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Managerial Incentives, Risk Aversion, and Debt

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Abstract

We investigate the risk choices of risk-averse CEOs. Following recent theoretical work, we expect CEO risk aversion to be more pronounced in firms with high leverage or high default probability. We find that the CEOs of these firms reduce firm risk, even in the presence of strong risk-taking incentives. Our results are robust to controls for the sensitivity of CEO wealth to stock price changes, firm risk determinants, the endogenous feedback effects of firm risk on CEO incentives, unobserved firm and market effects, and debt governance. The impact of CEO risk aversion is economically significant.

I. Introduction

The extensive literature on asset substitution, that is, shareholders' shifting of firm risk to bondholders, concentrates on the risk preferences of shareholders and bondholders. The impact of managerial risk aversion is thought to be mitigated through compensation arrangements. In particular, prior studies assume that shareholders can always reduce managerial risk aversion by providing risk-taking incentives. This paper challenges that view by identifying conditions under which risk-averse CEOs reduce firm risk even in the presence of strong risk-taking incentives. We also show that the effect of risk aversion on CEO risk choices can be more important than debt contracting restrictions imposed upon a firm by bondholders.

Prior research on managerial incentives suggests that the two most important measures in capturing incentives are the sensitivity of managerial wealth to

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stock price, that is, compensation delta, and the sensitivity of managerial wealth to stock return volatility, that is, compensation vega (e.g., Guay (1999), Core and Guay (2002)). This literature finds that the effect of delta on managerial risk taking is ambiguous. On the one hand, an increase in the sensitivity of compensation to stock price improves the alignment of interests between managers and shareholders, since both benefit from an increase in the stock price; on the other hand, high deltas expose risk-averse managers to greater risk, which prior research argues might deter managers from increasing their preference for risk taking (Amihud and Lev (1981), Smith and Stulz (1985), and Lambert, Larcker, and Verrecchia (1991)). In contrast, recent empirical studies present consistent evidence of a positive relationship between vega and managerial risk taking (Guay (1999), Cohen, Hall, and Viceira (2000), Coles, Daniel, and Naveen (2006), and Low (2009)). The underlying rationale is that convex payoffs (e.g., those of stock options) provide managers strong incentives to increase the return volatility of the underlying asset, which will induce managers to take more risk so as to maximize their expected wealth.

The validity of the above argument with respect to vega depends, however, on managers' utility function (Pratt (1964), Smith and Stulz (1985), Guay (1999), Carpenter (2000), Ju, Leland, and Senbet (2003), Ross (2004), and Lewellen (2006)). Pratt and, more recently, Guay argue that a trade-off exists between the wealth effect (i.e., the change in a manager's expected wealth from a change in firm risk), and the risk-aversion effect (i.e., the impact of risk aversion on managerial utility). This implies that managers' risk preferences are determined by which of the two effects dominates at any given point in time. The recent empirical studies on the relationship between vega and firm risk concentrate on the wealth effect alone, abstracting from the impact of the risk-aversion effect. Guay indicates that such a focus results from the difficulty in collecting manager-specific data, which limits the ability of the researcher to calculate managerial risk aversion.

In this paper we exploit the fact that while the precise calculation of managerial risk aversion is indeed difficult, following prior (mainly theoretical) studies we can identify firm conditions under which average managerial risk aversion is expected to be high. Recent papers highlight the role of high levels of corporate debt and, in particular, high probability of default on debt in creating these firm conditions (Cadenillas, Cvitanić, and Zapatero (2004), Berk, Stanton, and Zechner (2010), and Carlson and Lazrak (2010)). This allows us to empirically examine whether under these firm conditions the risk-aversion effect dominates, which would lead managers to respond to compensation vega by reducing firm risk. Our findings support a negative association between compensation vega and firm risk in firms with high leverage or high default probability. This result is consistent with the prediction that risk-averse managers try to avoid bankruptcy and make debt safe when compensated with equity-based compensation (Carlson and Lazrak), even if this translates to a (temporary) pay cut (Berk et al.). Berk et al. attribute this managerial behavior to the large human costs of bankruptcy they face, that is, managerial career concerns. The extant literature identifies two main reasons for the impact of career concerns on managerial risk aversion: employment incentives (Amihud and Lev (1981), Grossman and Hart (1982),

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Agrawal and Mandelker (1987), and Kempf, Ruenzi, and Thiele (2009)) and reputational concerns (Holmstrom and Ricart i Costa (1986), Hirshleifer and Thakor (1992)).

Using a large panel of U.S. firms over the 1992 to 2005 period, we begin by investigating the relationship between compensation vega and firm risk. We find that this relationship is negative. This result is driven by CEOs in high-risk industries. Given that these industries are associated with higher CEO employment risk (Peters and Wagner (2014)), this result provides an initial indication of the importance of career concerns in the vega-risk relation. Controlling for the joint effect of delta and vega as well as firm characteristics previously shown to affect firm risk does not alter our results. Testing the relationship on different measures of firm risk (i.e., total, systematic, and unsystematic risk) also does not affect our conclusions. We note that the negative vega-risk association in our unconditional tests contrasts the findings of recent empirical studies, in particular Coles et al. (2006), which we follow closely in our modeling approach. We find that a positive vega coefficient obtains only for specific sample periods and model specifications. In our larger sample and for various model specifications, we do not find support of a strong positive vega-risk relation. Any positive effect of equity incentives on firm risk stems from compensation delta.

Next, to examine the role of debt in the incentives-risk relationship, we investigate the impact of debt levels, default probability, and debt governance. Consistent with the prediction of a dominant managerial risk-aversion effect in highly levered firms, we find a negative relation between vega and firm risk for firms with above-median financial leverage. We also find that this negative relation is more pronounced for CEOs with low wealth incentives or high effective risk aversion (Carlson and Lazrak (2010)). In contrast, we find no significant vega-risk relation for below-median leverage firms. We thus establish a nonmonotonic link between CEO risk-taking incentives and firm risk, consistent with recent theoretical predictions (Cadenillas et al. (2004), Carlson and Lazrak (2010)). This nonmonotonic link continues to hold when we use alternative risk measures and include compensation delta, as well as several control variables for firm risk.

Given that the literature on career concerns emphasizes the positive effect of bankruptcy and the probability of default on managerial risk aversion, we more directly examine the role of default probability using firms' market-implied distance to default (Vassalou and Xing (2004), Fang and Zhong (2004), Larsen (2006), Bharath and Shumway (2008), and Hjortshøj and Wei (2009)). We find a negative relationship between vega and firm risk only for firms that are close to default, that is, with below-median distance to default; no significant relationship obtains for firms with above-median distance to default. This result provides direct evidence that in the presence of high default risk, the risk-aversion effect dominates the wealth effect. We obtain similar results when using alternative proxies for firm default probability, such as Altman's Z-score, Moody's investment grades, or interest coverage.

To address potential concerns that our results could be driven by bondholder power instead of CEO risk aversion, we additionally examine the impact of debt governance on the vega-risk relation. Following the literature on the agency costs of debt, we proxy for the quality of debt governance using debt maturity and debt

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covenant intensity. We find that debt governance impacts CEO risk preferences only when it is likely to increase CEO career concerns. In particular, we find a significant negative relationship between vega and firm risk in firms with high debt levels and good debt governance quality (i.e., short-term debt maturity or high covenant intensity). No significant relationship obtains in the comparison group (i.e., firms with low debt levels and good debt governance quality).

This paper makes several contributions to the literature. First, the paper contributes to the executive compensation literature by providing new evidence on the relationship between incentives and risk. While the literature on executive compensation is extensive, few papers directly determine managerial incentives using vega and delta or test for their joint effect using a large sample. Prior studies that do test for the effect of vega and delta on risk taking examine specific events, such as changes in the Delaware takeover regime (Low (2009)); or a specific industry, such as oil and gas (Rajgopal and Shevlin (2002)) or banking (Hagendorff and Vallascas (2011)); or are based on a small sample size due to limited data availability (Guay (1999)). In this sense, our study is most closely related to that of Coles et al. (2006), who find a positive relationship between vega and riskier policy choices for a large sample. However, our analysis indicates that the positive vega-risk relation is sample and model specific. Furthermore, their analysis does not explore the role of risky debt in the vega-risk relationship. Our results challenge a common assumption in the compensation literature, namely that the provision of convex payoffs in managerial contracts always reduces managerial risk aversion.

