): (1) the natural logarithm of the value

Table 2
One-stage Tobit regressions of the extent of derivatives hedging

Independent variables	Column (1)		Column (2)		Column (3)		Column (4)	
	Coefficient	*p* value	Coefficient	*p* value	Coefficient	*p* value	Coefficient	*p* value
Intercept	−0.3474	0.0001	−0.3566	0.0001	−0.3628	0.0001	−0.3587	0.0001
Debt ratio	0.1749	0.0002	0.1936	0.0001	0.1886	0.0001	0.1940	0.0001
Book market of assets	0.0571	0.2374	0.0448	0.3683	0.0334	0.4890	0.0279	0.5634
R&D ratio	0.1153	0.3966	0.1417	0.3214	0.1265	0.3681	0.1173	0.4079
Capital expenditures ratio	0.0229	0.8553	0.0208	0.8744	0.0235	0.8572	0.0293	0.8227
Log (book value of assets)	0.0232	0.0001	0.0217	0.0011	0.0280	0.0001	0.0275	0.0001
Return on assets	−0.0265	0.8538	0.0317	0.8278	−0.0004	0.9977	0.0007	0.9960
NOL carryforwards	−0.4152	0.0533	−0.5367	0.0166	−0.4650	0.0326	−0.4470	0.0348
Institutional ownership pct	0.1183	0.0090	0.1622	0.0005	0.1683	0.0003	0.1626	0.0005
Log (CEO stock value)	0.0111	0.0014						
# of options held by CEO	0.0086	0.5796						
Vega of all stock and options			0.1623	0.3114				
Delta of all stock and options			0.0134	0.2702				
Vega-to-delta ratio – all					−0.0675	0.0900		
Vega-to-delta ratio – existing							−0.1121	0.0184
Vega-to-delta ratio – current							0.0153	0.2996
Regulated industry dummy	−0.0486	0.0684	−0.0398	0.1476	−0.0588	0.0326	−0.0598	0.0287
Number of observations	390		400		400		400	
Number of noncensored obs	146		149		149		149	
Value of log likelihood function	−12.15		−21.14		−20.88		−19.37	
Slope coefficient conversion	0.3024		0.3023		0.3053		0.3049	

Table 2 shows coefficient estimates from Tobit regressions of net derivative holdings on the listed independent variables. The debt ratio measures the book value of total debt divided by the book value of total assets. The book market of assets is the book value of assets divided by the sum of equity market value and book values of total debt and preferred stock. The R&D ratio is research and development expense divided by the book value of total assets. The capital expenditures ratio is capital expenditures from the cash flow statement divided by the book value of total assets. Return on assets is operating income divided by the book value of total assets. NOL carryforwards is the book value of NOL carryforwards divided by the book value of total assets. Institutional ownership pct is the percentage of shares owned by institutional investors. Log (CEO stock value) is the natural logarithm of the value of CEO stock holdings. Vega and delta are the incentives of the CEO to increase risk and stock price, respectively. Equity-based pay is the value of restricted stock and option grants relative to the value of total compensation. Option-based pay excludes the value of restricted stock. The regulated industry dummy is equal to one if the firm's primary two-digit SIC code is 49, 61, or 63. The slope coefficient conversion is the marginal effect of the Tobit regression coefficients evaluated at the means of the independent variables.

of CEO stock holdings and (2) the number of options held by the CEO. The results show a positive and significant coefficient on the value of CEO stock holdings. This finding is consistent with firms hedging because of managerial motives. However, CEO option holdings are not negatively related with derivative holdings as predicted.

Guay (1999) shows that the simple proxies used in the previous model explain only a small portion of managerial incentives. Column (2) shows results using the Core and Guay (2000) delta and vega variables. The results show a positive, but insignificant, relation between vega and net derivatives. The coefficient on delta is also positive and insignificant.

