Preliminary
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Measuring managerial incentives to increase firm volatility provided by debt, stock, and options

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Abstract

A large literature uses the sensitivity of stock options to an increase in stock volatility ("vega") as a proxy for managers' risk-taking incentives. Vega captures the sensitivity of options to stock volatility, but ignores the fact the employee options are warrants. When an increase in volatility increases option value, the increase in option value comes from a decrease in the value of the stock. Accordingly, a manager of a low-leverage firm who owns much stock but little options can have incentives to decrease risk. Further, the managers receive debt-like compensation that can give them incentives to reduce firm volatility. We derive a new measure of managers' incentives from debt, stock, and options that captures the interrelation between the securities' sensitivities to firm volatility. When we examine the relation with firm risk choices, we find mixed evidence that our measure performs better than vega. In addition, we derive an improved measure of the relative incentives from inside debt and equity. Our analysis indicates that the relative measures used in this recent literature are also noisy and biased because they do not correctly incorporate risk-taking incentives from options.

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1. Introduction

A large literature (e.g., Guay, 1999; Core and Guay, 2002; Coles et al., 2006; Hayes et al., 2012) studies how options provide managers incentives to increase risk. This literature uses the sensitivity of stock options to an increase in stock volatility ("vega") as a proxy for managers' risk-taking incentives. While this literature yields important insights, one oversight of this literature is that employee options are warrants that require the firm to issue new stock when options are exercised. Therefore, when an increase in volatility increases option value, the increase in option value comes from a decrease in the value of the stock. Accordingly, a manager of a low-leverage firm who owns much stock but little options can have incentives to decrease risk. An implication is that a complete measure of risk-taking needs to incorporate stock as well as options. A second oversight of this literature is that many firms also give their managers unsecured pensions and deferred compensation. The payout structure of this debt-like compensation gives managers incentives to reduce firm volatility (e.g., Cassell et al., 2011; Edmans and Liu, 2011; Sundaram and Yermack, 2007; and Wei and Yermack, 2011). Accordingly, a manager of a high-leverage firm who owns much inside debt but little stock and options can have incentives to decrease risk. An implication is that a complete measure of risk-taking needs to incorporate inside debts as well as as stock and options. We add to this literature by creating a comprehensive measure of managers' risk-taking incentives incentives from debt, stock, and options. Our measure explicitly recognizes the interrelation between debt, stock, and option sensitivities to firm risk.

Limited liability implies that firm equity is an option on firm value with a strike price equal to the face value of debt. Consequently, an increase in firm volatility increases equity value by reducing debt value (Black and Scholes 1973; Merton, 1973, 1974). When a firm has options,

this increase in equity value is shared between the stock and options. When there is little debt, there is no debt sensitivity to volatility, and the increase in value of options comes from a reduction in the value of stock.[1] These interrelations at the firm level imply that a manager's attitude toward an increase in firm volatility will be affected by the relative magnitudes of the firm's option, debt, and stock sensitivities to firm volatility and by the relative magnitudes of the managers' holdings of options, debt, and stock.

To estimate the sensitivities of the firm's debt, stock, and options to firm volatility, we follow the literature that uses the Black-Scholes-Merton model of firm equity and debt value (e.g., Crosbie and Bohn, 2003; Vassalou and Xing, 2004; Campbell et al., 2008; Bharath and Shumway, 2008). We value total firm equity (stock and stock options) as an option on the value of firm assets. This option pricing model gives an estimate of the sensitivity of debt value to an increase in firm volatility. To divide the sensitivity of total equity value between stock and stock options, we show that the option sensitivity to *firm* volatility is a weighted sum of the stock sensitivity to firm volatility and of the option sensitivity to *stock* volatility (that is, the "vega" used in prior literature). This relation allows us to divide the equity sensitivity to firm volatility between stock and stock options.

The typical firm in our sample of 4,050 Execucomp firms from 2006 to 2009 has low leverage and low default probability. It is intuitive therefore that the typical firm has a very low debt sensitivity to firm volatility, and therefore low equity sensitivity to firm volatility, where equity is the sum of stock and options. When we sort the sample firms by leverage, the debt

[1] This relation follows from the fact that employee options are warrants. If an increase in volatility increases the value of an option by increasing the chance that the option will finish in the money, the increase in option value comes from a reduction in stock value. Stock value is lower because the stock is more likely to be diluted when managers exercise their options.

sensitivity to firm volatility increases sharply, as does the stock sensitivity to firm volatility, while the option sensitivity remains fairly constant.

CEOs' incentives are determined by their ownership of the firm sensitivities. The average CEO in our sample owns roughly 2% of the debt, 2% of the stock, but 16% of the options. We calculate a total sensitivity measure that sums our values for the sensitivity of the CEO's debt, stock, and options to firm volatility. Accordingly, in terms of incentives to increase volatility, the typical CEO has small incentives from debt, small or negative incentives from stock, and large incentives from options. In terms of total incentives from debt, stock, and options, 93% of our CEOs have positive incentives, and these incentives can be substantial. A one standard deviation increase in firm volatility increases CEO wealth by $3 million, or 5% of total wealth. As leverage increases for our sample CEOs, the CEOs' debt sensitivity to firm volatility increases, but his equity sensitivity (the sum of stock and option sensitivities) to volatility increases faster. Total incentives more than double as leverage increases. In contrast, the traditional option vega decreases with leverage. The difference occurs because the traditional vega ignores the fact that options participate in gains to stock as a result of firm volatility increases.

This difference between our measure of total sensitivity and vega illustrates that traditional measures of option vega (e.g., Guay, 1999; Core and Guay, 2002) that ignore debt and stock sensitivities are noisy measures of risk-taking incentives and can be biased. Our new measure of total sensitivity more accurately reflects the fact that options are warrants and that option sensitivities are interrelated with debt and stock sensitivities. For this reason, we expect it to exhibit a higher association with CEO's risk-taking choices. We find some evidence consistent with this conjecture, but the evidence is mixed. Both measures exhibit an unexpected negative association with future stock volatility, and both measures exhibit the expected positive

association with future R&D expense. The option vega exhibits an unexpected significant negative association with future leverage. While these negative associations between option vega and future firm volatility and leverage are in contrast to the positive associations found by Coles et al. (2006) for a 1992 to 2002 sample period, they are consistent with the findings of Hayes et al. (2012) for a sample similar to ours.

Our analysis of the interrelation between the sensitivity of debt, stock, and options also implies that the relative risk-taking measures used in the recent literature summarized in Table 1 are noisy and can be biased. The two measures follow the intuition in Jensen and Meckling (1976) that in a firm with no options, the ratio of CEO's relative risk-reducing to risk-taking incentives is equal to the ratio of the CEO's percentage debt ownership to percentage equity ownership. Although the calculations are slightly different, these measures do not correctly incorporate the sensitivity of option value to firm volatility. Accordingly, the measures are biased and understate the managers' equity incentives to increase volatility. The amount of the understatement grows as leverage decreases. Since the understatement occurs in the denominator of the ratios, the ratios tend to be most upwardly biased for the firms that have the least amount of leverage. This bias leads to a negative correlation between the ratios and firm leverage, which can lead to the incorrect conclusion that CEOs with more inside debt take on less firm debt and less firm risk.

We calculate a "relative sensitivity ratio" that attempts to correctly weight the manager's debt, stock, and option sensitivities, and compare it with the relative incentive measures used by prior literature. The prior measures suggest that CEOs on average tend to have a fairly large identification with debt holders: the average CEO has debt incentives to reduce volatility that are 2.6 times his equity incentives to increase volatility. By contrast, our measure, which explicitly

takes into account volatility incentives from options, is about eight times smaller, suggesting that CEOs have little identification with debt holders: the average CEO has incentives to reduce volatility that are equal to 0.3 times his equity incentives to increase volatility.

The remainder of the paper proceeds as follows. In the next section, we first define the sensitivity of firm debt, stock, and options to firm volatility, and then define the corresponding measures of manager's sensitivities to volatility. In the third section, we describe how we select a sample of CEOs from 2006 to 2009, and compare various measures of incentives. In the fourth section, we compare regressions using the measures to explain various firm outcomes. In the fifth section, we conclude.

2. Definition of incentive measures

In this section we first show how firm debt, equity, and option value change with changes in asset volatility, and then we relate these changes to measures of managerial incentives.

2.1 Sensitivity of firm capital structure to asset volatility

In general, firms are financed with debt, equity, and employee options:

$$V = Debt + Stock + Options = D + nP + qnO \qquad (1)$$

Debt is the market value of the debt, *Stock* is the market value of stock, and *Options* is the market value of options. It is convenient to express stock and option values in per share amounts, and we assume the firm has n shares of stock outstanding with stock price P. The firm has qn stock options outstanding with option price O. For simplicity in our notation, we assume for the moment that all options have the same exercise price and time to maturity and that each option is worth O.

To begin, suppose that there are no stock options outstanding, so that (1) becomes:

$$V = D + nP \tag{2}$$

Black and Scholes (1973) and Merton (1973) show that equity can be valued as a call with a strike price equal to the face value of debt. Changes in firm volatility do not change the value of the firm, so:

$$0 = \frac{\partial D}{\partial \sigma_v} + n\frac{\partial P}{\partial \sigma_v} \tag{3}$$

Therefore, any loss in debt value due to volatility increases is offset by an equal gain in equity value:

$$-\frac{\partial D}{\partial \sigma_v} = n\frac{\partial P}{\partial \sigma_v} \tag{4}$$

More volatile returns increase the value of equity holders' call option, which reduces the value of debt. The interests of debt and equity conflict. Equity prefers higher firm volatility, which raises the value of its call; debt prefers lower firm volatility, which increases the value of its short call.

Now consider a firm with no debt financed with stock and employee stock options. Employee stock options are warrants because the options result in the firm issuing new shares of stock and receiving the strike price. From above:

$$V = Stock + Options = nP + qnO \tag{5}$$

Analogous to (4), an increase in asset volatility has the following effect on the stock price and the option price:

$$-\frac{\partial P}{\partial \sigma_v} = q\frac{\partial O}{\partial \sigma_v} \tag{6}$$

Equation (6) shows that the price of a share of stock in a firm with only stock and employee stock options decreases when firm volatility increases (Galai and Schneller, 1978). The share price decreases because the increased volatility makes it more likely that the option will be in the money and that the current value of a share outstanding will be diluted. This result for options on

stock is similar to the result when stock is an option on the value of the levered firm. Increases in volatility do not change the value of the firm: Therefore, any gains to the options are offset by losses to the stock.

Now we combine the results for debt and options. An increase in firm volatility affects debt, stock, and option value according to the following relation:

$$-\frac{\partial D}{\partial \sigma_v} = n\frac{\partial P}{\partial \sigma_v} + qn\frac{\partial O}{\partial \sigma_v} \tag{7}$$

In firms with both debt and options, shareholders have purchased a call on the assets, and they have "sold" a call on the equity to employees. They are in a position with respect to the equity similar to the position of the debt holders with respect to the assets. When the firm is levered, increasing firm volatility causes shareholders to gain from the call on the asset but to lose on the call on the equity. Since the change in stockholders' value is a combination of these two opposing effects, whether stockholders prefer more volatility depends on the number of options outstanding and firm leverage, as we illustrate next.