Second, our results shed new light on the literature relating to the agency costs of debt. Early theoretical work predicts more managerial risk taking in the form of asset substitution, that is, risk shifting, in highly levered firms (Jensen and Meckling (1976)). We empirically demonstrate that this is not necessarily the case. Specifically, in line with prior literature, which highlights the role of risky debt in increasing managerial risk aversion (e.g., Holmstrom and Ricart i Costa (1986), Hirshleifer and Thakor (1992), and Berk et al. (2010)), we find the opposite result: Even though shareholders of highly levered firms provide higher risk-taking incentives in the form of vega, CEOs reduce firm risk. The extensive literature on the agency costs of debt suggests that debt covenants and debt maturity can be used to *partially* mitigate asset substitution in firms with financial leverage (see Jensen and Meckling (1976) and Smith and Warner (1979) for the role of debt covenants; for the effect of short-term debt, see Barnea, Haugen, and Senbet (1980) and Leland and Toft (1996)).[1] Our results emphasize the role of managerial career concerns in the determination of risk-taking choices, as the presence of good debt governance, that is, short-term debt or intense debt covenants, does not affect CEO risk choices in firms with low levels of risky debt. Debt governance has little impact on CEO risk preferences in low-levered

[1]Recent empirical studies provide mixed results on the impact of debt covenants and maturity. Brockman, Martin, and Unlu (2010) find that short-maturity debt mitigates the impact of vega on bond yields. Hjortshøj and Wei (2009) find that covenant intensity *partially* mitigates the effect of vega on risk taking. In contrast, Esmer (2010) provides strong empirical evidence of a positive relationship between covenant violations and risk taking.

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firms, since covenant violations and debt restructuring carry less weight for the CEOs of these firms (i.e., do not lead to a significant increase in the firm's default probability). We show that the risk-aversion effect can have a stronger influence on CEO choices than ex ante contractual restrictions.

Third, our paper contributes to the recent literature on managerial termination risk and risk taking. Chakraborty, Sheikh, and Subramanian (2007) find that CEOs facing high termination risk reduce firm risk. They also find that for these CEOs, risk-taking incentives are insignificantly related to firm risk. Using a larger panel, we extend their results on termination risk and risk taking by illustrating the negative vega-risk relation in high-risk industries, which are associated with higher CEO termination risk (Peters and Wagner (2014)). Furthermore, we extend their study by highlighting the important role of risky debt in determining whether the wealth or risk-aversion effect dominates.

The remainder of the paper is organized as follows: In Section II we develop our hypothesis. In Section III we describe the data and variables, and present descriptive statistics. Section IV presents our main results, and Section V presents robustness checks. We summarize our findings and conclude in Section VI.

II. Hypothesis Development

Managerial risk preferences are determined by the trade-off between expected wealth and risk aversion. According to Pratt (1964), a risk-averse manager is indifferent between a risky payoff and a smaller but certain payoff that removes his exposure to risk. The certainty equivalent (CE) is smaller than the expected wealth by the risk premium that the manager is willing to pay to avoid bearing the risk. Several studies use this CE framework to provide utility-based explanations of the risk-taking incentive effects of stock options. They conclude that the *perceived* economic value of options to their recipients (the managers) can be at a substantial discount compared to the options' market value because of the risk premium (Lambert et al. (1991), Carpenter (2000), Hall and Murphy (2002), and Tian (2004)). The discount is positively related to the degree of managerial risk aversion (Lambert et al. (1991), Hall and Murphy (2002), and Tian (2004)), as well as firm equity volatility (Lambert et al., Carpenter), in particular unsystematic risk (Tian). Managerial preferences toward firm risk thus depend on the rates of increase of both the discount (risk-aversion effect) and market (wealth effect) values from an increase in firm risk. A marginal increase in firm risk that increases the discount level more than the market value will lead to a negative rate of change of the CE with respect to firm risk.[2] In this case, a utility-maximizing manager will have an incentive to reduce firm risk in order to receive a higher

[2]Lambert et al. ((1991), pp. 136–137) argue that "an increase in that variance [of the firm's stock returns] has two conflicting effects on the option's value to the manager: a positive effect from the convexity of the option's payoff, and a negative effect from the concavity of the manager's utility function." Using numerical integration, they show that the partial derivative of a manager's expected utility with respect to the standard deviation of stock returns can be negative when managers are risk averse. The higher the level of risk aversion, the higher the negative values the partial derivate can take.

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CE of wealth. Indeed, Lambert et al., Carpenter, and Tian find that stock options can create incentives to risk-averse managers to reduce firm risk.[3]

Extending the above argument, we posit that enhanced career concerns in high-leverage or high-default probability firms lead to an increase in the risk-aversion effect, in which case the risk-aversion effect is likely to dominate the wealth effect. Recent theoretical studies provide the appropriate framework. Berk et al. (2010) argue that employees face large human costs of bankruptcy. They contend that these costs take the form of either involuntary turnover (employment risk) or future compensation cuts (reputational costs). A rich literature supports this contention. Amihud and Lev (1981) find that managers engage in firm risk-reducing mergers to decrease their largely undiversifiable employment risk. Agrawal and Mandelker (1987) argue that managerial risk taking decreases the value of human capital, since managers' future employment income is tied to the continued survival of the firm. Gilson (1989) provides empirical evidence in support of a positive link between high debt levels and employment risk. He finds that more than half of the sample firms that default on their debt, file for bankruptcy, or enter into debt restructuring experience senior management turnover. Most of the turnover appears to be involuntary and results in a lack of subsequent employment in a listed firm for a period of at least 3 years. Gilson (1990) draws similar conclusions.[4] This unemployment following a bankruptcy is one (indirect) form of reduction in future compensation (Berk et al.). A more direct form involves compensation cuts for CEOs who retain their jobs in firms that experience bankruptcy. Gilson and Vetsuypens (1993) find that CEOs who keep their jobs after bankruptcy experience compensation cuts of approximately 35%. Eckbo and Thorburn (2003) report a reduction in CEO income after bankruptcy of 47%. These results warrant the conclusions of earlier work by Holmstrom and Ricart i Costa (1986) and Hirshleifer and Thakor (1992), who argue that reputational concerns are substantial, may be more important than effort aversion in explaining managerial risk preferences, and could lead managers of levered firms to risk aversion.

Berk et al. (2010) argue that given the above human costs of bankruptcy, employees choose to avoid bankruptcy and ensure full payment of debt even if this translates to a (temporary) pay cut. Carlson and Lazrak (2010) reach a similar conclusion. They argue that CEOs choose the level of firm risk that makes debt safe when they receive stock compensation (equity incentives). They show that risk-averse CEOs of high-leverage firms choose lower firm risk when there is an increase in equity incentives (relative to cash compensation), even though this

[3]There is no closed-form solution for the estimation of CE, so prior studies estimate numerically the CE value of the option portfolio. In our analysis, we follow prior empirical literature and use the market value of the option portfolio, but investigate separately conditions when we expect high managerial risk aversion. An increase of the sensitivity of managerial expected wealth to firm risk when managers are risk averse could lead to a negative partial derivative of CE with respect to firm risk, and therefore a reduction of firm risk by the managers. In this paper, we investigate whether indeed this is the case.

[4]Subsequent empirical studies corroborate the positive relationship between financial distress and managerial forced turnover (e.g., Gilson and Vetsuypens (1993), LoPucki and Whitford (1993), and Betker (1995)).