As argued earlier, a ratio of vega-to-delta provides a convenient economic definition of risk-taking incentives per dollar of value-increasing incentives. In columns (3) and (4), I utilize the vega-to-delta ratios to proxy for CEO risk aversion. Column (3) aggregates the vega and delta of all option and stock holdings. Column (4) uses separate variables for current option/stock grants versus existing holdings. Both models confirm a negative relation between risk-taking incentives and derivative holdings. The relation is statistically weak when all option and stock holdings are aggregated in the computation of vega-to-delta. The results shown in column (4) suggest that existing holdings drive the relation. The vega-to-delta ratio of current compensation shows a positive and insignificant relation with the risk management variable.

The one-stage regression shows consistent, but weak, support that CEOs with fewer risk-taking incentives hedge more with derivatives. This result is consistent with the theories of Stulz (1984) and Smith and Stulz (1985). Furthermore, this finding supports the findings of Tufano (1996) that managerial motives are an empirically important determinant of hedging, and contradicts the results of prior cross-sectional studies that find that managerial motives do not impact hedging.

5.2. Two-stage tests of risk-taking incentives and risk management

In this portion of the paper, I recognize that the risk-taking incentive proxies utilized in the risk management model are also choice variables. This choice is modeled by first solving for a specification of CEO risk-taking incentives. The predicted value from this model is then incorporated as an explanatory variable into the risk management model. [15]

Table 3, panel A, shows the results of first-stage managerial incentives models incorporating different dependent variables as proxies. Panel B shows

[15] An alternative method to address the endogeneity problem is to use the residual from the first-stage incentive regression. Utilizing the residual instead of predicted incentives generates no change in the results.

the results of the risk management model with the corresponding predicted value from the managerial incentive specification. The models in columns (1) and (2) utilize the vega-to-delta ratio of all options and stock holdings, and the vega-to-delta ratio of current equity-based compensation, respectively. The results of panel A illustrate the determinants of CEO risk-taking incentives. Lower returns are associated with higher vega-to-delta ratios. Risk is positively related to overall CEO risk-taking incentives but not with the current vega-to-delta ratio. Firm size has a positive impact on the incentive proxies, while leverage exhibits a negative relation with CEO risk-taking incentives. An evaluation of the log likelihood functions suggests that the better fitted model uses the vega-to-delta ratio of all stock and option holdings as the dependent variable.

Panel B shows the results of the second stage model explaining the extent of risk management with derivatives. In contrast to the results of the one-stage model (from Table 2), I find weaker evidence that CEO risk-taking incentives are an important factor in the risk management decision (if derivatives are used to hedge) when such incentives are modeled as an endogenous variable. Column (1) shows an insignificant negative relation between derivatives hedging and the predicted vega-to-delta ratio of all stock and option holdings. Column (2) also shows an insignificant negative association among risk management and the predicted vega-to-delta ratio of current stock and option grants.

5.3. Simultaneity of derivatives usage and CEO incentives

The model employed in the Table 3 analysis assumes that net derivative holdings are a partial function of predicted CEO risk-taking incentives. In this subsection, I construct two alternative hypotheses. If hedging due to managerial motives is costly to the firm (as in Tufano, 1998), then expected executive risk-taking incentives should offer no additional power in explaining risk management behavior over variables that proxy for value-maximizing hedging rationales (such as reducing financial distress and/or underinvestment costs). Rather, the firm should structure CEO incentives to be consistent with the appropriate risk management rationales (while controlling for other determinants of incentives).