2.1.1 Empirical estimation of firm sensitivities

To empirically estimate the sensitivities described above, we price employee options using the Black-Scholes model, as modified to account for dividend payouts by Merton (1973), and modified to reflect warrant pricing by Galai and Schneller (1978). Second, we price firm equity as an option on the levered firm following Merton (1974) using the Black-Scholes formula. See Appendix A.1 and A.2 for details.

Third, we calculate total firm value and firm volatility following the approach of Bharath and Shumway (2008). We proxy for the market value of debt as the current portion of long-term debt plus one-half of the non-current portion of long-term debt, and estimate asset volatility as:

$$\sigma_v = \frac{E}{V} * \sigma_s + \frac{D}{V}(0.05 + .25\sigma_s) \quad (8)$$

Where V is firm value, E is the market value of stock and options, and D is the market value of debt. Bharath and Shumway (2008) find that this approach yields similar results to simultaneously solving an option pricing model for value and volatility, but avoid the data loss that occurs when the solution to this simultaneous equation does not converge.

Finally, note that an employee stock option is a compound call on the assets, and that an increase in asset volatility increases the value of the stock option through two channels:

$$\frac{\partial O}{\partial \sigma_v} = \frac{\partial O}{\partial P}\frac{\partial P}{\partial \sigma_v} + \frac{\partial O}{\partial \sigma_s}\frac{\partial \sigma_s}{\partial \sigma_v} \quad (9)$$

As shown in the first term, increases in firm volatility increase option value indirectly through the stock price, and, as shown in the second term, increases in firm volatility increase option value indirectly through changes in equity volatility (that is, the traditional option vega).

With these assumptions, we calculate firm sensitivities using Black-Scholes partial derivatives as detailed in Appendix A.4. The Appendix also notes the necessary Compustat and CRSP variables. We follow the literature (e.g., Guay, 1999) and multiply all sensitivities by 0.01 to give them the interpretation of the sensitivity a 0.01 increase in asset volatility.

2.1.2 Example of firm sensitivities

In Panel A of Table 2, we show an example firm with $2.5 billion market value assets and asset volatility of 26.4%. Options are 5% of shares outstanding, and have a price-to-strike ratio of 1.3. The options and the debt have a maturity of four years. Leverage is the face value of debt divided by the market value of assets. To calculate the sensitivities, we assume an interest rate of 2.25% and no dividends.

Panel A shows the change in the value of debt, stock, and options for a 0.01 change in the standard deviation of the assets at various levels of leverage. Options always benefit from increases in volatility. When leverage is low, there is essentially no probability that the firm will default, and the sensitivity of debt to firm volatility is very low. Since there is little debt to transfer value from, option holders gain at the expense of stockholders when volatility increases. As leverage increases, the sensitivity of debt to firm volatility increases. As this happens, the stock sensitivity becomes positive as the stock offsets losses to options with gains against the debt.

We also show the sensitivity of the debt, stock, and options as a percentage of the market value of each security. As leverage increases, the market value of the debt increases because more debt is outstanding. However, the increase in the sensitivity of the debt increases faster than the value of the debt, as shown in Column (7). The scaled stock sensitivity in Column (8) and the scaled option sensitivity in Column (9) both increase as leverage increases.

2.2 Managers' incentives from the sensitivity of firm capital structure to firm volatility

2.2.1 Total incentives to increase asset volatility

We now use the above results to derive measures of managerial incentives. A manager's (risk-neutral) incentives to increase volatility from a given security are equal to the security's sensitivity to volatility multiplied by the fraction owned by the manager. If the manager owns α of the outstanding stock, β of the outstanding debt, and N_M options, the manager's total incentives to increase asset volatility are:

$$\beta \frac{\partial D}{\partial \sigma_V} + \alpha n \frac{\partial P}{\partial \sigma_v} + N_M \frac{\partial O_M}{\partial \sigma_v} \tag{10}$$

where $\frac{\partial O_M}{\partial \sigma_v}$ is the manager's average per option sensitivity to firm volatility.[2]

2.2.2 Option vega incentives to stock volatility

Prior literature uses the option vega, the sensitivity of managers' option holdings to a change in stock volatility, as a proxy for incentives to increase volatility (Guay, 1999; Core and Guay, 2002; Coles et al., 2006; Hayes et al., 2012). The option vega is given by:

$$N_M \frac{\partial O_M}{\partial \sigma_s} \tag{11}$$

Comparing the option vega with the total sensitivity in (10), one can see that the option vega is a subset of total risk-taking incentives, and in particular does not include incentives from debt and stock. (Computing the total sensitivity requires disclosures on executive pensions and deferred compensation as well as on firm options outstanding, and only in 2006 were these disclosures required.)

2.2.3 Relative incentives to increase volatility

Jensen and Meckling (1976) suggest a scaled measure of incentives: the ratio of risk-reducing incentives to risk-increasing incentives. To create an incentive ratio similar to prior literature, we compute the ratio of risk-reducing incentives to risk-increasing incentives in (10). The ratio of risk-reducing to risk-taking incentives in (10) is equal to the ratio of debt incentives (multiplied by -1) to stock and option incentives:

$$\frac{-\beta(\frac{\partial D}{\partial \sigma_v})}{\alpha n \frac{\partial P}{\partial \sigma_v} + N_M \frac{\partial O_M}{\partial \sigma_v}} \tag{12a}$$

[2] To simplify notation, we imagine that the manager has an "average" option. In our calculations, we reflect the fact that CEOs have a variety of tranches of options with different exercise prices and maturities.

From Panel A of Table 2 above, the sensitivity of price to volatility can be negative when the firm has options, and in this case the ratio of risk-reducing to risk-taking incentives is:

$$\frac{-\beta\left(\frac{\partial D}{\partial \sigma_v}\right)-\alpha n\frac{\partial P}{\partial \sigma_v}}{N_M\frac{\partial O_M}{\partial \sigma_v}} \tag{12b}$$

We term this ratio the "relative sensitivity ratio." As in Jensen and Meckling, the ratio is informative about whether the manager has net incentives to increase or decrease firm risk. If the ratio is less than one, then the manager has more risk-taking incentives than risk-reducing incentives and vice versa if the ratio is greater than one. If the numerator exactly equals the denominator, then the manager will not have any incentives to transfer wealth among capital providers by increasing the risk of the underlying assets.

If the firm has no options outstanding, the relative sensitivity ratio (12) becomes:

$$\frac{\beta^{\partial D}/_{\partial \sigma_v}}{\alpha^{\partial D}/_{\partial \sigma_v}} = \frac{\beta}{\alpha} = \frac{\frac{Debt_{Mgr}}{Debt_{Firm}}}{\frac{Stock_{Mgr}}{Stock_{Firm}}} \tag{13}$$

The first equality follows from (4): $-\frac{\partial D}{\partial \sigma_v} = n\frac{\partial P}{\partial \sigma_v}$, and the sensitivity of total debt value to volatility divides off. The second equality follows from the definition of β and α as the manager's fractional holdings of debt and stock. An advantage of this ratio is that, if in fact the firm has no employee options, one does not have to estimate the sensitivity of debt to volatility to compute the ratio. Much prior literature (e.g., Anantharaman et al., 2011; Cassell et al., 2012; Sundaram and Yermack, 2007; Tung and Wang, 2011; Wang et al., 2010, 2011) uses this measure, and terms it the "relative leverage ratio," as it compares the manager's leverage to the firm's leverage. Since most firms have options in their capital structure, to operationalize the relative leverage ratio, researchers make an ad hoc adjustment by adding the value of the options to the value of the firm's stock and CEO's stock:

$$\frac{\beta}{\alpha} = \frac{\frac{Debt_{Mgr}}{Debt_{Firm}}}{\frac{Equity_{Mgr}}{Equity_{Firm}}} = \frac{\beta}{\frac{\alpha nP + N_M O_M}{nP + qnO}} \tag{14}$$

Alternatively, Wei and Yermack (2011) make a different ad hoc adjustment for options by converting the options into equivalent units of stock by multiplying the options by their delta:

$$\frac{\beta}{\alpha} = \frac{\frac{Debt_{Mgr}}{Debt_{Firm}}}{\frac{Delta_{Mgr}}{Delta_{Firm}}} = \frac{\beta}{\frac{\left(\alpha n + N_M \frac{\partial O_M}{\partial P}\right)}{\left(n + qn\frac{\partial O}{\partial P}\right)}} \tag{15}$$

These adjustments for options are ad hoc and incorrect because the correct relative sensitivity measure shown in (12) uses the option sensitivity to volatility, which is quite different than the option value or the option delta.

Assuming that the ratio is correctly calculated, it may be useful to know whether risk-reducing incentives are greater than risk-increasing incentives (whether the ratio is greater or less than one). When the manager's portfolio of debt, stock, and options mirrors the firm's capital structure, the ratio is one. Jensen and Meckling (1976) posit that a manager with such a portfolio "would have no incentives whatsoever to reallocate wealth" between capital providers (p. 352). However, if these agency costs of debt are smaller than the benefits of providing incentives to take advantage of risky growth opportunities, then firms will provide compensation packages with net risk-taking incentives. Similarly, if firms can use less costly contracting devices such as covenants, they will design compensation contracts with less concern for debt contracts.

Further, it is not clear that one wishes to scale away the levels information contained in (10). For example, imagine two CEOs who each have a ratio of 0.9. Although they are otherwise identical, CEO A (B) has risk-increasing incentives of $1,000 ($100,000) and risk-reducing incentives of $900 ($90,000). The relative measure scales away the sensitivities and suggests that

both CEOs make the same risk choices. However, CEO B's wealth will increase one-hundred times more for the same risk choice.

2.2.4 Empirical estimation of CEO incentives

We calculate CEO sensitivities using Black-Scholes partial derivatives as detailed in Appendix A.5 (using the firm sensitivities estimated as described above). The Appendix also notes the necessary Compustat and CRSP variable names. We calculate CEO sensitivities using Black-Scholes partial derivatives as detailed in Appendix A.5 (using the firm sensitivities estimated as described above). We follow the literature (e.g., Guay, 1999) and multiply all sensitivities by 0.01 to give them the interpretation of the sensitivity a 0.01 increase in asset volatility.

2.2.5 Example of CEO incentives

In Panel B of Table 2, we illustrate how incentives to take risk vary with firm leverage for an example CEO (of the example firm introduced above). The average CEO in our sample owns 1.5% of the firm's debt, 1.9% of the firm's stock, and 16.0% of the firm's options. Given these assumption, the CEO has debt, stock, and options sensitivities shown in Columns (2) to (4). For this example CEO, the sensitivity of debt to an increase in firm volatility decreases monotonically with leverage, while the sensitivities of stock and options to an increase in firm volatility increase monotonically with leverage. Column (5) shows the total sensitivity of the holdings to a change in volatility, and these total risk-taking incentives increase monotonically with leverage.

Column (6) shows the option vega for the example CEO. In contrast to total risk-taking incentives which increase in leverage, the option vega decreases with leverage in this example. Part of the reason for this may be seen from Equation (9) which shows that two channels determine the sensitivity of the option to firm volatility: (1) the sensitivity of the stock price to volatility (multiplied by the option delta), and (2) the sensitivity of the option price to volatility (multiplied by the sensitivity of stock volatility to asset volatility). As leverage increases, the sensitivity of stock price to firm volatility increases dramatically as illustrated by Column (4) of Panel A, but this effect is omitted from the traditional option vega calculations. Consequently, the option vega is likely to be a good approximation of the CEO's incentives to increase risk when leverage is very low, but the approximation is much noisier as leverage increases. (Sample descriptive statistics in Panel B of Table 4 below support this conjecture.)