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reduction in firm risk also reduces the expected value of equity compensation. Thus, consistent with earlier work, they show that risk-taking incentives could make utility-maximizing risk-averse CEOs reduce firm risk in high-leverage firms. For low-leverage firms, Carlson and Lazrak illustrate that similar (to those for high-leverage firms) changes in equity incentives result in less pronounced changes in firm risk. Thus, they predict a nonmonotonic relation between equity incentives and firm risk. This nonmonotonic relation is also in line with the earlier predictions of Cadenillas et al. (2004).

While the theoretical literature highlights the role of debt in increasing managerial risk aversion, to the best of our knowledge no prior study presents empirical evidence documenting the impact of debt on the relationship between incentives and firm risk. Based on the above arguments, we predict increased CEO risk aversion in firms with high financial leverage or high default probability, which leads to an enhanced risk-aversion effect. It is an empirical question whether in such cases the risk-aversion effect dominates, which would lead to a negative relationship between compensation vega and firm risk.

One alternative (to CEO risk aversion) explanation for the relationship between incentives and firm risk stems from bondholder power. The extensive agency cost of debt literature concentrates on bondholders' actions to constrain managerial risk taking. Better debt governance should in principle limit the ability of managers to shift risk from shareholders to bondholders. The extant literature proxies for the quality of debt governance using debt maturity and the intensity of debt covenants. Recent studies empirically demonstrate the importance of debt maturity in risk shifting (Larsen (2006), Brockman et al. (2010)). Hjortshøj and Wei (2009) also find evidence that covenant intensity *partially* mitigates the positive effect of vega on asset risk. The debt governance literature fails to incorporate in its predictions the managers' own agendas. Consistent with the theoretical literature presented above, we argue that in the presence of high levels of risky debt, risk-averse managers not only avoid asset substitution but proactively reduce their firms' risk. Debt covenants and short-term debt are likely to have little impact on managerial risk preferences in firms with low levels of risky debt since covenant violations and debt restructuring carry less weight for the managers of these firms. For example, in firms with low levels of debt, debt contracting violations do not lead to a significant increase in default probability, which would trigger managerial career concerns.[5] In other words, if our results are driven by CEO risk aversion and not bondholder power, we would expect the risk-aversion effect to be more important than debt governance in analyzing managerial risk preferences.[6]

[5]Beneish and Press (1993) find that technical violations of debt covenants result in an increase in refinancing costs (i.e., costs related to increased interest rates on loans and notes following a violation), as well as an increase in restructuring costs (i.e., costs that stem from lenders' demands for partial or full repayment). Both types of costs are not expected to significantly increase the default probability of a low-levered firm.

[6]The two effects are not conflicting but lead to different predictions. For example, a breach of covenants carries reputational costs for the managers. However, we argue that these costs are sufficiently significant to alter managerial risk preferences only in highly levered firms. We have differing predictions compared to the debt governance literature, as this literature ignores the effect of managerial risk aversion.

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III. Data and Variables

A. Data

We use the universe of firms covered in Standard & Poor's (S&P) ExecuComp database for the period 1992 to 2005. ExecuComp provides compensation details for the constituent firms of the following indices: S&P 500, S&P Midcap 400, and S&P Smallcap 600. Following the extant literature, we concentrate on the compensation arrangements of the CEOs. The database provides the dates on which CEOs assumed and left office. We use this information to identify CEOs, since the relevant indicator variable in ExecuComp fails to properly classify all CEO-years (Coles et al. (2006)). We exclude financial firms and utilities, given the substantial differences in their regulatory environments (Coles et al. (2006), Low (2009)). We limit our sample period to firms' 2005 fiscal year-end to avoid potential reporting differences[7] introducing inconsistencies in the calculation of the incentive measures (i.e., vega and delta). For each year in our sample, we winsorize all variables at the 1% level in both tails (Low (2009), Brockman et al. (2010)).

The final sample consists of an unbalanced panel of 2,053 firms (3,787 CEOs), with a total of 18,836 firm-years. We collect firm-specific information from Compustat and stock returns from the Center for Research in Security Prices (CRSP).

B. Variables and Methodology

To test our research questions, we use proxies for firm risk, CEO incentives, leverage, default probability, and debt governance (debt maturity and debt covenant intensity). We also include various control variables identified by prior literature to be important determinants of firm risk. We discuss our measures for each of these constructs in turn.

Following Low (2009), we proxy for firm risk using equity risk. Coles et al. (2006) use investment and financial policy variables to capture any CEO risk-taking behavior. However, the interrelation of the different policies and their intricate effects on managerial incentives make interpretation of the results difficult. We instead choose to examine firm risk directly, as we wish to isolate the net effect of all CEO risk-taking choices. We measure total firm risk as the logarithmic transformation of the annualized variance of daily stock returns over the firm's fiscal year. We also decompose total risk into its components (i.e., systematic and idiosyncratic risk). Jin (2002) illustrates that systematic and idiosyncratic risk may affect optimal CEO incentive levels differently.[8] We therefore investigate whether these differences in optimal incentive levels affect CEO risk-taking

[7]In 2006, FAS123R changed the reporting requirements of firms' relevant proxy statement (DEF14A Securities and Exchange Commission (SEC) form). As a result, ExecuComp has modified the way it reports post-2005 information, especially with respect to the value of executive stock options.

[8]Low (2009) further argues that managers can affect not only the level of risk but also its composition.

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behavior. We separate total risk into systematic and unsystematic risk by running the market model, using CRSP value-weighted returns as our proxy for the returns of the market portfolio. We employ the Dimson-beta (Dimson (1979)) to account for nonsynchronous trading using five leads and lags of market returns in the regression model. To estimate systematic risk, we take the logarithmic transformation of the annualized variance of the predicted firm returns from the market-model regression. To estimate unsystematic risk, we take the logarithmic transformation of the variance of the residuals from the above regression. In all calculations above, we require at least 60 daily returns during the fiscal year.

We calculate CEO incentives using the approximation method developed by Core and Guay (2002). The vast majority of the empirical literature on CEO compensation uses noisy proxies for incentives (e.g., number and value of options held and/or granted over the year). At best, however, these measures only partially capture vega and delta, which the theoretical literature highlights as the most relevant characteristics of an executive's compensation package (Core and Guay (2002), Coles et al. (2006)). Several recent studies apply Core and Guay's methodology (e.g., Knopf, Nam, and Thornton (2002), Rajgopal and Shevlin (2002), Burns and Kedia (2006), Coles et al. (2006), Low (2009), and Brockman et al. (2010)). In line with this approach, we use the sensitivity of CEOs' stock option portfolios to changes in stock price and stock return volatility as a proxy for their overall equity incentives. We estimate vega and delta using a European option pricing framework (Black and Scholes (1973)), including dividends (Merton (1973)). As a robustness check, we also calculate asset vega and asset delta, following the methodology developed in Chesney, Stromberg, and Wagner (2011); we treat stocks (stock options) as options (compound options) on the underlying firm asset value. Asset vega is the sensitivity of the value of the CEO stock and option portfolio to firm asset return volatility, and asset delta is the sensitivity of the value of the CEO stock and option portfolio to firm asset value. The use of asset vega and asset delta allows us to control for the fact that levered-stock compensation provides a convex payoff to the manager, similar to the option portfolio payoff structure, and therefore potentially a nontrivial vega.