Prior sections of the paper model CEO incentives using proxies of standard agency cost arguments. However, no prior research incorporates the firm's risk management choice into the model of optimal CEO incentives. If risk management is a factor in determining incentives (but not vice versa), then the framework of the model should be a system of the following form:

$$\text{Risk management} = f(\text{value-maximizing hedging incentives}). \tag{3}$$

$$\text{CEO incentives} = f(\text{optimal risk management, other variables}). \tag{4}$$

Table 3
Two-stage Tobit regressions of the extent of derivatives hedging (Dependent variables for panel A: Column 1 – Vega/delta – all, Column 2 – Vega/delta – current)

Independent variables	Column (1)		Column (2)	
	Coefficient	p value	Coefficient	p value
Panel A. First-stage Tobit regressions of CEO incentives				
Intercept	−0.1290	0.2543	−0.8882	0.0267
Average stock return (long run)	−4.9943	0.0001		
Average return (recent)			−3.3366	0.0291
Std deviation of stock returns	0.8578	0.0082	0.5534	0.5451
Log (cash compensation)	−0.0347	0.2642	−0.1248	0.2351
Book market of assets	−0.0140	0.8282	0.0335	0.8812
R&D expense ratio	0.0110	0.9730	2.1599	0.0439
Debt ratio	−0.2908	0.0001	−0.7808	0.0037
Marginal tax rate	−0.1310	0.2039	0.1778	0.5890
Log (book value of assets)	0.0670	0.0001	0.1593	0.0004
Vega-to-delta ratio – existing			0.9440	0.0001
Regulated industry dummy	−0.1903	0.0001	−0.1147	0.4351
Number of observations	381		381	
Number of noncensored obs	312		237	
Value of log likelihood function	−66.86		−385.67	
Slope coefficient conversion	0.7918		0.6429	
Panel B. Second-stage Tobit regressions of the extent of derivatives hedging				
Intercept	−0.3694	0.0001	−0.3744	0.0001
Debt ratio	0.2049	0.0001	0.2066	0.0063
Book market of assets	0.0003	0.9942	−0.0014	0.9773
R&D ratio	0.4853	0.0315	0.4921	0.0842
Capital expenditures ratio	0.1247	0.3113	0.1544	0.2108
Log (book value of assets)	0.0394	0.0001	0.0343	0.0026
Return on assets	−0.1006	0.5420	−0.0414	0.7874
NOL carryforwards	−0.4313	0.0276	−0.4249	0.0291
Institutional ownership pct	0.1355	0.0021	0.1485	0.0008
Vega-to-delta – all (predicted)	−0.2138	0.1219		
Vega-to-delta ratio – existing			−0.0765	0.3718
Vega-to-delta – current (predicted)			−0.0289	0.7108
Regulated industry dummy	−0.0646	0.0935	−0.0324	0.2131
Number of observations	348		348	
Number of noncensored obs	140		140	
Value of log likelihood function	7.80		9.60	
Slope coefficient conversion	0.3331		0.3327	

Table 3 shows Tobit coefficient estimates from regressions of CEO risk-taking incentives (panel A) on the listed independent variables, and of net derivative holdings (panel B) on the predicted values of CEO incentives (from panel A) and other control variables. Average stock returns are five-year and six-month returns, respectively. Standard deviation of stock returns is measured using monthly return data over a minimum of 12 and a maximum of 60 months. Log (cash compensation) is the natural logarithm of salary plus bonus. The marginal tax rate is the simulated tax rate from Graham et al. (1998). Other variables are defined in Table 2.

A key feature of the above system is that the risk management choice is based upon variables proxying only for "value-maximizing" hedging incentives (i.e., CEO incentives are not included if CEO motives are assumed to be a non-value-increasing reason for hedging). If optimal risk management is negatively related to CEO incentives in Eq. (4), such a result suggests that incentives are determined, in part, by the firm's value-maximizing incentives to hedge. This, in turn, implies that predicted CEO incentives should add no additional power (beyond these incentives) in explaining hedging behavior.

A further alternative to the model presented above is a system in which Eq. (3) above is presented as follows:

$$\text{Risk management} = f(\text{value-maximizing incentives, optimal CEO risk-taking incentives}). \tag{5}$$

This addition to the risk management specification implies a simultaneous system of Eqs. (4) and (5). If the risk management decision imparts a negative impact on CEO risk-taking incentives, then the optimal level of such incentives may play a role in the hedging decision.