While the level measures of the CEO's incentives are useful, they essentially assume the same amount of CEO wealth across comparisons. If, as is frequently assumed in the literature (e.g., Hall and Murphy, 2002; Conyon et al., 2011), CEOs have constant relative risk aversion, CEOs with different levels of wealth will value incentives with the same payoffs differently (Lewellen, 2006). Similarly, the same level of incentives will motivate a less wealthy CEO much more than a wealthier CEO. Assuming that CEOs have constant relative risk aversion, a direct way to generate a measure of the strength of incentives across CEOs is to scale the level of incentives by the CEO's wealth.

Column (7) of Panel B shows the example CEO's total wealth, which we compute by assuming that value of the CEO's wealth outside the firm is 50% of the value of the CEO's debt, stock, and options. Wealth for our example CEO in Panel B of Table 2 decreases with leverage. Because the CEO owns a smaller percentage of the debt than of the equity, as leverage increases

his debt value increases more slowly than his equity value decreases. Columns (8) and (9) show the total sensitivity and the option vega as percentages of total wealth. These scaled measures show similar, but muted, relations with leverage as do the level measures. The percentages shown by the scaled measures appear small, but recall that the underlying sensitivities are for a 0.01 change in volatility. If the CEO of the lowest leverage firm could increase volatility by 0.20 (our sample standard deviation), the CEO's total wealth would increase by 2.2%.

In columns (10) and (11) of Panel B of Table 2, we illustrate how the relative leverage and relative incentive ratios change with firm leverage for our example CEO. Columns (1) through (3) show that the CEO's risk-reducing and risk-taking incentives both increase in leverage. However, the magnitude of the risk-reducing incentives increases 23 times, while the magnitude of the risk-taking incentives only increases 5 times. Since the relative increase in risk-reducing incentives is greater than the increase in the risk-taking incentives, the ratio should also increase. In contrast, the relative leverage ratio shows a slight decrease and the relative incentive ratio show no change as leverage increases. Again, as noted above, these ratios only measures relative incentives when the firm has little or no options. When this happens, $\frac{\partial D}{\partial \sigma_v}$, the sensitivity of total debt value to volatility, divides off the incentive ratio. Our example firm issues a typical (and constant) fraction of employee stock options, so it is not correct to ignore the sensitivity of total debt value to volatility. Accordingly, the relative leverage and relative incentive ratios, which ignore the sensitivity of total debt value to volatility, show essentially the same incentives to increase risk for the low leverage firm (where CEO debt sensitivity is zero) as for the high leverage firm (where CEO debt sensitivity is very high).

Unlike the relative leverage and incentive ratios, the relative sensitivity ratio in Column (12) is low for low values of leverage and high for high values of leverage. While the CEO's

percentage ownership of debt and equity value remains constant by assumption, the CEO's percentage ownership of positive sensitivity to firm risk decreases substantially as leverage increases. This occurs because the managers own a much greater percentage of options than stock. The option sensitivity for the entire firm is always positive, whereas the stock sensitivity for the entire firm goes from being large and positive to small and negative as leverage decreases (see Panel A). When the stock sensitivity is positive, stockholders also have incentives to take on risk. Since the manager owns a smaller fraction of stock than of options, the manager's incentives to increase risk relative to his debt incentives to decrease risk are relatively stronger than at low levels of leverage. Note well, as discussed above, that the incentive ratios are not informative about the *magnitude* of the sensitivity of the manager's portfolio to an increase in firm volatility.

3. Sample and Variable Construction

3.1 Sample Selection

We gather a sample of 4,050 CEO-year observations from Execucomp, Compustat, and CRSP. We begin our sample in 2006 when inside debt data becomes available. We end the sample in 2009 because some of our tests require one year-ahead data that is only available through 2009. We identify executives as CEOs if we can calculate CEO tenure from Execucomp data and they are in office at the end of the year. If the firm has more than one CEO during the year, we choose the individual with the higher total pay. Following Coles et al. (2006) and Hayes et al. (2012), we do not include CEOs from financial (two-digit SIC codes 60-69) and regulated industries (two-digit SIC codes 48 and 49), because finance and regulated firms have much

different incentives and abilities to take risk than industrial firms. From this sample, we eliminate 422 observations with missing data. We provide details on sample selection in Panel A Table 3.

3.2 Descriptive statistics – firm size, volatility, and leverage

Table 3, Panel B shows descriptive statistics for volatility, the market value of firm debt, stock, and options, and leverage for the firms in our sample. We describe in Appendix A.3 how we estimate firm market values. To mitigate the effect of outliers, we winsorize all variables each year at the 1st and 99th percentiles.

Since our sample consists of S&P 1500 firms, the firms are large, with mean (median) market value of assets of $7.6 ($1.7) billion dollars. The mean (median) value is $6.6 ($1.4) billion for common stock and $0.7 ($0.1) billion for debt. Employee stock options are a much smaller part of the capital structure with the mean (median) value of the firm's outstanding stock options is $120 ($28) million. A majority of firms in our sample have low leverage. The median value is 0.141, although the mean in our sample is 0.235. These low amounts of leverage suggest low agency costs of asset substitution for most sample firms (Jensen and Meckling, 1976).

Table 3, Panel D provides an analogue to Table 2, Panel A. We divide the sample into ten leverage bins, and show the sensitivity of the firm's securities to an increase in volatility. Appendix A.4 details how we calculate these sensitivities.

If the debt holders will be repaid with a very high probability, the value of their claims changes little with increases in asset volatility. Column (4) of Panel D illustrates this by providing the mean sensitivity of firm debt to asset volatility. The debt and stock sensitivities generally increase with leverage, similar to Table 2, Panel A. The option sensitivity in Column (6), however, does not increase in leverage. To provides a clearer comparison across the leverage

bins, we scale the sensitivities by the market value of the securities. When scaled by market value, the mean debt, stock, and option sensitivities in Columns (8) through (10) all increase with leverage, similar to Table 2, Panel A.

3.3 Descriptive statistics – CEO incentive measures

Table 4, Panel A shows full sample descriptive statistics for the incentive measures. (We detail how we construct the incentive measures in Appendix A.4 and A.5.)

We begin by looking at the incentives provided by the CEOs' debt, stock, and options. The average CEO in our sample has some incentives from debt to decrease risk, but the amount of these incentives is low. This is consistent with low leverage in the typical sample firm. In fact, a CEO with large debt incentives (at the first quartile of the distribution) gains only $1,160 in additional wealth for a 0.01 decrease in firm volatility. Over half the CEOs have no debt incentives. The magnitude of the incentives from stock to increase firm risk is also small on average. However, there is substantial variation in the stock incentives, with a standard deviation of approximately $69 thousand as compared to $14 thousand for debt incentives. The average sensitivity of the CEO's options to firm volatility is an order of magnitude larger. The mean value of the total (debt, stock, and option) sensitivity is $147 thousand, which indicates that a 0.01 increase in firm risk provides the average CEO in our sample with $147 thousand in additional wealth. The option vega used in prior literature is smaller than the total sensitivity, and has strictly positive values as compared to the total sensitivity which has 303 negative values.

To provide another comparison that abstracts away from size differences, we scale the sensitivities by CEO total wealth. We estimate CEO total wealth as the sum of the value of the CEO's debt, stock, and option portfolio and the proxy for non-firm outside wealth developed by

Dittman and Maug (2007).[3] The distributions of the scaled incentive measures are similar to the unscaled measures. The average scaled total sensitivity is positive. The values are low because the sensitivities are calculated with respect to a 0.01 increase in firm volatility. If the CEO increases firm volatility by one standard deviation (0.20 in our sample), the average CEO's wealth increases by 5%. While some CEOs have net incentives to decrease risk, these incentives are a small fraction of the CEOs' total wealth. For the CEO with large risk-reducing incentives (at the first percentile of the distribution), a one standard deviation decrease in firm volatility increases the CEO's wealth by 0.4%.

The mean (median) relative leverage ratio is 2.65 (0.09), and the mean (median) relative incentive ratio is 3.49 (0.13). These values are similar to those in Cassell et al. (2012), who also use an Execucomp sample. These ratios are skewed, and are approximately one at the third quartile, suggesting that 25% of our sample CEOs have incentives to decrease risk. This fraction is much larger than the 7.5% of CEOs with net incentives to reduce risk based on the total sensitivity measure, and highlights the bias in the relative leverage and incentive measures. By contrast, the mean (median) relative incentive ratio is 0.32 (0.03), suggesting low incentives to decrease risk.

To shed light on these differences, in Panel B we divide the sample into ten bins based on leverage. We report mean values for the variables shown at each level of leverage. Risk-reducing incentives from the CEOs' debt sensitivity are greater at high levels of leverage than at low

[3] To develop the proxy, Dittman and Maug assume that the CEO enters the Execucomp database with no wealth, and then accumulates outside wealth from cash compensation. Dittman and Maug assume that the CEO does not consume any of his outside wealth. The only reduction in outside wealth comes from using cash to exercise his stock options and paying U.S. federal taxes. Dittman and Maug claim that their proxy is the best available given that managers' preferences for saving and consumption are unobservable. We follow Dittman and Maug (2007) and set negative estimates of outside wealth to missing. Dittman and Maug provide the measure on their website. For those CEOs missing the measure, we impute the fraction of equity wealth to total wealth using a generalized linear model. We use the same explanatory variables in this model as in the model for incentive determinants described in 4.1 below.

levels. When leverage is high, stock sensitivity is large. CEOs' option sensitivity has no relation with leverage. The CEOs' total sensitivity to firm volatility in Column (6) generally increases across leverage bins. By contrast, the option vega decreases with leverage. The option vega excludes one of the two channels that affect option sensitivity to firm volatility: the stock-sensitivity channel. When leverage is high, the stock price responds strongly to increases in firm volatility. Since the option vega excludes this channel, it is biased downwards when leverage is high. Total sensitivity scaled by total wealth in Column (8) and option vega scaled by total wealth in Column (9) show similar relations with leverage as the unscaled variables.

The relative leverage ratio in Column (10) is high for low levels of leverage and decreases steadily in leverage. The relative incentive ratio shows a similar pattern. The relative sensitivity ratio in Column (12) is below one for each level of leverage. In contrast to the relative leverage and incentive ratios, the average relative sensitivity ratio does not show much variation across leverage bins.

Panel C of Table 4 shows correlations between the sensitivity measures for the full sample. The total sensitivity and option vega are highly correlated with each other. The Pearson (Spearman) correlation coefficient is 0.81 (0.87). The fact that the total sensitivity measure can take on negative values differentiates this measure from the option vega measure. In addition, nearly five percent of the firms in our sample do not provide the CEO with stock options. These firms still provide their CEOs with differing levels of incentives using stock and inside debt even though all of these CEOs have an option vega of zero.

The scaled incentive measures exhibit large positive correlations with the level measures and low correlations with the relative measures. The relative leverage and relative incentive ratios are show positive Spearman correlations with option vega that exceed 20%. This result is

inconsistent with the option vega proxying for incentives to increase risk and the relative leverage ratio proxying for incentives to decrease risk. The relative leverage and relative incentive ratios are almost perfectly correlated with each other. Because the correlation is so high, we do not include the relative incentive ratio in our subsequent analyses below. Of the three relative measures, only the relative sensitivity ratio is negatively correlated with the total sensitivity: The -36% Spearman correlation is consistent the total sensitivity proxying for incentives to increase risk and the relative sensitivity ratio proxying for incentives to decrease risk.