As we discuss above, managerial risk aversion is expected to be more pronounced in highly levered firms. Driven by career concerns, managers are likely to avoid risky projects in firms with high levels of risky debt, as project failure in these firms is more likely to lead to default or bankruptcy. Such financial distress inflicts substantial reputational and employment costs on managers (Hirshleifer and Thakor (1992), Berk et al. (2010)). To empirically verify this argument, we calculate book leverage as the ratio of book value of total debt to the book value of assets and split our sample each year into above- and below-median book leverage firms. Our hypothesis predicts above- (below-) median book leverage firms to be associated with higher (lower) managerial risk aversion.[9]

[9]Notice, however, that because financial leverage is a risk factor, our split-sample analysis based on debt levels might be based on firms with systematically different risk profiles. To address the impact of debt on firm risk, we include book leverage as an independent variable in all our models. In addition, John and John (1993) argue that shareholders of highly levered firms will ex ante design compensation contracts with low sensitivity to performance in an effort to reduce managerial risk

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In order to empirically verify our conjectures regarding the role of managerial risk aversion in highly levered firms, we also build proxies that capture the managerial effective risk aversion, as well as the strength of the wealth effect. We further condition our above- and below-median leverage analysis on these proxies. This approach allows us to capture managerial risk choices from a stationary model where career concerns may always be present in the cross section but where economic conditions amplify the wealth or risk-aversion effects. Following Carlson and Lazrak (2010), our main proxy for effective risk aversion is the ratio of a CEO's salary to the CEO's effective stock holdings (Salary-to-Stock). In additional analyses, we also use CEO wealth, age, and tenure as alternative proxies for effective risk aversion (Shleifer and Vishny (1989), Hermalin and Weisbach (1998), Allgood and Farrell (2003), and Dittmann and Maug (2007)). In order to proxy for overall (nonfirm-specific) CEO wealth, we utilize the measure estimated by Dittmann and Maug. CEO wealth is defined as the CEO's income over all years that he appears in the ExecuComp database.[10] Furthermore, we measure the strength of the wealth effect using the ratio of the value of the CEO stock and option portfolio to CEO wealth (Equity Pay-to-Wealth).

To more directly examine the impact of a firm's default probability on the incentives-firm risk relationship, we also investigate the market-implied distance to default following Bharath and Shumway (2008).[11] These authors test the forecasting ability of several default risk measures alongside the original distance to default stemming from Black and Scholes (1973) and Merton (1973). They conclude that the functional form of the market-implied distance to default is superior to Merton's distance to default as well as a reduced-form alternative using the same input variables. Inputs to Bharath and Shumway's distance to default are market value of equity, equity volatility over the fiscal year, face value of debt, and the equity return over the previous fiscal year. Several recent studies apply this model or variations of it (e.g., Fang and Zhong (2004), Vassalou and Xing (2004), Larsen (2006), and Hjortshøj and Wei (2009)). Our hypothesis predicts that managerial risk aversion is more pronounced among firms with greater probability of default. As with leverage, we split our sample firms each year into below- and above-median distance to default firms. Our hypothesis thus predicts that below- (above-) median distance to default firms have higher (lower) probability of default, and hence are associated with higher (lower) managerial risk aversion.

taking, which could lead to bankruptcy and the loss of their investment. If this is true, then our results might be driven by low values of vega in highly levered firms. Our univariate results report a concave relationship between vega and book leverage, but the median vega values are significantly higher (lower) for above- (below-) median book leverage firms for every year in our sample.

[10]Dittmann and Maug (2007) make several assumptions regarding the exercising of old option grants, the tax treatment of income, and the reinvestment of any cash surplus. They provide details on the calculation of the measure in their Appendix B (pp. 339–340). The estimates were retrieved from http://people.few.eur.nl/dittmann/data.htm.

[11]As a robustness check, we also calculate the distance to default following Vassalou and Xing (2004). In addition, we use alternative measures of default probability, such as Altman's Z-score, Moody's investment grade classification, and interest coverage. Our results remain qualitatively the same.

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To alleviate concerns that debt governance, instead of managerial risk aversion, drives our results, we construct proxies for the extent of a firm's need for debt refinancing and the intensity of a firm's debt covenants. Following Brockman et al. (2010), we capture a firm's refinancing needs using *ST3* (*ST5*), that is, the book value of the debt maturing within the next 3 (5) years scaled by the book value of total debt. In order to test the impact of debt covenants on the incentives-risk relationship, we follow Billett, King, and Mauer (2007) and construct an index of debt covenant intensity based on 15 covenant intensity indicators. Covenant information for each debt issue of our sampled firms comes from the Fixed Income Securities Database (FISD). Our hypothesis predicts above- (below-) median book leverage firms and good debt governance to be associated with higher (lower) managerial risk aversion. In other words, we expect the results to be driven by the level of debt and not by good debt governance.

Following the extant literature, we include in all model specifications several control variables identified by prior literature to be important determinants of equity risk. As a proxy for firm size, we use the logarithm of sales. We use market-to-book ratio (M2B), defined as the market value of the firm divided by the book value of total assets, to proxy for investment growth opportunities. We also include research and development (R&D) expenditures scaled by total assets, net capital expenditures scaled by total assets (CAPEX), and book leverage, since changes in these firm policies might lead to changes in firm risk that are unrelated to managerial risk aversion (Low (2009)). Consistent with Coles et al. (2006), we further add CEO tenure and cash compensation. These variables capture the effect of CEO entrenchment and wealth diversification (Berger, Ofek, and Yermack (1997), Guay (1999)) on firm risk.[12]

To alleviate concerns about endogeneity and spurious inferences, in addition to including the control variables above that the literature identifies as important determinants of firm risk, all model specifications include firm fixed effects to control for time-invariant omitted firm-level factors that affect firm risk. We also include year effects to control for cross-sectional dependence, that is, marketwide factors that affect firm risk, and we control for time-series dependence by clustering the standard errors at the firm level.

While earlier studies model the contemporaneous risk-incentives relationship (Guay (1999)), recent studies argue that the causation is likely to run in both directions (e.g., Coles et al. (2006)). To avoid capturing any feedback effects of firm risk on compensation incentives and thus to isolate the direction of causality, in each model specification we use as exogenous variables the lagged values of vega and delta (Rajgopal and Shevlin (2002), Coles et al. (2006)).[13] We find that

[12]CEO tenure and cash compensation also help alleviate concerns that managerial self-selection might bias our results. It is possible that risk-loving managers will choose to work in highly levered firms. These individuals do not need strong risk-taking incentives to increase firm risk, and hence our split-sample analysis might be biased by systematic differences in the degree of managerial risk aversion. If that is true, one would expect a strong bias toward a positive relationship between vega and firm risk in highly levered firms. We report the opposite result. Even so, by including in all model specifications managerial characteristics that proxy for the level of risk aversion (i.e., tenure and cash compensation), we are able to alleviate such concerns.

[13]This modeling choice is also consistent with the theoretical models of Cadenillas et al. (2004) and Carlson and Lazrak (2010). In Cadenillas et al., compensation and leverage are decided at the

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these variables are valid instruments. Using panel instrumental variable regressions, we show that the null hypothesis that the chosen instruments are exogenous cannot be rejected. In contrast, we reject the exogeneity hypothesis in most of our models when using the contemporaneous vega and delta values. We use CEO age and shareholdings as additional exogenous instruments when testing the validity of lagged vega and delta. CEO shareholdings are defined as the number of shares, scaled by total shares outstanding, in the hands of the CEO.

C. Summary Statistics

Table 1 provides summary statistics for the variables in our study. Recall that vega captures the change in the value of a CEO's option portfolio (in \$100Ks USD) due to a 1% increase in stock return volatility, and delta captures the change in the value of the CEO's stock and option portfolio (in \$100Ks USD) due to a 1% increase in stock price. The average CEO in our sample holds a portfolio that is sensitive to the firm's stock price, a result that is in line with the trend of increased pay-to-performance sensitivity over our sample period. We find that a 1% increase in the firm's stock price translates into an average \$679K USD increase in portfolio value. A 1% increase in stock return volatility increases the portfolio value by \$104K USD. Delta and vega both increase over our sample period. The average delta (vega) in 1992 is 4.49 (0.24), compared to 8.19 (1.73) in 2005 (untabulated result), an increase of 82% (621%) over this period. The differences in median values are less pronounced but follow the same trend (Table 1). The average CEO also receives just above \$1M USD in cash compensation, owns 3% of the firm's equity, is 55 years old, and has been the chief executive for approximately 8 years.

The average firm in our sample has annual sales of \$3,139M USD, spends 3.9% of its book value of assets on research and development (R&D), and spends 6.1% on net capital expenditure. The average firm's book leverage is 21%, 45% (65%) of its debt matures in less than 3 (5) years, and its covenant intensity index is 43%.