Table 4 shows results of the two systems discussed. I utilize the vega-to-delta ratio of all stock and options in the following specifications to avoid issues of endogeneity of existing incentives. In column (1), the risk management specification is assumed to include only value-maximizing incentives (i.e., the CEO risk-taking incentive variable is excluded). The predicted value from the Tobit model is utilized as an explanatory variable in the second-stage model to explain CEO vega-to-delta ratios. Table 4 shows that the predicted extent of net derivative holdings is negatively related to CEO risk-taking incentives, but not significant at conventional levels. This result suggests that firms establish incentives in a manner weakly consistent with value-maximizing incentives to hedge.

Column (2) of Table 4 shows the second-stage results of the simultaneous system (Eqs. (4) and (5)). In this specification, predicted CEO risk-taking incentives are negatively related to the extent of risk management. This result suggests that derivatives usage is partially driven because of relatively low CEO risk-taking incentives. Additionally, predicted net derivative holdings are a factor in setting the executive's overall level of risk-taking incentives. Thus, corporate derivatives usage is partially a function of optimal CEO risk-taking incentives, and these incentives are driven partially by firms' optimal net derivative holdings. The negative relations documented are consistent with net derivatives serving as a proxy for corporate hedging.

5.4. *Do options matter?*

The results of Tables 2 and 4 suggest that CEO risk-taking incentives impact the derivatives usage decision in a manner consistent with derivatives being

Table 4
CEO incentives as a function of risk management

Independent variables	Column (1) Net derivatives		Column (2) Net derivatives	
	Coefficient	p value	Coefficient	p value
Intercept	−0.3563	0.0001	−0.3970	0.0001
Debt ratio	0.1865	0.0001	0.0757	0.0926
Book market of assets	0.0140	0.7543	0.0269	0.5208
R&D ratio	0.1272	0.3649	0.5807	0.0025
Capital expenditures ratio	0.0169	0.8983	0.0909	0.3837
Log (book value of assets)	0.0282	0.0001	0.0803	0.0001
Return on assets	0.0245	0.8570	−0.4287	0.0020
NOL carryforwards	−0.5198	0.0185	−0.2122	0.0947
Institutional ownership pct	0.1463	0.0011	0.0965	0.0104
Vega-to-delta – all (predicted)			−0.9633	0.0001
Regulated industry dummy	−0.0568	0.0307	−0.2313	0.0001
Number of observations	426		348	
Number of noncensored obs	152		140	
Value of log likelihood function	−25.92		39.80	
Slope coefficient conversion	0.2789		0.3176	
	Vega-to-delta (all)		Vega-to-delta (all)	
Intercept	−0.1840	0.1679	−0.3110	0.0184
Net derivatives (predicted)	−0.1895	0.1246	−0.5000	0.0001
Average stock return (long run)	−4.8004	0.0002	−4.6400	0.0002
Std deviation of stock returns	0.7893	0.0207	0.7008	0.0364
Log (cash compensation)	−0.0218	0.5002	−0.0140	0.6591
Book market of assets	−0.0076	0.9116	0.0274	0.6859
R&D expense ratio	0.0634	0.8537	0.0438	0.8963
Debt ratio	−0.2344	0.0080	−0.1760	0.0441
Marginal tax rate	−0.1102	0.3219	−0.0527	0.6290
Log (book value of assets)	0.0716	0.0001	0.0818	0.0001
Regulated industry dummy	−0.2137	0.0001	−0.2413	0.0001
Number of observations	348		348	
Number of noncensored obs	283		283	
Value of log likelihood function	−66.28		−60.23	
Slope coefficient conversion	0.7871		0.7927	

Table 4 shows Tobit coefficient estimates from regressions of net derivative holdings and of the vega-to-delta ratio. Column (1) models the system as a first-stage regression predicting optimal net derivative holdings, and a second-stage regression of the vega-to-delta ratio on the predicted level of net derivatives and the other listed independent variables. Column (2) shows second-stage results from a system of simultaneous regressions using the values of vega-to-delta and net derivatives predicted from corresponding first-stage Tobit regressions.

used for hedging purposes. The results from Table 2, model 1, also suggest that the level of CEO wealth held in company stock is positively related to derivatives usage, but that option holdings are not. While the model of Table 2 is clearly misspecified, the question remains as to the impact of options in affecting risk management behavior. To examine this, I recalculate the vega-to-delta ratios excluding the effect of stock holdings (recall that stock is assumed to have no risk-increasing incentives), and repeat analyses from the one-stage, two-stage, and simultaneous regressions performed earlier.