4. Determinants of incentives

4.1 Research Design

Prior research focuses on: (1) what determines incentives (i.e., what types of firms use incentives more); and (2) how incentives determine firm policy. Coles et al. (2006) and Hayes et al. (2012) examine both of these questions, and we generally follow their research designs. Our regressions for the determinants of incentives take the following form:

$$Managerial\ Incentives_{it} = \sum_j \gamma_j Control_{jit} + \varepsilon_{it} \qquad (16)$$

Our control variables generally follow Coles et al. (2006) and Hayes et al. (2012). The CEO's *Cash Compensation* is intended to control for the manager's outside wealth and risk aversion (Guay, 1999). In addition, higher cash compensation leads to higher pension payments and deferred compensation, so cash compensation will be related to inside debt, and hence to our incentive measures. We include the CEO's age and tenure as CEO as additional proxies for wealth and risk-aversion. We also expect age and tenure to be positively related to inside debt.

Assuming the same level of payments, the present value of an older CEO's pension plan is higher because payments to older CEOs are discounted over fewer periods (Sundaram and Yermack, 2007). We expect tenure to be positively related to inside debt since pension values are an increasing function of tenure (Sundaram and Yermack, 2007). We control for firm size using the natural logarithm of total revenue, *log(Sales)*, and for growth opportunities using the market-to-book assets ratio, *Market-to-Book*. We use *R&D Expense* and *CAPEX* as additional controls for growth opportunities. We also control for *Book Leverage,* the debt-to-assets ratio, and for *log(Monthly Stock volatility)*, which is the natural logarithm of stock volatility estimated over the past five years.

We include a number of additional variables related to the firm's and CEO's desire to defer compensation. We include an indicator variable for whether the CEO's salary is greater than $1 million. Section 162(m) of the Internal Revenue Service code limits the tax deductibility of non-performance based compensation in excess of $1 million, and many firms require executives to defer compensation above this limit. Ceteris paribus, these firms will show lower cash compensation, higher equity incentives, and higher debt incentives.

Because the value of deducting cash compensation is low when current tax rates are low, we expect higher compensation deferrals (and higher equity incentives and inside debt) when firms face lower current tax rates. We proxy for the firm's marginal tax rate using the before interest rate calculated by Blouin et al. (2010). We also include the interaction between the marginal tax rate and the indicator for a salary above $1 million. Firms with high marginal tax rates will be more concerned with the limits to deductibility of non-performance compensation. On the other hand, it will be less advantageous for executives to defer compensation when their current tax rates are lower. We proxy for low executive tax rates with an indicator for whether

there is no state income tax on personal income in the state where the firm is headquartered and an indicator for whether the firm's headquarters are outside of the U.S.

We also include an indicator for *Liquidity Constraint* if the firm generates negative cash flow from operations. By offering employees non-cash compensation, cash-constrained firms can conserve cash. Finally, we include the stock return in years *t* (*Return*) and *t-1* (*Lag Return*). We also include year effects and fixed effects for industries at the 2-digit SIC level in all of the regressions. Appendix B summarizes how we measure these variables.

4.2 Results – determinants of incentives

Table 5 presents the results of our regressions that examine the determinants of our incentive measures. Columns (1) and (2) examine the determinants of option vega and of the total sensitivity to firm volatility. We base the sign predictions for these models on findings in Coles et al. (2006) and Hayes et al. (2012). The two measures are consistent with each other and with prior research for the following variables: The level of risk-taking incentives is positively related to *CEO Tenure*, size (*Cash Compensation* and *log(Sales)*), and growth options (proxied by *R&D Expense* and *Market-to-Book*). The greatest difference in the measures is in leverage: Total sensitivity is positively related to *Book Leverage*. This result is consistent with risky firms providing incentives for CEOs to take risk. In contrast, option vega is negatively related to *Book Leverage*.

Columns (3) and (4) examine the determinants of the relative sensitivity and the relative leverage ratios. Since the ratios have a mass at 0, we estimate Tobit models. Consistent with our Table 4 findings that the ratios are uncorrelated with each other, the ratios differ in their

significant determinants. Both ratios are positively associated with firm size and negatively associated with *Book Leverage*. The relative sensitivity ratio is positively associated with CEO tenure, *Market-to-Book*, and *log(Monthly Stock Volatility).* In contrast, the relative leverage ratio is negatively associated with CEO tenure, *Market-to-Book*, and *log(Monthly Stock Volatility).* As noted above, the relative leverage and incentive ratios are almost perfectly correlated, so we do not include an analysis of the relative incentive ratio. (Results for it are virtually identical to those shown for the relative leverage ratio.)

Column (5) provides an analysis of the determinants of *Equity Delta* as a comparison with our measures of risk-taking incentives. Consistent with the literature, larger firms provide more incentives. Longer-serving CEOs have more incentives, and firms with high growth options use more incentives.

5. Associations of incentive measures with firm risk choices

5.1 Research Design

We examine how the CEO's incentives at time *t* are related to firm risk choices at time *t+1*. Similar to Coles et al. (2006) and Hayes et al. (2012), our regressions are:

$$Firm\ Risk\ Choice_{it+1} = \alpha_0 + \beta Managerial\ Incentives_{it} + \sum_j \gamma_j Control_{jit} + \varepsilon_{it} \quad (17)$$

For parsimony, we concentrate on three *Firm Policy*$_{t+1}$ variables: (1) *log(Stock Volatility*$_{t+1}$*)* measured using daily stock volatility over year *t+1*, (2) *R&D Expense*$_{t+1}$ measured as the ratio of R&D expense to total assets, and (3) *Book Leverage*$_{t+1}$ measured as the book value of long-term debt to the book value of assets. Like the prior literature, we consider *log(Stock Volatility*$_{t+1}$*)* to be a summary measure of the outcome of firm risk choices, *R&D Expense* to be a major input to increased risk through investment risk, and *Book Leverage* to be a major input to increased risk

through capital structure risk. Somewhat different than Coles et al. (who include some contemporaneously measured control variables), we measure all control variables at *t* and all risk choice variables at *t+1*. By doing this, we hope to mitigate concerns about reverse causality (that is, that all of the outcomes of incentives in (17) above are determinants of incentives in (16)).

Our control variables in these regressions also follow Coles et al. (2006) and Hayes et al. (2012). In addition to year effects, fixed effects for industries at the 2-digit SIC level, and the variables discussed above, we also control for the delta of the manager's equity incentives, measured following Core and Guay (2002). This variable measures the incentives to increase stock price. Higher equity delta exposes managers to more firm-specific risk, so this variable also proxies for risk aversion. In the regression with *R&D Expense*, we also control for *log(Sales Growth)* and *Surplus Cash*, which proxies for the firm's investment opportunity set and its ability to finance new projects (Coles et al., 2006; Cassell et al., 2012). In the regression with *Book Leverage* as the dependent variable, we control for *ROA* and follow Hayes et al. (2012) and also control for *PPE*; bankruptcy risk with the quartile rank of a modified version of the Altman (1968) Z-score; and whether the firm has a long-term issuer credit rating.

5.2 Multivariate Results – association of option vega with firm risk choices

In order to benchmark our findings against prior literature, in Table 6 we first show associations between stock option vega and firm risk choices over time. We do this in part because we can compute stock option vega starting in 1992, whereas our total sensitivity and relative sensitivity measures require data on inside debt that becomes available only in 2006. We include in Table 6 all Execucomp CEOs with complete data. We divide this sample into three time periods: (1) 1992 to 2001, similar to Coles et al. (2006); (2) 2002 to 2004, the pre-SFAS

123(R) period in Hayes et al. (2012); and (3) 2005 to 2009, the Hayes et al. post-SFAS 123(R) period. If option vega motivates risk-taking and if our regression models are well-specified, we will find a positive relation between stock option vega and the three risk measures in each period.

We find a significant relation between option vega and stock volatility in Column (1) of Table 6 for the first period, as do Coles et al. (2006). However, the positive relation does not continue to hold in the subsequent periods. In fact, the relation becomes more negative over time. This finding of a more negative relation is consistent with Hayes et al. (2012), who find a negative change in the relation between option vega and volatility in a similar Execucomp sample. For *R&D Expense*, we find that the relation between option vega and R&D expense is consistently positive and significant through time. Option vega never has the expected positive relation with *Book Leverage*. These regressions include controls based on Hayes et al. (2012), and the results therefore are not directly comparable to the Coles et al. findings. However, the relation between option vega and leverage becomes more negative over time, like the relation between option vega and stock volatility. Similarly, the relation between option vega and leverage is also highly significant during the two later periods. Changes in the relation between leverage and risk-taking incentives over time will affect our expectations of the relation between the level measures and our proxies for risk.

5.3 Multivariate Results – association of incentive measures with firm risk choices

Table 7, Panels A presents the results of our regressions for *R&D Expense*, *Stock Volatility*, and *Book Leverage*. We exclude the controls for parsimony, and because they are presented in Table 6. Option vega in Column (1) is significantly negatively related to future stock volatility. This result is inconsistent with an expected positive relation, but is consistent

with our results in Table 6 that suggest changes over time in the estimated relation between stock volatility and option vega. (The sample sizes and results in the two tables are different because of additional data required to compute the total sensitivity, relative sensitivity, and relative leverage measures.) The total sensitivity measure and the relative sensitivity ratio also have unexpected, significant negative coefficients. The relative leverage ratio is not significantly related to stock volatility.

In contrast, all four measures have significant relations with *R&D Expense* that are consistent with greater risk-taking (risk-reducing) incentives leading to more (less) R&D. Option vega is unexpectedgly negatively related to *Book Leverage*. In contrast, we find the expected positive relation between total sensitivity and leverage. The relative measures also both have the expected negative relation with leverage.

As we noted in Section 2.2.2, scaling the level of incentives by total wealth can provide a better cross-sectional measure of CEOs' incentives. Panel B of Table 7 is similar to Panel A, except that we substitute the scaled measures (including the scaled measure of equity delta) for the level measures. After scaling by total wealth, the sign on option vega is still unexpectedly negative, but is not significant. The scaled total sensitivity is positively but insignificantly related to stock volatility. The inclusion of the scaled equity delta changes the coefficients but not the inference on the relative measures: The relative sensitivity ratio continues to have a significant unexpected, positive coefficient, and the relative leverage ratio has an insignificant coefficient.

The scaled incentive measures all have the expected relation with *R&D Expense*, as in Table 6 and Panel A of Table 7. In addition, the relation between the incentive measures and R&D expense are statistically strong. We find the expected relation between option vega scaled by wealth and *Book Leverage*, but the relation is weak. The relation is highly significant for

scaled total sensitivity. The relative sensitivity ratio is not significantly related to leverage. The relative leverage ratio has the expected relation with leverage, and is highly significant.

Considering the three proxies for risk-taking, only the scaled total sensitivity measure enters each regression with the expected sign. The relative leverage ratio also enters two regressions significantly and with the right sign, but lacks the theoretical support of the total sensitivity measure.