The distributions of our key variables are directly comparable to those reported in prior studies. For example, our vega and delta values are identical to those reported in Brockman et al. (2010), who investigate the same time period (i.e., 1992–2005). We use our data to replicate the analyses in Coles et al. (2006) and Brockman et al., which are closest to our study, and obtain similar results.

On a univariate and contemporaneous level, both vega and delta appear to be significantly negatively related to total risk (untabulated result). This relationship is driven by unsystematic risk. In contrast, both measures of CEO incentives are positively related to firms' systematic risk. The levels of the correlation coefficients of all variables used in our study do not indicate potential multicollinearity problems in our subsequent analyses (untabulated result).

first stage by the shareholders (in Carlson and Lazrak the managers, and not the shareholders, choose leverage levels at the first stage), whereas the managers choose firm volatility at the second stage.

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TABLE 1

Summary Statistics

Table 1 presents the summary statistics. The sample contains 18,836 firm-year observations covering the 1992–2005 period. Panel A presents the time series of the median CEO vega and delta. Panel B provides the descriptive statistics for all the variables used in this study. Total Risk (ln) is the natural logarithm of the annualized variance of daily stock returns over a firm's fiscal year. Systematic Risk (ln) is the natural logarithm of the annualized variance of the predicted portion of the market model. Unsystematic Risk (ln) is the natural logarithm of the annualized variance of the residuals of the market model. Delta is the change in value (in $100Ks USD) of a CEO's stock and option portfolio for a 1% change in the firm's stock price. Vega is the change in value (in $100Ks USD) of a CEO's option portfolio for a 1% change in the firm's stock return volatility. Equity Pay-to-Wealth is the value of a CEO's stock and option portfolio scaled by the CEO's wealth, as estimated by Dittmann and Maug (2007). Salary-to-Stock is the ratio of a CEO's salary to the CEO's effective stock holdings (Carlson and Lazrak (2010)). CEO Ownership is stock ownership excluding options scaled by the total number of shares outstanding. CEO Cash Compensation is the sum of salary and bonus. CEO Tenure is the number of years the CEO has served in the position. Sales is the firm's net turnover over the fiscal year. M2B is the market-to-book ratio. R&D is research and development expenditure scaled by assets. CAPEX is capital expenditure net of sales of property, plant, and equipment, scaled by assets. Leverage is total debt scaled by assets. D2D is the Bharath and Shumway (2008) distance-to-default. ST3 (ST5) is the proportion of total debt maturing in 3 (5) years or less. Covenant Intensity Index is the arithmetic mean of 15 covenant indicators, as per Billett et al. (2007). A value of 0 indicates no covenant restrictions, while a value of 1 indicates maximum protection due to debt covenants.

Panel A. Medians by Fiscal Year

Year	Delta	Vega
1992	0.977	0.083
1993	1.179	0.141
1994	1.171	0.153
1995	1.381	0.226
1996	1.635	0.235
1997	2.098	0.312
1998	1.863	0.366
1999	2.228	0.405
2000	2.213	0.492
2001	2.315	0.602
2002	1.864	0.562
2003	2.515	0.681
2004	2.840	0.733
2005	2.757	0.708

Panel B. Descriptive Statistics

				Percentile		
Variable	*N*	Mean	Std. Dev.	25th	50th	75th
Total Risk (ln)	17,846	2.870	0.902	2.209	2.832	3.483
Systematic Risk (ln)	17,846	0.915	1.070	0.166	0.885	1.612
Unsystematic Risk (ln)	17,842	2.666	0.927	1.986	2.632	3.321
Delta (in $100Ks USD)	16,954	6.791	17.146	0.721	1.921	5.281
Vega (in $100Ks USD)	17,940	1.045	2.056	0.101	0.355	1.037
Equity Pay-to-Wealth	15,331	17.048	86.109	0.891	2.381	6.591
Salary-to-Stock	16,872	0.451	1.234	0.042	0.136	0.358
CEO Ownership	17,293	0.031	0.067	0.001	0.004	0.022
CEO Cash Compensation (in $Ms USD)	18,836	1.105	1.009	0.481	0.799	1.376
CEO Tenure (years)	17,498	7.577	7.366	2.384	5.085	10.088
CEO age (years)	15,302	55	8	50	55	60
Sales (in $Ms USD)	18,807	3,139	6,975	305	834	2,474
M2B	18,627	2.271	1.973	1.271	1.694	2.530
R&D	18,836	0.039	0.065	0.000	0.005	0.051
CAPEX	18,598	0.061	0.055	0.025	0.046	0.077
Leverage	18,748	0.214	0.181	0.046	0.197	0.330
D2D	15,029	9.288	7.075	4.552	7.729	12.190
ST3	13,689	0.452	0.344	0.152	0.380	0.757
ST5	13,356	0.651	0.324	0.398	0.686	0.993
Covenant Intensity Index	10,291	0.431	0.184	0.267	0.400	0.600

IV. Results

In this section, we first empirically investigate the relationship between vega and firm risk. We compare our results to the extant literature and highlight important differences. We then study the role of risky debt in the incentives-risk relationship and establish its importance in increasing CEO risk aversion.

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A. Vega and Risk

Table 2 presents the results on the vega-risk relationship. Even though we are interested in the effect of vega on firm risk, we control for compensation delta as well as the other control variables discussed previously.

In Panel A of Table 2, we report our results on the effect of vega on total risk and its components (i.e., systematic and unsystematic risk). All three vega coefficients are negative and highly significant. This result contradicts the findings of three prior studies that also report results on the vega-risk relationship (Guay (1999), Coles et al. (2006), and Low (2009)). The differences appear to be driven by sample selection and model specification choices. In particular, all these studies investigate the vega-risk relation during the 1990s. Guay examines a small sample of firms for 1993 only. Coles et al. report results for the period 1992–2002, largely focusing on the bull markets of the 1990s. Low examines a specific event in 1995, namely, the change in the Delaware takeover regime.

TABLE 2

Vega and Risk

Table 2 presents panel-data regression results on the vega-risk relationship. Panel A (Panel B) reports the results on the full sample (for firms in industries with Low/High risk). An industry is classified as Low (High) risk if its average distance to default is above (below) the median. The industry average is calculated as the equally weighted 5-year distance of default of all the firms in that industry. The dependent variables are the level and composition of firm risk. Total Risk (ln) is the natural logarithm of the annualized variance of daily stock returns over a firm's fiscal year. Systematic Risk (ln) is the natural logarithm of the annualized variance of the predicted portion of the market model. Unsystematic Risk (ln) is the natural logarithm of the annualized variance of the residuals of the market model. Vega is the change in value of a CEO's option portfolio for a 1% change in the firm's stock return volatility. Delta is the change in value of a CEO's stock and option portfolio for a 1% change in the firm's stock price. CEO Tenure is the number of years the CEO has served in the position. CEO Cash Compensation is the sum of salary and bonus. Sales (ln) is the natural logarithm of the firm's net turnover over the fiscal year. M2B is the market-to-book ratio. R&D is research and development expenditure scaled by assets. CAPEX is capital expenditure net of sales of property, plant, and equipment, scaled by assets. Leverage is total debt scaled by assets. All regressions include firm and year fixed effects. Intercepts are not reported. The *p*-values are reported in square brackets. Statistical significance is based on heteroskedasticity robust firm-clustered standard errors. ** and * indicate significance at the 1% and 5% levels, respectively.