Table 5 shows the results from these tests. [16] Column (1) presents results from a repeat of the one-stage analysis, column (2) shows the two-stage analysis, and column (3) shows the second-stage results from simultaneous regressions. The results suggest that option holdings alone have some power in explaining cross-sectional differences in corporate derivative holdings. If the vega-to-delta ratio of option holdings is assumed to be an exogenous variable, CEO risk-taking incentives from options show no relation with derivatives usage. The two-stage and simultaneous regression settings show significantly negative associations between CEO risk-taking incentives and the choice of derivative holdings. Interestingly, firms' net derivative holdings have no impact on the level of CEO risk-taking incentives provided by options. This suggests that optimal risk management policy is not a consideration in firms' decisions regarding option compensation.

6. Concluding remarks

This paper shows CEO risk-taking incentives provided by portfolios of stock and options are negatively related to derivative holdings for a broad cross-section of firms. This negative relation is consistent with derivatives being used for hedging purposes. The evidence suggests that managerial risk-taking incentives are an empirically important determinant of corporate risk management behavior. This finding is significant because only single-industry studies (Tufano, 1996; Schrand and Unal, 1998) have previously found managerial motives to be significantly related to the risk management decision.

The analysis takes into account the positive hedging incentives of stock holdings and the negative hedging incentives of option holdings. Both types of securities are important in determining corporate hedging. The risk-taking incentives from options are negatively related to corporate derivative holdings, as expected. The negative relation is stronger when CEO risk-taking incentives are measured using both stock and options. The hedging decision also plays a

[16] This analysis was also conducted using the delta of stock holdings as an additional control variable in the hedging and CEO incentive regressions. Because stock holdings are assumed to provide no risk-taking incentives, the "options only" vega-to-delta ratios should only differ because of a change in the denominator. The inclusion of delta of stock holdings as a right hand side variable separates relative risk-taking incentives from purely value-increasing incentives. The results reported in Table 5 do not change in this alternate specification.

Table 5
Relation between derivative holdings and CEO risk-taking incentives provided by options

Independent variables	Column (1) Net derivatives		Column (2) Net derivatives		Column (3) Net derivatives	
	Coefficient	p value	Coefficient	p value	Coefficient	p value
Intercept	−0.3580	0.0001	−0.3377	0.0001	−0.3381	0.0001
Debt ratio	0.1950	0.0001	0.1865	0.0005	0.1704	0.0011
Book market of assets	0.0271	0.5770	0.0095	0.8438	0.0173	0.7190
R&D ratio	0.1348	0.3432	0.4869	0.0298	0.5480	0.0143
Capital expenditures ratio	0.0124	0.9254	0.1343	0.2739	0.1364	0.2610
Log (book value of assets)	0.0255	0.0001	0.0378	0.0001	0.0431	0.0001
Return on assets	0.0164	0.9098	−0.1070	0.5016	−0.1498	0.3419
NOL carryforwards	−0.5243	0.0174	−0.4624	0.0187	−0.4502	0.0195
Institutional ownership pct	0.1627	0.0005	0.1354	0.0020	0.1313	0.0025
Vega-to-delta – all	0.0004	0.9818				
Vega-to-delta – all (predicted)			−0.1557	0.0300	−0.2211	0.0021
Regulated industry dummy	−0.0485	0.0726	−0.0395	0.1441	−0.0541	0.0499
Number of observations	400		348		348	
Number of noncensored obs	149		140		140	
Value of log likelihood function	−22.32		8.97		11.36	
Slope coefficient conversion	0.3029		0.3305		0.3157	
			Vega-to-delta (all)		Vega-to-delta (all)	
Intercept			0.0271	0.9061	−0.0378	0.8908
Net derivatives (predicted)					−0.0402	0.8735
Average stock return (long run)			−11.1486	0.0001	−10.8873	0.0001
Std deviation of stock returns			1.1832	0.0723	1.1316	0.1086
Log (cash compensation)			−0.0395	0.5311	−0.0365	0.5845
Book market of assets			0.0473	0.7187	0.0554	0.6980
R&D expense ratio			0.1500	0.8201	0.4660	0.5127
Debt ratio			−0.4899	0.0015	−0.3948	0.0310
Marginal tax rate			0.1807	0.3888	0.2074	0.3681
Log (book value of assets)			0.0748	0.0042	0.0792	0.0087
Regulated industry dummy			−0.1270	0.1533	−0.1672	0.0926
Number of observations			381		348	
Number of noncensored obs			312		283	
Value of log likelihood function			−294.65		−277.91	
Slope coefficient conversion			0.8122		0.8050	