5.4 Robustness

The relative sensitivity ratio and total sensitivity to firm volatility depend on our estimates of firm value and firm volatility. We test the robustness of our results to our assumptions using two different methods that simultaneously solve the equations relating asset volatility to stock volatility and the equity call to estimate these values. Each uses different assumptions about the face value of debt and the time until the debt matures. First following Lewellen (2006), we use the full value of long-term debt as the strike price of the equity call and assume that all debt matures in 10 years. Estimates of firm volatility are approximately four percentage points higher. The market values of each security are estimated to be within 5% of those reported. We also use the method to estimate firm value and volatility that Campbell et al. (2008) describe in their appendix. The strike price of the equity call is generally the current portion of long-term debt plus one half of the non-current long-term debt. Campbell et al. (2008) assume that this amount of debt matures in one year. Estimates of firm volatility using this estimator are about two percentage points lower.

Both the relative sensitivity ratio and total sensitivities based on these estimates of firm value and volatility have correlations of at least 0.95 with the measures presented above. The results of our multivariate analysis using the sensitivity measures calculated following Lewellen (2006) and Campbell et al. (2008) are also qualitatively similar to those reported. This relieves concerns that the assumptions from Bharath and Shumway's (2008) naïve estimator are driving our results.

6. Conclusion

The purpose of this paper is to examine the sensitivity of CEOs' holdings of debt, stock, and options to firm volatility. Prior literature uses two types of proxies for managers' risk-taking incentives: (1) option vega and (2) the relative leverage and incentive ratios. Both of these measures are biased. The option vega ignores the sensitivity of the managers' debt and stock to changes in firm volatility. The relative leverage and relative incentive ratios used by prior literature understate the sensitivity of options to changes in firm volatility. We develop a measure of the total sensitivity of managers' debt, stock, and option holdings to changes in firm volatility. This measure incorporates the incentives from each part of the capital structure. The measure also incorporates the complex interrelation between debt, stock, and options sensitivities to firm risk. We then examine the relation between our measure of incentives and firm risk choices. We compare the results using our measure and those in the prior literature. We find mixed evidence that our measure performs better than those used in the prior literature. When we scale our measure by a proxy for total wealth, we find somewhat stronger results than using the

level of our measure. We acknowledge, however, that the usefulness of the measures we develop depend on the quality of the assumptions used to calculate the measures and to calculate our proxy for total wealth.

Appendix A: Measurement of firm and manager sensitivities

A.1 Value and sensitivities of employee options

We value employee options using the Black-Scholes model with the warrant pricing approximation described by Galai and Schneller (1978).

$$O = \frac{1}{1+q}\left[Pe^{-\delta T_{Opt}}N(Z) - Xe^{-rT_{opt}}N\left(Z - \sigma_s\sqrt{T_{opt}}\right)\right] \qquad \text{(A1)}$$

Where

q = options outstanding / shares outstanding
P = stock price
δ = natural logarithm of the dividend yield (*dvpsx_f* / *prcc_f*)
T_{Opt} = time to maturity of the option
N = cumulative probability function for the normal distribution
$Z = \left[\ln(P/X) + T_{Opt}\left(r - \delta + \frac{1}{2}\sigma_s^2\right)\right]/\left(\sigma_s\sqrt{T_{Opt}}\right)$
X = exercise price of the option
r = natural logarithm of the risk-free interest rate
σ_s = stock-return volatility (calculated as monthly volatility for 60 months, with a minimum of 12 months)

The Galai and Schneller (1978) adjustment is an approximation that ignores situations when the option is just in-the-money and the firm is close to default.[4] Since leverage ratios for our sample are low (see Panels B and D of Table 3), bankruptcy probabilities are also low. Therefore, our approximation should be reasonable.

We use the derivatives of (A1) above to calculate the sensitivity of a stock option to an increase in stock price:

$$\frac{\partial O}{\partial P} = \frac{1}{1+q} * e^{-\delta T_{Opt}}N(Z), \qquad \text{(A2)}$$

and the sensitivity of a stock option to an increase in stock volatility:

$$\frac{\partial O}{\partial \sigma_s} = \frac{1}{1+q} * e^{-\delta T_{Opt}}N'(Z)P\sqrt{T_{Opt}} \qquad \text{(A3)}$$

Where:

N′ = probability density function for the normal distribution

[4] Geske (1979) derives an exact formula for valuing compound options, but the formula involves the cumulative density function of the bivariate normal distribution. There is not a closed form representation for the cumulative density function of the bivariate normal distribution. Other work valuing compound options (Crouhy and Galai, 1994; Dittman and Yu, 2010; Chesney et al., 2011) solve these problems numerically.

A.2 Value and sensitivity of firm equity

We assume the firm's total equity value E (stock and stock options) is priced as a call on the firm's assets:

$$E = Ve^{-\delta T_D}N(Z') - Fe^{-rT_D}N\left(Z' - \sigma_v\sqrt{T_D}\right) \tag{A4}$$

Where:

V = firm value
δ = natural logarithm of the dividend yield
T_D = time to debt maturity, assumed to be 4 years.
N = cumulative probability function for the normal distribution
$Z' = \left[\ln(V/F) + T_D\left(r - \delta + \frac{1}{2}\sigma_v^2\right)\right]/\left(\sigma_v\sqrt{T_D}\right)$
F = the future value of the firm's debt including interest, i.e., (*dltt* + *dlc/2*) e^{rT_D}
σ_v = firm volatility from (A7) below

The sensitivity of equity value (stock and options) to an increase in asset volatility is:

$$e^{-\delta T_D}N'(Z')V\sqrt{T_D} \tag{A5}$$

Thus, the sensitivity of debt to an increase in asset volatility is equal to:

$$-e^{-\delta T_D}N'(Z')V\sqrt{T_D} \tag{A6}$$

A.3 Values of firm stock, options and debt

The market value (*V*) of the firm is the sum of the market value of stock and options (*E*) plus the market value of debt (*D*).

The market value of stock is the stock price *P* (*prcc_f*) times shares outstanding (*csho*).

To value total options outstanding at the firm, we multiply options outstanding (*optosey*) by the per share option value *O* estimated using (A1) above. Because we do not have data on individual option tranches, we assume that the options are a single grant with weighted-average exercise price (*optprcey*). We follow prior literature (Cassell et al., 2012; Wei and Yermack, 2011) and assume that the time to maturity of these options is four years.

Following Bharath and Shumway (2008), we estimate the market value of debt as the current portion of long-term debt plus one-half of the non-current portion of long-term debt (*dltt* + *dlc*/2).

We also follow Bharath and Shumway (2008) and estimate asset volatility as:

$$\sigma_V = \frac{E}{V}\sigma_S + \frac{D}{V}(0.05 + 0.25\sigma_S) \qquad \text{(A7)}$$

Bharath and Shumway (2008) find that defining asset volatility in this way yields estimates that are similar to simultaneously solving an option pricing model for the value of the firm and for firm volatility. The Bharath and Shumway (2008) approximation avoids data loss that occurs when the solution to this simultaneous equation does not converge.

A.4 Sensitivities of firm stock, options and debt to a 0.01 increase in volatility

We follow the literature (e.g., Guay, 1999) and multiply all sensitivities by 0.01 to give them the interpretation of the sensitivity a 0.01 increase in asset volatility.

For example, we multiply (A6) above by 0.01 to estimate *the sensitivity of debt to a 0.01 increase in asset volatility* as:

$$-e^{-\delta T_D} N'(Z') V \sqrt{T_D} * 0.01 \qquad \text{(A8)}$$

To calculate the sensitivity of stock and options, we use the partial derivative of (A7) to calculate the sensitivity of stock return volatility to an increase in firm volatility.

$$\frac{\partial \sigma_S}{\partial \sigma_v} = \frac{V}{E + .25D} \qquad \text{(A9)}$$

The *sensitivity of firm option value to a 0.01 increase in firm volatility* based on (9) is:

$$qn\left(\frac{\partial O}{\partial P}\frac{\partial P}{\partial \sigma_v} + \frac{\partial O}{\partial \sigma_S}\frac{\partial \sigma_S}{\partial \sigma_v}\right) * 0.01 \qquad \text{(A10)}$$

Where:

$\frac{\partial O}{\partial P}$, $\frac{\partial O}{\partial \sigma_S}$ and $\frac{\partial \sigma_S}{\partial \sigma_v}$ are defined as in equations (A2), (A3), and (A7), respectively.

To calculate the *sensitivity of stock value to a 0.01 increase in firm volatility*, we substitute the expression for $\frac{\partial O}{\partial \sigma_S}$ in Eq. (A10) into (7) and multiply by 0.01 to obtain:

$$-\left(\frac{\partial D}{\partial \sigma_v} + qn\frac{\partial O}{\partial \sigma_S}\frac{\partial \sigma_S}{\partial \sigma_v}\right) / \left(1 + q\frac{\partial O}{\partial P}\right) * 0.01 \qquad \text{(A11)}$$

Where:

$\frac{\partial D}{\partial \sigma_v}$, $\frac{\partial O}{\partial \sigma_S}$, $\frac{\partial \sigma_S}{\partial \sigma_v}$, and $\frac{\partial O}{\partial P}$ are defined as in equations (A6), (A3), (A9), and (A2), respectively.

A.5 Sensitivities of CEO stock options, debt, and stock

A.5.1 Option vega

We use (A1) above to calculate the sensitivity of the CEO's stock option portfolio to a 0.01 increase in stock volatility:

$$N_M * \frac{1}{1+q} * e^{-\delta T_{Opt}} N'(Z) P \sqrt{T_{Opt}} * 0.01 \qquad \text{(A12)}$$

Where:

N_M is the number of options in the CEO's portfolio.

X and T_{Opt} follow the Core and Guay (2002) assumptions about option tranches and option maturities (in general that unexercisable options have a maturity of 9 years and that exercisable options have a maturity of 6 years).

Note that unlike prior literature, we use the warrant correction $\left(\frac{1}{1+q}\right)$ shown in (A1).

A.5.2 Option delta

The sensitivity of the CEO's stock and option portfolio to a 1% increase in stock price:

$$\alpha n * 0.01 * P + N_M * \frac{1}{1+q} * e^{-\delta T_{Opt}} N(Z) * 0.01 * P \qquad \text{(A13)}$$

Where:

α is the CEO's ownership of stock shares (*shrown_excl_opts*) divided by firm shares outstanding (*csho*).

n is the number of shares outstanding (*csho*)

Again, unlike prior literature, we use the warrant correction $\left(\frac{1}{1+q}\right)$ shown in (A1).

A.5.3 Total sensitivity to firm volatility

Total sensitivity to firm volatility is the sum of the CEO's debt, stock, and option sensitivities to a 0.01 increase in asset volatility.

The *CEO's debt sensitivity* is the CEO's percentage ownership of firm debt β multiplied by the firm's debt sensitivity shown in (A6) above.

$$-\beta e^{-\delta T_D} N'(Z') V \sqrt{T_D} * 0.01 \qquad \text{(A14)}$$

Where:

β follows follow Cassell et al. (2012), and is the CEO's ownership inside debt (*pension_value_tot* plus *defer_balance_tot*) divided by firm debt (*dlc* plus *dltt*).