Panel A. Full Sample

Independent Variables	Total Risk (ln)	Systematic Risk (ln)	Unsystematic Risk (ln)
$Vega_{t-1}$	−0.018**	−0.045**	−0.018**
	[0.000]	[0.000]	[0.000]
$Delta_{t-1}$	0.003**	0.005**	0.002**
	[0.000]	[0.000]	[0.000]
CEO Tenure	−0.002	−0.001	−0.002
	[0.128]	[0.572]	[0.168]
CEO Cash Compensation	−0.046**	−0.027*	−0.053**
	[0.000]	[0.027]	[0.000]
Sales (ln)	−0.162**	−0.022	−0.185**
	[0.000]	[0.376]	[0.000]
M2B	−0.003	0.046**	−0.012**
	[0.419]	[0.000]	[0.001]
R&D	0.779**	−0.471	1.045**
	[0.000]	[0.119]	[0.000]
CAPEX	−0.055	0.625**	−0.130
	[0.740]	[0.003]	[0.437]
Leverage	0.319**	0.108	0.362**
	[0.000]	[0.136]	[0.000]
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
No. of obs.	13,281	13,281	13,277
R^2	52.8%	44.6%	52.4%

(continued on next page)

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TABLE 2 (continued)
Vega and Risk

Panel B. Low/High Industry Risk

Independent Variables	Total Risk (ln)		Systematic Risk (ln)		Unsystematic Risk (ln)	
	Low Ind. Risk	High Ind. Risk	Low Ind. Risk	High Ind. Risk	Low Ind. Risk	High Ind. Risk
$Vega_{t-1}$	−0.009	−0.029**	−0.037**	−0.049**	−0.008	−0.031**
	[0.114]	[0.001]	[0.000]	[0.000]	[0.159]	[0.001]
$Delta_{t-1}$	0.003**	0.002**	0.004**	0.007**	0.002**	0.001
	[0.000]	[0.008]	[0.000]	[0.000]	[0.000]	[0.241]
CEO Tenure	−0.001	−0.003	0.001	−0.004	−0.001	−0.002
	[0.752]	[0.097]	[0.755]	[0.094]	[0.694]	[0.201]
CEO Cash Compensation	−0.050**	−0.026	−0.023	−0.002	−0.055**	−0.038**
	[0.000]	[0.065]	[0.158]	[0.921]	[0.000]	[0.008]
Sales (ln)	−0.155**	−0.175**	−0.015	−0.048	−0.181**	−0.191**
	[0.000]	[0.000]	[0.665]	[0.165]	[0.000]	[0.000]
M2B	0.003	−0.016*	0.045**	0.033**	−0.005	−0.025**
	[0.502]	[0.010]	[0.000]	[0.004]	[0.263]	[0.001]
R&D	0.663*	0.737*	−0.797*	−0.448	0.953**	1.050**
	[0.013]	[0.021]	[0.032]	[0.386]	[0.000]	[0.001]
CAPEX	0.018	0.097	1.210**	0.493	−0.109	0.023
	[0.939]	[0.672]	[0.000]	[0.110]	[0.647]	[0.922]
Leverage	0.286**	0.367**	0.099	0.167	0.351**	0.375**
	[0.001]	[0.000]	[0.346]	[0.146]	[0.000]	[0.000]
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	6,281	6,731	6,281	6,731	6,281	6,729
R^2	55.3%	48.5%	45.1%	42.2%	54.5%	48.3%

Even though Low's sample covers the 1996–2004 period, the difference-in-differences approach that she uses focuses on capturing the effects of the specific event. When we restrict our sample to the 1990s, that is, the 1992–2000 period, we also find a positive and marginally significant vega coefficient (untabulated result).[14] Given that our modeling approach is very similar to that of Coles et al., we replicate their results for the 1992–2002 period. When we additionally include year effects to capture the effect of marketwide factors on firm risk, we observe that the positive relationship goes away. It appears that the positive vega-risk relation is driven either by model specification choices, that is, excluding year effects, or by sample period, that is, focusing on the bull markets of the 1990s, when managerial career concerns are expected to be low.

To provide initial evidence that our reported negative vega-risk relation in the unconditional analysis is related to career concerns, we focus on the cross section and concentrate on identifying conditions that would allow us to better capture career concerns.[15] Peters and Wagner (2014) find that CEO dismissal risk

[14]The market crisis in 2000 inflates firm risk for the whole cross section of firms in our sample. Given the increase of vega over the sample period, this risk inflation appears to be driving the observed positive relationship.

[15]Further time-series analyses also corroborate our conjectures regarding the role of career concerns. Information from the Bureau of Labor Statistics (http://www.bls.gov) reveals that employment levels for the Management Occupations group (code 11-0000) substantially and monotonically drop post-2000. Total employment for 2005 is 26% lower than that for 1999. It appears that CEO career

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is positively associated with industry risk. Consistent with this finding, we argue that CEOs of firms in high- (low-) risk industries have higher (lower) career concerns. We test this argument by splitting our cross section into high versus low industry risk firms. We define industry risk using a measure of industry distance to default (D2D), in particular, the past 5-year D2D industry average. We split our industries into above-/below-median D2D industry average, and using prior-year values ($t - 1$), we group our firms into two portfolios (i.e., high vs. low industry risk). We present the results of this analysis in Panel B of Table 2. Total risk and vega are negatively related for firms in high-risk industries (-0.029, $p < 0.001$). In contrast, vega has no effect on total risk in firms in low-risk industries. The effect on total risk is mainly driven by unsystematic risk. For unsystematic risk and vega there is a negative (insignificant) association for high (low) industry risk firms. This result is consistent with the argument that CEOs can trade the market portfolio and hedge their exposure to market risk (Jin (2002), Garvey and Milbourn (2003)). Depending on their level of risk aversion, they adjust their firm-specific risk accordingly. The negative vega-systematic risk relationship remains for all firms, but it is significantly more pronounced for firms in high-risk industries. Overall, these results suggest that the negative vega-risk relation in the unconditional analysis is driven by CEO career concerns.

Turning to the estimated coefficients on the control variables in the regression analyses of this section, we find that all coefficient estimates are consistent with the existing literature. In particular, delta and leverage have a significant positive effect on firm risk; cash compensation and firm size have a negative effect on risk; and R&D, CAPEX, and M2B deliver mixed results.

B. Vega, Risk, and Leverage

To test the role of risky debt in the vega-risk relationship, for each year we sort our sample firms according to whether they have below- or above-median book leverage. We then form portfolios using prior-year ($t - 1$) leverage and run separate regressions for the two subsamples.[16] We expect CEO career concerns

concerns remain increased during the 2000–2005 period, compared to the 1990s. When we run our models for this period, we find a negative and highly significant vega coefficient (untabulated result). We also run an additional analysis splitting all the years in our sample into bull and bear CEO employment years. We use the annual changes in employment levels in the Chief Executive Occupation group (code 11-1011); an annual increase (decrease) in total CEO employment level leads to that year being classified as a bull (bear) CEO employment market. Our conclusions remain unchanged (untabulated result). In particular, the negative association between vega and risk obtains in bear CEO employment markets. We note that all the findings presented in this section are robust to stylized facts about the period under investigation, in particular, the bust of new economy firms after the 2000 financial markets crisis and the effect of the Sarbanes-Oxley Act (SOX) on the structure of the average compensation package. These additional analyses are available from the authors.

[16]Coles et al. (2006) and Carlson and Lazrak (2010) find an effect of compensation structure on optimal leverage choices. To mitigate concerns that our results are driven by the effect of delta and vega on the level of book leverage, we also form our portfolios using the 2-year before ($t - 2$) leverage level. Our results remain unchanged (unreported results).

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to increase the risk-aversion effect, thus making it more likely to dominate the wealth effect, in firms with high levels of debt.