Table 5 shows Tobit coefficient estimates of regressions of net derivative holdings and of vega-to-delta ratios calculated using only CEO option holdings, respectively. Column (1) shows the results from a one-stage Tobit regression of net derivative holdings on the vega-to-delta ratio and other control variables. Column (2) shows the results from a second-stage Tobit regression of net derivative holdings on the predicted vega-to-delta of options (from the lower portion of column 2) and other control variables. Column (3) shows the second-stage Tobit results from the simultaneous system of net derivative holdings and CEO risk-taking incentives from options.

determining role in the level of CEO risk-taking incentives when both options and stock are considered, but not when only options are considered.

The results also establish the simultaneity of decisions regarding risk management and the establishment of CEO risk-taking incentives. When the simultaneous nature of these decisions is ignored, the associations between hedging and risk-taking incentives are weak, at best. Simultaneous regressions show the relations to be much stronger.

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Appendix A. Calculating the incentive effects of stock options

As in Core and Guay (2000), the delta and vega measures are the option value's sensitivity with respect to a 1% change in stock price and a 0.01 change in standard deviation, respectively, and are expressed in Eqs. (A.1) and (A.2) below.

$$\frac{\partial Value}{\partial S}\frac{S}{100} = \exp\{-\mathrm{d}T\}N(Z)\frac{S}{100}, \tag{A.1}$$

$$\frac{\partial Value}{\partial \sigma} \times 0.01 = 0.01[\exp\{-\mathrm{d}T\}N'(Z)S\sqrt{T}], \tag{A.2}$$

where

$$Z = \frac{\ln(S/X) + T(r - d + \sigma^2/2)}{\sigma\sqrt{T}},$$

$N(\cdot)$ is cumulative probability function for the normal distribution, $N'(\cdot)$ is normal probability density function, S is share price of stock at fiscal year-end, d is dividend yield as of fiscal year-end, X is exercise price of the option, r is risk-free rate. US T-bond yields corresponding to the option's time to maturity are used, σ is annualized standard deviation of daily stock returns measured over 120 days prior to fiscal year-end and T is remaining years to maturity of option.

Exact values of exercise price and time to maturity are obtained from proxy statements for current year option grants. For options granted in prior years, I use the Core and Guay (2000) algorithm. I estimate average exercise prices by subtracting the ratio of realizable value of options to the number of options (for both exercisable and unexercisable options) from fiscal year-end stock prices. Time to maturity is set at one year less than the time to maturity of the current year's grant (or nine years if no new grant is made) for unexercisable options. Time to maturity is set at three years less than the time to maturity of exercisable options (or six years if no new grant is made).

Delta and vega values for shares of stock held are assumed to be equal to 1 and 0, respectively.

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