The *CEO's stock sensitivity* is the CEO's percentage ownership of stock multiplied by the firm's stock sensitivity shown in (A11) above.

$$-\alpha\left(\frac{\partial D}{\partial \sigma_v}+qn\frac{\partial O}{\partial \sigma_s}\frac{\partial \sigma_s}{\partial \sigma_v}\right)/\left(1+q\frac{\partial O}{\partial P}\right)*0.01 \qquad \text{(A15)}$$

The *CEO's option sensitivity* is:

$$\sum\left(\frac{\partial O_{CEO}}{\partial P}\frac{\partial P}{\partial \sigma_v}+\frac{\partial O_{CEO}}{\partial \sigma_s}\frac{\partial \sigma_s}{\partial \sigma_v}\right)*0.01 \qquad \text{(A16)}$$

Where:

$\frac{\partial D}{\partial \sigma_v}$, $\frac{\partial O_{CEO}}{\partial P}$, $\frac{\partial O_{CEO}}{\partial \sigma_s}$, $\frac{\partial \sigma_s}{\partial \sigma_v}$, and $\frac{\partial P}{\partial \sigma_v}$ are defined as in equations (A6), (A2), (A3), (A9), (A11), and O_{CEO} is calculated following Core and Guay (2002).

A.5.4 Relative sensitivity ratio

If the sensitivity of stock price to volatility is positive, the ratio is:

$$\frac{-CEO\ debt\ sensitivity}{CEO\ stock\ sensitivity+CEO\ option\ sensitivity} \qquad \text{(A17a)}$$

If the sensitivity of stock price to volatility is negative, the ratio is:

$$\frac{-CEO\ debt\ sensitivity-CEO\ stock\ sensitivity}{CEO\ option\ sensitivity} \qquad \text{(A17b)}$$

A.5.5 Relative leverage ratio

Following Sundaram and Yermack (2007) the relative leverage ratio is the ratio of the CEO's percentage debt holdings divided by the CEO's percentage equity holdings.

$$\frac{\beta}{\frac{EquityValue_{Mgr}}{EquityValue_{Firm}}} \qquad \text{(A18)}$$

Where:

$EquityValue_{Mgr}$= sum of the value of the CEO's stock holding and the Black-Scholes value of the CEO's option portfolio calculated following Core and Guay (2002) and not including the warrant pricing correction

$EquityValue_{Firm}$= sum of the market value of stock and the Black-Scholes value of options calculated according to (A1) above and not including the warrant pricing correction.

A.5.5 Relative incentive ratio

Following Wei and Yermack (2011), the relative incentive ratio is the ratio of the CEO's percentage debt holdings divided by the CEO's percentage holdings of equity delta.

$$\frac{\beta}{\frac{EquityDelta_{Mgr}}{EquityDelta_{Firm}}} \tag{A19}$$

Where:

$EquityDelta_{Mgr}$= sum of the delta of the CEO's stock holding and the Black-Scholes delta of the CEO's option portfolio calculated following Core and Guay (2002) and not including the warrant pricing correction.

$EquityDelta_{Firm}$= sum of the number of shares outstanding and the delta of the options calculated according to (A2) above and not including the warrant pricing correction.

Appendix B: Measurement of Other Variables

The measurement of other variables, with the exception of *No State Tax*, is based on compensation data in Execucomp, financial statement data in Compustat, and stock market data from the Center for Research in Security Prices (CRSP) database.

log(Monthly Stock Volatility)	The natural logarithm of the variance of monthly stock returns over the previous 60 months, requiring at least 12 observations
log(Stock Volatility)	The natural logarithm of the variance of daily stock returns over the fiscal year
R&D Expense	The ratio of the maximum of zero and R&D expense (*xrd*) to total assets (*at*)
Market-to-Book	The ratio of total assets (*at*) minus common equity (*ceq*) plus the market value of equity (*prcc_f* * *csho*) to total assets
Book Leverage	The ratio of long-term debt (*dlc* + *dltt*) to total assets (*at*)
Cash Compensation	The sum of salary (*salary*) and bonus compensation (*bonus*)
High Salary	An indicator variable set to one when *salary* is greater than $1 million
log(Sales)	The natural logarithm of total revenue (*revt*)
log(Sales Growth)	The natural logarithm of the quantity total revenue in year *t* ($revt_t$) divided by sales in year *t-1* ($revt_{t-1}$)
CEO Tenure	The tenure of the executive as CEO through year *t*
CEO Age	The age of the CEO in year *t*
Non-U.S. Firm	An indicator variable set to one when the firm's headquarters in the Compustat North America database is not located in a U.S. state
No State Tax	An indicator variable set to one when the firm is headquartered outside of the United States and when the maximum state tax rate on individual income calculated using the TAXSIM model (Feenberg and Coutts, 1993) and obtained from http://www.nber.org/~taxsim/state-rates/ is zero
Marginal Tax Rate	The marginal tax rate calculated according to Blouin et al. (2010)
CAPEX	The ratio of capital expenditures (*capx*) less sales of property, plant, and equipment (*sppe*) to total assets (*at*)
Liquidity Constraint	An indicator variable set to one if the firm generates negative cash flow from operations, and zero otherwise
Return	The stock return over the fiscal year
Lag Return	The stock return over the previous fiscal year
Cash Surplus	The ratio of net cash flow from operations (*oancf*) less depreciation (*dpc*) plus R&D expense (*xrd*) to total assets (*at*). If depreciation expense is missing (*dpc*), and if PPE is less than 1% of total assets, we set depreciation expense to zero.
ROA	The ratio of operating income before depreciation (*oibdp*) to total assets (*at*)
PPE	The ratio of net property, plant, and equipment (*ppent*) to total assets (*at*)

Modified Z-Score	The quartile rank by year of a modification to the original Altman (1968) Z-Score: 3.3 * *oiadp* / *at* + 1.2 * (*act* – *lct*) / *at* + *sale* / *at* + 1.4 * *re* / *at*
Rating	An indicator variable set to one when the firm has a long-term issuer credit rating from S&P

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Table 1

Prior literature that measures CEOs debt incentives and measures used

Authors	Measure	Sample	Incentives examined: Increase Volatility	Incentives examined: Other
Sundaram and Yermack (2007)	Relative Leverage Ratio	Public Fortune 500 firms with and without inside debt that have 10 years of Execucomp data	✓	
Wei and Yermack (2011)	Relative Incentive Ratio	Firms with inside debt and publicly-traded bonds	✓	✓
Cassell et al. (2012)	Relative Leverage Ratio; Relative Incentive Ratio	Firms with inside debt	✓	
Tung and Wang (2010)	Relative Leverage Ratio	Banks with and without inside debt that do not experience CEO turnover during the financial crisis	✓	
Wang et al. (2010)	Relative Leverage Ratio	Firms with and without inside debt	✓	
Anantharaman et al. (2011)	Relative Leverage Ratio	Non-financial firms with and without inside debt with DealScan loan data	✓	*
Wang et al. (2011)	Relative Leverage Ratio	Non-financial firms with and without inside debt with DealScan loan data	✓	
Chen et al. (2010)	Leverage Ratio[1]	Firms with and without inside debt that have positive long-term debt	✓	*
Lee and Tang (2011)	Ratio of Deferred Compensation to Total Compensation	Firms with and without inside debt		§
Chava et al. (2010)	Ratio of Pension Compensation to Total Compensation	Firms that have public bonds	✓	✓

Notes:

The relative leverage ratio is the ratio of the CEO's percentage debt holdings divided by the CEO's percentage equity holdings. The relative incentive ratio is the ratio of the CEO's percentage debt holdings divided by the CEO's percentage holdings of equity delta.

* Mentions incentives to increase dividend payout.

§ Focus on manager's extracting excess compensation from the firm.

[1] Use CEO's leverage ratio, not scaled by firm's leverage ratio.

Table 2

Sensitivity of debt, stock, and options to asset volatility holding the firm constant ($ Thousands)

The example firm has a $2.5 billion market value of assets and an asset volatility of 26.4%. Options are 5% of shares outstanding, and have a price-to-strike ratio of 1.3. The options and the debt have a maturity of four years. Leverage is the face value of debt divided by the market value of assets. All values and sensitivities are calculated using Black-Scholes formulas assuming an interest rate of 2.25% and no dividends. Options are valued as warrants following Galai and Schneller (1978).

Panel A: Entire firm

The debt, stock, and option sensitivity is the dollar change in value for a 0.01 increase in asset volatility. The equity sensitivity is the total stock and option sensitivity.

Leverage	Firm Value	Debt Sensitivity	Stock Sensitivity	Option Sensitivity	Equity Sensitivity	Debt Sensitivity / Debt Value	Stock Sensitivity / Stock Value	Option Sensitivity / Option Value	Equity Sensitivity / Equity Value
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
0.01	$2,500,000	($ 0)	($ 622)	$ 622	$ 0	0.00%	-0.03%	1.41%	0.00%
0.25	$2,500,000	($ 185)	($ 471)	$ 656	$ 185	-0.03%	-0.02%	1.80%	0.01%
0.50	$2,500,000	($ 4,335)	$ 3,525	$ 809	$ 4,335	-0.39%	0.26%	2.87%	0.31%
0.75	$2,500,000	($12,349)	$11,311	$1,038	$12,349	-0.79%	1.24%	4.95%	1.32%
1.00	$2,500,000	($18,151)	$17,006	$1,145	$18,151	-0.96%	2.85%	7.59%	2.96%

Panel B: CEO

The example CEO owns 1.5% of the firm's debt and 2.2% of the firm's equity (1.9% of the firm's stock, and 16.0% of the firm's options). The CEO's debt and stock sensitivity is the CEO's percentage holding times the firm sensitivity from Panel A. Option vega is the sensitivity of the CEO's option portfolio to a 0.01 increase in equity volatility and scaled by the warrant adjustment in Galai and Schneller (1978). Total wealth is 150% of the value of the CEO's debt, stock, and option portfolio. The relative leverage ratio is the CEO's percentage debt holdings divided by divided by the CEO's percentage holdings of equity value. The relative incentive ratio is the ratio of the CEO's percentage debt holdings divided by the CEO's percentage holdings of equity delta. The relative sensitivity ratio is the ratio the manager's risk-reducing incentives to his risk-taking incentives. See Appendix A for detailed definitions of the incentive variables.

Leverage	Debt Sensitivity	Stock Sensitivity	Option Sensitivity	Total Sensitivity	Option Vega	Total Wealth	Tot. Sens. / Tot. Wealth	Opt. Vega / Tot. Wealth	Relative Leverage Ratio	Relative Incentive Ratio	Relative Sensitivity Ratio
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
0.01	$ 0	($ 12)	$100	$ 88	$101	$81,319	0.11%	0.12%	0.702	0.615	0.120
0.25	($ 3)	($ 9)	$105	$ 93	$ 82	$76,405	0.12%	0.11%	0.697	0.617	0.113
0.50	($ 66)	$ 68	$130	$131	$ 60	$71,443	0.18%	0.08%	0.691	0.619	0.335
0.75	($189)	$ 218	$166	$195	$ 41	$67,240	0.29%	0.06%	0.682	0.619	0.491
1.00	($277)	$ 327	$183	$233	$ 26	$64,077	0.36%	0.04%	0.673	0.618	0.543

Table 3
Sample Description

This table provides the sample reconciliation (Panel A), firm descriptive statistics (Panel B), and sample distribution by 1-digit Standard Industrial Classification (SIC) industry (Panel C) and leverage (Panel D). The sample period begins in 2006 because the Securities and Exchange Commission's expanded executive compensation disclosure requirements became effective for fiscal years ending on or after December 15, 2006. We collect observations from 2006 to 2009 and identify all firms with complete compensation data in the Execucomp database necessary to compute the incentive measures defined in Appendix A and with sufficient data in the Compustat and CRSP databases to estimate firm volatility according to Bharath and Shumway (2008) as well as dependent and control variables. Our primary sample consists of 4,050 firm-year observations, representing 1,684 unique firms.