We report our results in Table 3. Total risk and vega are negatively related for highly levered firms (-0.038, $p < 0.000$). An increase in vega of \$94K USD, which is a 1-standard-deviation increase around its mean, is associated with a reduction in the firm's annualized variance by 1% (a decrease of 6% compared to the mean total risk of 17.6%). In contrast, vega has no effect on total risk in firms with low levels of debt. Any positive effect of equity incentives on firm risk stems from compensation delta. This result holds not only for total risk but also its components. Unsystematic risk, which is the component of risk that CEOs are not allowed to diversify away, is negative and highly significant only for firms with high financial leverage (-0.036, $p < 0.000$). The negative vega-systematic risk relationship remains for all firms, but it is significantly more pronounced for above-median leverage firms. A Wald test reveals that the two coefficients are statistically significantly different. The vega coefficient of highly levered firms

TABLE 3

Vega, Risk, and Leverage

Table 3 presents panel-data regression results on the vega-risk relationship for above-/below-median leverage firms. Low (High) models report results for below- (above-) median leverage firms. The dependent variables are the level and composition of firm risk. Total Risk (ln) is the natural logarithm of the annualized variance of daily stock returns over a firm's fiscal year. Systematic Risk (ln) is the natural logarithm of the annualized variance of the predicted portion of the market model. Unsystematic Risk (ln) is the natural logarithm of the annualized variance of the residuals of the market model. Vega is the change in value of a CEO's option portfolio for a 1% change in the firm's stock return volatility. Delta is the change in value of a CEO's stock and option portfolio for a 1% change in the firm's stock price. CEO Tenure is the number of years the CEO has served in the position. CEO Cash Compensation is the sum of salary and bonus. Sales (ln) is the natural logarithm of the firm's net turnover over the fiscal year. M2B is the market-to-book ratio. R&D is research and development expenditure scaled by assets. CAPEX is capital expenditure net of sales of property, plant, and equipment, scaled by assets. Leverage is total debt scaled by assets. All regressions include firm and year fixed effects. Intercepts are not reported. The *p*-values are reported in square brackets. Statistical significance is based on heteroskedasticity robust firm-clustered standard errors. ** and * indicate significance at the 1% and 5% levels, respectively.

	Total Risk (ln)		Systematic Risk (ln)		Unsystematic Risk (ln)	
Independent Variables	Low	High	Low	High	Low	High
$Vega_{t-1}$	0.002	−0.038**	−0.022**	−0.071**	0.002	−0.036**
	[0.721]	[0.000]	[0.009]	[0.000]	[0.765]	[0.000]
$Delta_{t-1}$	0.002**	0.004**	0.003**	0.008**	0.001*	0.004**
	[0.001]	[0.000]	[0.000]	[0.000]	[0.040]	[0.003]
CEO Tenure	−0.002	0.000	0.001	−0.001	−0.003	0.001
	[0.294]	[0.984]	[0.767]	[0.596]	[0.184]	[0.647]
CEO Cash Compensation	−0.063**	−0.053**	−0.036	−0.032	−0.069**	−0.064**
	[0.000]	[0.000]	[0.059]	[0.052]	[0.000]	[0.000]
Sales (ln)	−0.151**	−0.135**	−0.006	−0.032	−0.178**	−0.149**
	[0.000]	[0.000]	[0.850]	[0.394]	[0.000]	[0.000]
M2B	−0.003	−0.003	0.040**	0.068**	−0.011**	−0.021
	[0.457]	[0.777]	[0.000]	[0.000]	[0.007]	[0.062]
R&D	0.686**	−0.131	−0.511	−2.261**	0.909**	0.466
	[0.000]	[0.802]	[0.096]	[0.008]	[0.000]	[0.373]
CAPEX	0.606**	−0.626*	1.389**	−0.356	0.522*	−0.634*
	[0.004]	[0.011]	[0.000]	[0.266]	[0.013]	[0.011]
Leverage	0.212*	0.395**	0.042	0.201	0.261**	0.412**
	[0.014]	[0.000]	[0.728]	[0.078]	[0.004]	[0.000]
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	6,617	6,641	6,617	6,641	6,617	6,637
R^2	54.7%	51.5%	43.6%	45.3%	54.2%	51.2%

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is more than three times that of the comparison group (−0.022 vs. −0.071).[17,18] Overall, the results reported in Table 3 illustrate a nonmonotonic relation between compensation incentives and firm risk, consistent with recent theoretical predictions (Cadenillas et al. (2004), Carlson and Lazrak (2010)).

To strengthen our findings, we extend the results presented in Table 3 by introducing conditions that allow us to better distinguish managerial behavior in the cross section. In particular, we further condition our analysis using proxies that capture CEO effective risk aversion or the strength of the CEO wealth effect. Carlson and Lazrak (2010) argue that the ratio of salary to effective stock ownership (Salary-to-Stock) proxies for effective risk aversion. They argue that high levels of Salary-to-Stock operate as insurance against bad outcomes, that is, the salary satisfies "with certainty" the CEO's reservation utility. We argue that in firms not under stress, high Salary-to-Stock might result in less risk-averse CEOs. But in firms under stress, these CEOs will reduce risk taking to secure the satisfaction of their reservation utility. We therefore expect that in firms under stress, CEOs with high Salary-to-Stock will be more risk averse. To test this prediction, we double sort the firms in our sample using firm leverage and CEO Salary-to-Stock. Using prior-year values ($t - 1$), we form four different portfolios that capture different levels (above/below median) of leverage and Salary-to-Stock and run our analysis for each portfolio. For highly levered firms, the vega coefficients are negative and significant, but the effect is more pronounced (almost double: −0.029 vs. −0.053) for high Salary-to-Stock CEOs. For low-leverage firms, vega coefficients remain insignificant. Any positive effect of equity incentives on firm risk stems from delta. Indeed, the delta coefficient for high Salary-to-Stock CEOs is more than double that for low Salary-to-Stock CEOs. This result confirms the Carlson and Lazrak assertion that in firms not under stress, cash compensation could reduce managerial risk aversion.

In untabulated results, we repeat the analysis using alternative proxies for risk aversion, such as CEO wealth, age, and tenure. Consistent with prior literature, we hypothesize that less wealthy and older CEOs, as well as CEOs with shorter tenures, are more risk averse (Shleifer and Vishny (1989), Barsky, Juster, Kimball, and Shapiro (1997), Hermalin and Weisbach (1998), Allgood and Farrell (2003), and Dittmann and Maug (2007)). We predict and find the largest negative and significant vega coefficients for these CEOs in highly levered firms.

As a proxy for the strength of the wealth effect, we calculate the ratio of the value of the CEO stock and option portfolio to CEO wealth (Equity Pay-to-Wealth). The higher the ratio, the stronger is the effect of equity incentives

[17]The results reported in Table 3 are based on the bifurcation of leverage (i.e., above/below median). In order to test the sensitivity of our results to this decision, for every year in our sample we sort our firms by book leverage, form quartile, and decile portfolios and rerun our analysis. The vega coefficients become more negative and significant as we move from the portfolio with the least levered firms to the one with the most levered firms (untabulated results).

[18]John and John (1993) raise the possibility that rational shareholders will lower risk-taking incentives in highly levered firms in order to avoid CEO risk taking that might lead the firm to default on its debt, that is, to avoid the loss of shareholders' investment. Thus, our results might be driven by the presence of weak risk-taking incentives in firms with above-median leverage (i.e., lower vega in above-median leverage firms compared to below-median leverage firms). Indeed, we find the vega-leverage relationship to be concave. Still, the median vega for above-median leverage firms is always higher than that for below-median leverage firms.