Panel A: Sample Reconciliation

	Number
CEOs of non-regulated, non-financial firms in Execucomp with data on tenure and equity incentives	4,472
Missing data on inside debt	(212)
Missing control variables	(21)
Other	(189)
Final Sample	4,050

Panel B: Sample Descriptive Statistics

Dollar amounts are in millions of dollars. We estimate the volatility of asset returns following Bharath and Shumway (2008). The market value of debt is calculated as short-term debt plus one half of long-term debt, following Bharath and Shumway (2008). Employee options are valued as warrants using the end-of-year number of stock options outstanding and weighted average strike price and an assumed maturity of 4 years. The market value of assets is the sum of market value of stock, the market value of debt, and the Black-Scholes value of employee options.

Variable	Mean	Std. Dev.	P1	Q1	Median	Q3	P99
Volatility of Stock Returns	0.506	0.249	0.165	0.331	0.450	0.621	1.410
Volatility of Asset Returns	0.450	0.195	0.155	0.306	0.413	0.555	1.093
Market Value of Stock	$6,648	$17,963	$ 49	$ 547	$1,429	$4,336	$116,762
Market Value of Debt	$ 716	$ 1,617	$ 0	$ 12	$ 145	$ 591	$ 8,866
Black-Scholes Value of Employee Options	$ 120	$ 315	$ 0	$ 9	$ 28	$ 91	$ 1,583
Market Value of Assets	$7,635	$19,917	$ 75	$ 663	$1,732	$5,304	$127,585
Leverage (Book Value of Debt/Market Value of Assets)	0.235	0.288	0.000	0.019	0.141	0.329	1.291

Panel C: Sample Distribution by 1-digit SIC industry

1-digit SIC Industry	Number	Percent
0	13	0.32%
1	295	7.28%
2	798	19.70%
3	1419	35.04%
4	144	3.56%
5	581	14.35%
7	570	14.07%
8	219	5.41%
9	11	0.27%
Total	4,050	100.00%

Panel D: Sample Distribution by Leverage

Leverage is the book value of debt divided by the market value of assets. The market value of assets is calculated following Bharath and Shumway (2008). The sensitivities of firm securities to volatility are the calculated as described in Appendix A. All dollar values are in millions of dollars.

Leverage	Frequency		Debt Sensitivity	Stock Sensitivity	Option Sensitivity	Equity Sensitivity	Debt Sens. / Debt Value	Stock Sens. / Stock Value	Opt. Sens. / Opt. Value	Equity Sens. / Equity Value
	Number	Percentage								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
0%-10%	1,705	42%	($ 0.02)	($ 2.49)	$ 2.51	$ 0.02	-0.01%	-0.04%	1.81%	0.00%
10%-20%	719	18%	($ 0.40)	($ 2.66)	$ 3.06	$ 0.40	-0.09%	-0.02%	2.22%	0.02%
20%-30%	496	12%	($ 1.41)	($ 0.18)	$ 1.59	$ 1.41	-0.18%	0.02%	2.93%	0.06%
30%-40%	344	8%	($ 4.88)	$ 3.41	$ 1.46	$ 4.88	-0.31%	0.11%	3.62%	0.15%
40%-50%	221	5%	($ 7.76)	$ 6.32	$ 1.44	$ 7.76	-0.45%	0.25%	4.47%	0.30%
50%-60%	144	4%	($13.13)	$ 11.72	$ 1.41	$13.13	-0.61%	0.47%	6.43%	0.52%
60%-70%	109	3%	($20.22)	$ 17.96	$ 2.26	$20.22	-0.66%	0.68%	6.71%	0.74%
70%-80%	83	2%	($17.87)	$ 15.52	$ 2.35	$17.87	-0.70%	0.98%	8.05%	1.04%
80%-90%	56	1%	($14.99)	$ 13.86	$ 1.13	$14.99	-0.68%	1.16%	8.53%	1.22%
≥90%	173	4%	($25.64)	$ 23.73	$ 1.90	$25.64	-0.50%	2.05%	12.06%	2.12%

Table 4
Descriptive Statistics for incentive variables ($ Thousands)

The debt, stock, and option sensitivity is the dollar change in value of the CEOs' holdings for a 0.01 increase in asset volatility. The total sensitivity is the sum of the debt, stock, and option sensitivities. Option vega is the sensitivity of the CEOs' option portfolios to a 0.01 increase in stock volatility and scaled by the warrant adjustment in Galai and Schneller (1978). Total wealth is the sum of the CEOs' debt, stock, and option holdings and outside wealth from Dittman and Maug (2007). The relative leverage ratio is the CEO's percentage debt holdings divided by divided by the CEO's percentage holdings of equity value. The relative incentive ratio is the ratio of the CEO's percentage debt holdings divided by the CEO's percentage holdings of equity delta. The relative sensitivity ratio is the ratio the manager's risk-reducing incentives to his risk-taking incentives. See Appendix A for detailed definitions of the incentive variables.

Panel A: full sample

This panel presents descriptive statistics on the sensitivity and incentive measures for the full sample. All variables are winsorized by year at the 1% tails. The sensitivities and option vega are measured in thousands of dollars.

Variable	Mean	Std. Dev.	P1	Q1	Median	Q3	P99
Debt Sensitivity	($ 4.56)	$ 13.91	($ 80.45)	($ 1.16)	$ 0.00	$ 0.00	$ 0.00
Stock Sensitivity	$ 10.06	$ 68.62	($145.41)	($ 2.25)	($ 0.24)	$ 3.05	$ 366.55
Option Sensitivity	$141.72	$218.08	$ 0.00	$17.42	$59.58	$166.25	$1,170.63
Total Sensitivity to Firm Volatility	$147.22	$228.18	($ 54.88)	$18.59	$63.01	$172.92	$1,163.63
Option Vega	$125.80	$240.43	$ 0.00	$13.77	$48.48	$135.92	$1,146.25
Total Sensitivity / Total Wealth	0.25%	0.38%	-0.02%	0.00%	0.06%	0.37%	1.76%
Option Vega / Total Wealth	0.33%	0.37%	0.00%	0.07%	0.23%	0.47%	1.63%
Relative Leverage Ratio	2.652	12.825	0.000	0.000	0.093	1.030	64.936
Relative Incentive Ratio	3.491	17.332	0.000	0.000	0.125	1.290	87.168
Relative Sensitivity Ratio	0.324	0.779	0.000	0.007	0.027	0.128	3.184

Panel B: Incentive variables -- sorted by leverage

This panel provides mean sensitivity of elements of the CEOs' portfolio to firm volatility in addition to the mean incentive variables defined in Appendix A for the full sample sorted by leverage. Leverage is the book value of debt divided by the market value of assets. The market value of assets is calculated following Bharath and Shumway (2008), as in Table 3, Panel B. The CEO's debt and stock sensitivity is the CEO's percentage holding times the firm sensitivity. See Appendix A for detailed definitions of the incentive variables. All dollar values are in thousands of dollars.

Leverage	N	Debt Sensitivity	Stock Sensitivity	Option Sensitivity	Total Sensitivity	Option Vega	Total Sens. / Total Wealth	Option Vega / Total Wealth	Rel. Lev. Ratio	Rel. Incent. Ratio	Rel. Sens. Ratio
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
0%-10%	1,705	($ 0.11)	($ 10.58)	$ 110.67	$ 99.97	$133.81	0.16%	0.15%	5.339	6.983	0.421
10%-20%	719	($ 1.67)	($ 4.98)	$ 175.26	$ 168.61	$187.20	0.20%	0.08%	1.539	2.025	0.227
20%-30%	496	($ 4.41)	$ 5.81	$ 148.56	$ 149.96	$139.45	0.26%	0.07%	0.969	1.212	0.242
30%-40%	344	($ 9.45)	$ 16.03	$ 155.98	$ 162.56	$142.79	0.29%	0.08%	0.659	0.923	0.218
40%-50%	221	($ 12.40)	$ 49.92	$ 156.88	$ 194.40	$109.38	0.31%	0.09%	0.602	0.869	0.283
50%-60%	144	($ 17.49)	$ 42.79	$ 165.50	$ 190.81	$102.33	0.40%	0.09%	0.471	0.794	0.293
60%-70%	109	($ 18.16)	$ 79.20	$ 178.44	$ 239.47	$ 95.54	0.47%	0.05%	0.529	0.737	0.346
70%-80%	83	($ 18.14)	$ 111.94	$ 181.68	$ 275.48	$ 97.21	0.58%	0.08%	0.208	0.357	0.283
80%-90%	56	($ 15.11)	$ 97.85	$ 134.71	$ 217.45	$ 67.69	0.43%	0.05%	0.188	0.291	0.390
≥90%	173	($ 11.94)	$ 77.80	$ 181.15	$ 247.01	$ 61.54	0.53%	0.06%	0.259	0.503	0.268

Panel C: Correlation between Incentive Measures

This table shows the correlation coefficients between the incentive measures for the sample. See Appendix A for detailed definitions of the incentive variables. Pearson (Spearman) correlations are above (below) the diagonal. Coefficients greater than 0.03 in magnitude are significant at the 0.05 level.

	Total Sens.	Option Vega	Tot. Sens. / Tot. Wealth	Opt. Vega / Tot. Wealth	Rel. Lev.	Rel. Incent.	Rel. Sens.
Total Sensitivity to Firm Volatility		0.81	0.25	0.31	0.00	-0.01	-0.20
Option Vega	0.87		0.14	0.30	0.03	0.02	-0.13
Option Vega / Total Wealth	0.39	0.32		0.48	-0.04	-0.04	-0.23
Total Sensitivity / Total Wealth	0.53	0.61	0.50		0.04	0.04	-0.31
Relative Leverage Ratio	0.22	0.27	0.07	0.17		0.96	-0.03
Relative Incentive Ratio	0.21	0.26	0.08	0.18	0.99		-0.03
Relative Sensitivity Ratio	-0.36	-0.28	-0.43	-0.47	0.16	0.17	

Table 5
Determinants of Incentive Compensation

This table presents OLS (Tobit) regression results for various incentive measures in Columns (1), (2), and (5) (Columns (3) and (4)). Appendix A provides detailed definitions of the dependent variable. Appendix B provides detailed definitions of the right-hand side variables. All variables are measured in year *t*. The t- and z-statistics reported in parentheses are based on robust standard errors clustered by both firm and year. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively.

	Option Vega (1)	**Total Sensitivity** (2)	**Rel. Sens. Ratio** (3)	**Rel. Lev. Ratio** (4)	**Equity Delta** (5)
CEO Tenure	0.300***	0.497***	0.216***	-0.157***	0.065***
	(4.93)	(5.87)	(6.80)	(-4.05)	(4.78)
CEO Age	-0.001	-0.001	0.000	0.002***	0.000
	(-1.45)	(-1.54)	(0.30)	(4.47)	(0.25)
Cash Compensation	0.027***	0.052***	-0.006***	0.002	-0.001
	(3.43)	(3.30)	(-2.76)	(0.78)	(-1.07)
log(Sales)	0.051***	0.054***	0.005***	0.016***	0.004***
	(10.08)	(8.26)	(2.72)	(5.36)	(4.66)
R&D Expense	0.576***	0.575***	-0.109***	-0.320	0.009
	(4.86)	(5.06)	(-3.26)	(-1.41)	(1.04)
Market-to-Book	0.023***	0.009**	0.009***	0.001	0.004***
	(5.12)	(2.05)	(5.03)	(0.40)	(6.22)
Book Leverage	-0.493***	2.248***	-0.861***	-0.801***	-0.071***
	(-2.81)	(7.08)	(-8.91)	(-5.67)	(-4.08)
log(Monthly Stock Volatility)	-0.605**	-0.238	0.254***	-0.297***	-0.006
	(-2.21)	(-0.71)	(6.25)	(-4.62)	(-0.57)
No State Tax	-0.014*	-0.005	0.003	-0.014**	-0.000
	(-1.74)	(-0.46)	(0.54)	(-2.56)	(-0.25)
High Salary	-0.078	0.070	0.013	0.039***	-0.010**
	(-1.41)	(0.58)	(1.00)	(2.71)	(-2.10)
Marg. Tax Rate	-0.055	0.005	0.046**	0.032	-0.007**
	(-1.14)	(0.05)	(2.18)	(1.11)	(-2.25)
Marg. Tax Rate * High Salary	0.517***	0.161	-0.053	-0.125***	0.028**
	(3.24)	(0.48)	(-1.43)	(-2.96)	(2.03)
Non-U.S. Firm	-0.019	-0.075*	-0.031***	0.022**	-0.002

	(-0.82)	(-1.89)	(-3.42)	(1.98)	(-1.48)
CAPEX	-0.061	-0.084	-0.059*	-0.058	0.010
	(-0.78)	(-0.74)	(-1.88)	(-1.51)	(1.21)
Liquidity Constraint	-1.540***	1.137	0.189	-1.091	0.169**
	(-2.58)	(0.40)	(0.47)	(-0.45)	(2.46)
Return	-1.054	-0.152	-0.085	-0.006	0.057
	(-1.29)	(-0.16)	(-0.39)	(-0.06)	(1.55)
Lag Return	-3.118***	-1.835*	-0.107	-1.025**	0.055
	(-3.38)	(-1.65)	(-0.18)	(-1.99)	(1.14)
Intercept	-0.388***	-0.368***	0.000	-0.223***	-0.035***
	(-5.75)	(-3.95)	(0.01)	(-6.76)	(-3.72)
2-digit SIC fixed effects?	Yes	Yes	Yes	Yes	Yes
Year fixed effects?	Yes	Yes	Yes	Yes	Yes
Observations	3,983	3,983	3,983	3,788	3,983
R-squared	0.427	0.339			0.266
Adjusted R-squared	0.417	0.326			0.252

Table 6
Association between option vega and volatility, R&D, and leverage

This table presents OLS regression results using *Stock Volatility* (Columns (1) through (3)), *R&D Expense* (Columns (4) through (6)), and *Book Leverage* (Columns (7) through (9)) as the dependent variables. Incentive variables and all controls are measured in year *t*. The dependent variables are measured in year *t+1*. The incentive variables are described in detail in Appendix A. Dependent and control variables are described in Appendix B. The t-statistics reported in parentheses are based on robust standard errors clustered by both firm and year. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively.

	log(Stock Volatility)			**R&D Expense**			**Book Leverage**		
	1992-2001	2002-2004	2005-2009	1992-2001	2002-2004	2005-2009	1992-2001	2002-2004	2005-2009
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Option Vega	0.744***	-0.131***	-0.606***	0.030***	0.014***	0.028***	-0.032	-0.049***	-0.061***
	(2.91)	(-2.62)	(-3.69)	(2.83)	(3.54)	(4.80)	(-1.26)	(-3.10)	(-4.34)
Equity Delta	0.029***	-0.002	0.003	-0.000	0.000	0.001*	-0.002	-0.005*	-0.008***
	(3.30)	(-0.30)	(0.23)	(-0.29)	(0.36)	(1.82)	(-0.94)	(-1.71)	(-2.72)
CEO Tenure	-0.004**	0.002*	-0.001	-0.001***	-0.000**	-0.000***	-0.001*	0.001	0.001
	(-2.55)	(1.94)	(-0.38)	(-4.97)	(-2.44)	(-2.77)	(-1.79)	(1.43)	(1.40)
Cash Compensation	0.028	-0.057*	-0.149***	0.004***	0.001	0.001*	-0.007**	-0.000	-0.004
	(1.07)	(-1.86)	(-2.77)	(3.35)	(0.92)	(1.85)	(-2.31)	(-0.05)	(-1.47)
log(Sales)	-0.234***	-0.206***	-0.127***	-0.012***	-0.010***	-0.010***	0.007**	-0.003	0.007
	(-15.39)	(-6.70)	(-4.55)	(-8.26)	(-6.69)	(-10.09)	(2.35)	(-0.89)	(1.43)
Market-to-Book	0.043***	-0.106**	-0.124**	0.003**	0.005**	0.000	-0.006***	-0.004	-0.003
	(2.65)	(-2.09)	(-1.98)	(2.48)	(2.40)	(0.17)	(-2.59)	(-0.81)	(-0.43)
Book Leverage	0.567***	0.323***	0.707***	-0.021***	0.012*	0.005			
	(4.97)	(5.20)	(4.19)	(-2.93)	(1.83)	(0.75)			
log(Sales Growth)				-0.001	-0.022**	-0.009			
				(-0.19)	(-2.25)	(-1.35)			
Return				-0.010***	-0.003	-0.006**			
				(-3.67)	(-0.33)	(-2.15)			
Cash Surplus				0.116***	0.091***	0.185***			
				(4.66)	(3.67)	(9.67)			
R&D Expense	3.031***	3.948***	1.716***				-0.541***	-0.260***	-0.347***
	(11.20)	(6.35)	(3.32)				(-7.39)	(-2.86)	(-3.96)
CAPEX	-0.630*	-0.237	1.566*						
	(-1.73)	(-0.60)	(1.87)						

ROA							0.161***	0.101	0.127*
							(2.89)	(1.54)	(1.88)
PPE							0.035	0.050**	0.039
							(1.45)	(2.08)	(1.52)
Modified Z-score							-0.059***	-0.030***	-0.035***
							(-15.91)	(-4.33)	(-4.86)
Rating							0.086***	0.125***	0.118***
							(7.34)	(8.62)	(13.25)
Marginal Tax Rate							0.263**	0.048	0.256***
							(2.31)	(0.73)	(2.78)
Intercept	-5.836	-6.380***	-6.571	0.087***	0.051***	0.052***	0.111***	0.072**	0.172***
	(.)	(-53.56)	(.)	(10.27)	(4.38)	(6.61)	(3.40)	(2.57)	(5.26)
2-digit SIC fixed effects?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,202	3,274	5,463	9,201	3,245	5,391	8,714	3,148	5,147
R-squared	0.390	0.502	0.269	0.451	0.448	0.489	0.379	0.351	0.361
Adjusted R-squared	0.386	0.492	0.260	0.447	0.436	0.482	0.374	0.337	0.352

Table 7
Association between measures of managerial incentives and volatility, R&D, and leverage

This table presents OLS regression results using *Stock Volatility* (Columns (1) through (4)), *R&D Expense* (Columns (5) through (8)), and *Book Leverage* (Columns (9) through (12)) as the dependent variables. Incentive variables and controls are measured in year *t*. The dependent variables are measured in year *t+1*. The results using the level of incentives and the relative measures are presented in Panel A. The results using the scaled and relative incentive measures are presented in Panel B. The incentive variables are described in detail in Appendix A. Control and dependent variables are described in Appendix B and presented in Table 6. The t-statistics reported in parentheses are based on robust standard errors clustered by both firm and year. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively.

Panel A: Level and Relative Incentive Measures

	log(Stock Volatility)				R&D Expense				Book Leverage			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Option Vega	-0.840***				0.030***				-0.067***			
	(-5.67)				(4.02)				(-4.56)			
Total Sensitivity		-0.310***				0.015***				0.057***		
		(-5.50)				(4.29)				(5.96)		
Rel. Sens. Ratio			1.075***				-0.023***				-0.062*	
			(3.26)				(-2.82)				(-1.72)	
Rel. Lev. Ratio				0.007				-0.026***				-0.239***
				(0.04)				(-2.79)				(-5.56)
Equity Delta	0.434	0.144	-1.651	-0.447	0.108**	0.112**	0.169***	0.137***	-0.771**	-0.965**	-0.790**	-0.917**
	(0.22)	(0.08)	(-0.94)	(-0.26)	(2.22)	(2.41)	(3.81)	(3.29)	(-2.07)	(-2.29)	(-2.03)	(-2.20)
Intercept	-6.246***	-5.956***	-5.982	-5.024***	0.055***	0.047***	0.044***	0.043***	0.159***	0.223***	0.206***	0.195***
	(-25.57)	(-23.65)	(.)	(-24.33)	(6.96)	(5.19)	(5.29)	(5.75)	(5.39)	(7.52)	(7.63)	(5.70)
2-digit SIC fixed effects?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,050	4,050	4,050	3,853	4,003	4,003	4,003	3,808	3,905	3,905	3,905	3,714
R-squared	0.263	0.249	0.250	0.246	0.485	0.482	0.479	0.480	0.373	0.375	0.370	0.367
Adjusted R-squared	0.251	0.237	0.238	0.233	0.476	0.473	0.470	0.471	0.362	0.364	0.359	0.355

Panel B: Scaled and Relative Incentive Measures

	log(Stock Volatility)				R&D Expense				Book Leverage			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Opt. Vega / Tot. Wealth	-13.056				2.425**				2.416*			
	(-0.46)				(2.46)				(1.85)			
Tot. Sens. / Tot. Wealth		20.289				1.104**				10.344***		
		(1.21)				(2.35)				(7.02)		
Rel. Sens. Ratio			1.194***				-0.022**				-0.068	
			(8.94)				(-2.55)				(-1.59)	
Rel. Lev. Ratio				0.091				-0.027***				-0.240***
				(0.54)				(-2.92)				(-5.24)
Equity Delta / Total Wealth	28.363	11.732	25.419	21.904	-1.080**	-0.653*	-0.108	-0.121	-1.576	-6.159***	-0.711	-0.724
	(0.59)	(0.26)	(0.61)	(0.51)	(-2.56)	(-1.93)	(-0.38)	(-0.43)	(-1.00)	(-4.01)	(-0.47)	(-0.50)
Total Wealth	0.031	0.062	-0.053	0.045	0.011***	0.010***	0.011***	0.008***	-0.064**	-0.053**	-0.061**	-0.071**
	(0.19)	(0.35)	(-0.33)	(0.25)	(2.98)	(3.06)	(3.09)	(2.67)	(-2.24)	(-2.21)	(-2.11)	(-2.27)
Intercept	-5.724***	-5.751***	-5.935	-4.999***	0.035***	0.038***	0.042***	0.042***	0.194***	0.180***	0.208***	0.196***
	(-33.92)	(-48.13)	(-1.23)	(-24.43)	(3.01)	(3.67)	(4.95)	(5.53)	(5.95)	(5.46)	(6.89)	(5.26)
2-digit SIC fixed effects?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,050	4,050	4,050	3,853	4,003	4,003	4,003	3,808	3,905	3,905	3,905	3,714
R-squared	0.254	0.257	0.262	0.255	0.484	0.481	0.478	0.480	0.370	0.398	0.371	0.367
Adjusted R-squared	0.241	0.244	0.250	0.242	0.475	0.472	0.469	0.470	0.359	0.387	0.359	0.355