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on CEO behavior, since an increase in the expected value of the CEO's equity portfolio substantially affects his overall wealth. Therefore, the negative vega-risk relation is expected to be less pronounced for risk-averse CEOs with strong wealth incentives. We follow our prior analyses and double sort the firms in our sample using leverage and Equity Pay-to-Wealth. We then classify them into portfolios using the prior-year ($t-1$) median values of leverage and Equity Pay-to-Wealth as our cutoff points. We report the regression results for each portfolio in Table 4. Consistent with our predictions, the vega coefficient is negative and significant for high-leverage firms, but more so in firms with low Equity Pay-to-Wealth CEOs. The negative association between vega and firm risk exists in firms where we would expect the CEO to be more risk averse, on average, and it is more pronounced when the value of the CEO's equity portfolio is

TABLE 4

Vega, Risk, Leverage, CEO Effective Risk Aversion, and Wealth

Table 4 presents panel-data regression results on the vega-risk relationship for above-/below-median leverage firms and above-/below-median CEO wealth/effective risk aversion. Low Leverage (High Leverage) models report results for below- (above-) median leverage firms. Low Salary-to-Stock (High Salary-to-Stock) models report results for CEOs with below- (above-) median Salary-to-Stock. Similar distinction applies to Equity Pay-to-Wealth. Salary-to-Stock is the ratio of a CEO's salary to the CEO's effective stock holdings and proxies CEO effective risk aversion (Carlson and Lazrak (2010)). Equity Pay-to-Wealth is the value of a CEO's stock and option portfolio scaled by the CEO's wealth, as estimated by Dittmann and Maug (2007), and proxies the strength of the wealth effect. The dependent variable is Total Risk (ln), defined as the natural logarithm of the annualized variance of daily stock returns over a firm's fiscal year. Vega is the change in value of a CEO's option portfolio for a 1% change in the firm's stock return volatility. Delta is the change in value of a CEO's stock and option portfolio for a 1% change in the firm's stock price. CEO Tenure is the number of years the CEO has served in the position. CEO Cash Compensation is the sum of salary and bonus. Sales (ln) is the natural logarithm of the firm's net turnover over the fiscal year. M2B is the market-to-book ratio. R&D is research and development expenditure scaled by assets. CAPEX is capital expenditure net of sales of property, plant, and equipment, scaled by assets. Leverage is total debt scaled by assets. All regressions include firm and year fixed effects. Intercepts are not reported. The *p*-values are reported in square brackets. Statistical significance is based on heteroskedasticity robust firm-clustered standard errors. ** and * indicate significance at the 1% and 5% levels, respectively.

	Dependent Variable: Total Risk (ln)							
	Low Leverage		High Leverage		Low Leverage		High Leverage	
Independent Variables	Low Salary-to-Stock	High Salary-to-Stock	Low Salary-to-Stock	High Salary-to-Stock	Low Equity Pay-to-Wealth	High Equity Pay-to-Wealth	Low Equity Pay-to-Wealth	High Equity Pay-to-Wealth
$Vega_{t-1}$	0.002	−0.010	−0.029**	−0.053**	−0.008	0.002	−0.066**	−0.024**
	[0.803]	[0.323]	[0.002]	[0.000]	[0.424]	[0.849]	[0.000]	[0.000]
$Delta_{t-1}$	0.002**	0.005*	0.002	0.012**	0.004*	0.002**	0.013**	0.005**
	[0.001]	[0.031]	[0.236]	[0.000]	[0.029]	[0.005]	[0.004]	[0.000]
CEO Tenure	0.000	0.000	−0.002	0.000	−0.002	−0.001	0.001	−0.004
	[0.859]	[0.927]	[0.502]	[0.905]	[0.450]	[0.695]	[0.861]	[0.074]
CEO Cash Compensation	−0.100**	−0.051**	−0.055*	−0.058**	−0.067**	−0.059*	−0.061*	−0.052**
	[0.000]	[0.003]	[0.017]	[0.000]	[0.001]	[0.011]	[0.018]	[0.007]
Sales (ln)	−0.095**	−0.148**	0.001	−0.175**	−0.158**	−0.129**	−0.212**	−0.02
	[0.002]	[0.001]	[0.980]	[0.000]	[0.001]	[0.000]	[0.000]	[0.665]
M2B	−0.004	−0.001	0.002	−0.021	−0.003	−0.014*	−0.006	0.014
	[0.353]	[0.869]	[0.907]	[0.239]	[0.723]	[0.014]	[0.708]	[0.403]
R&D	0.362	1.328**	0.794	−0.299	1.193**	0.771**	0.334	0.186
	[0.116]	[0.001]	[0.295]	[0.690]	[0.001]	[0.009]	[0.623]	[0.820]
CAPEX	0.577*	0.034	0.134	−1.195**	0.221	0.992**	−1.155**	−0.282
	[0.016]	[0.931]	[0.675]	[0.001]	[0.522]	[0.001]	[0.002]	[0.438]
Leverage	0.199*	0.200	0.407**	0.367**	0.430**	0.117	0.522**	0.197
	[0.048]	[0.239]	[0.004]	[0.008]	[0.005]	[0.260]	[0.001]	[0.150]
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	3,785	2,802	2,648	3,983	2,908	3,046	3,070	2,826
R^2	53.8%	56.6%	46.0%	56.6%	51.8%	55.6%	52.4%	56.1%

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a small fraction of his total wealth; hence, the impact of equity incentives is weak. The differences in vega coefficients between low and high Equity Pay-to-Wealth CEOs are statistically significant at the 1% level. In untabulated results, we also modify the Equity Pay-to-Wealth measure, and we use only the value of the Option portfolio (i.e., Option Pay-to-Wealth) to run this analysis. The results remain unchanged.

C. Vega, Risk, and Distance to Default

An important determinant of managerial risk aversion, according to theoretical studies (Holmstrom and Ricart i Costa (1986), Hirshleifer and Thakor (1992), and Berk et al. (2010)), is the likelihood of bankruptcy. In particular, these studies suggest that CEOs of firms with high default probability face greater career concerns, which lead in turn to increased CEO risk aversion. To directly test this argument, we calculate firms' market-implied distance to default (Bharath and Shumway (2008)). For each year in our sample, we sort our firms according to whether they have below- or above-median distance to default (D2D), where below- (above-) median D2D indicates higher (lower) probability of default. We then form portfolios using prior-year ($t-1$) values and run our analyses separately for these two sets of firms.

Table 5 presents the results on the role of D2D. As predicted, the estimated coefficient on vega is negative and highly significant only for the below-median D2D firms (-0.030, $p = 0.007$). The effect of CEO risk aversion is economically significant. A 1-standard-deviation increase in vega is associated with a reduction in firm total risk by 1.5% (a decrease of 8.7% compared to the mean total risk of 17.6%). In contrast, there is no relationship between vega and total risk for firms with low probability of default. Consistent with the results based on leverage portfolios (Table 3), we also find a nonmonotonic relation between compensation incentives and firm risk. In addition, similar to leverage, this result is driven by the negative relationship between vega and unsystematic risk for below-median D2D firms (-0.035, $p = 0.004$). Thus, CEOs reduce firm-specific risk in firms with high probability of default, even when the firms' shareholders increase the CEOs' risk-taking incentives. The vega-systematic risk relationship remains negative and significant for all firms. The estimated coefficients are not significantly different for the two subsamples (-0.038 vs. -0.035).

To further strengthen our findings, we transform each firm's distance to default into an implied probability of default.[19] We follow the study of historical default probabilities by Moody's Investment Services and classify into the investment grade category (non-investment grade or junk) a firm with a default probability below (above) 0.68% (Moody's (2000)). We rerun the analysis reported in Table 5 separately for investment and non-investment grade firms (untabulated results).[20] For the non-investment grade firms, the vega coefficients are always

[19]We follow Bharath and Shumway (2008) and define the probability of default as $N(-D2D)$, where $N(\cdot)$ is the cumulative standard normal distribution function.

[20]There is substantial clustering of observations at the left tail of both distributions, that is, distance to default and default probability, rendering an analysis based on quartile or decile portfolios (similar to the one we run for leverage) meaningless.

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TABLE 5

Vega, Risk, and Distance-to-Default

Table 5 presents panel-data regression results on the vega-risk relationship for above-/below-median Distance-to-Default (D2D) firms. Low (High) models report results for below- (above-) median D2D firms. The dependent variables are the level and composition of firm risk. Total Risk (ln) is the natural logarithm of the annualized variance of daily stock returns over a firm's fiscal year. Systematic Risk (ln) is the natural logarithm of the annualized variance of the predicted portion of the market model. Unsystematic Risk (ln) is the natural logarithm of the annualized variance of the residuals of the market model. Vega is the change in value of a CEO's option portfolio for a 1% change in the firm's stock return volatility. Delta is the change in value of a CEO's stock and option portfolio for a 1% change in the firm's stock price. CEO Tenure is the number of years the CEO has served in the position. CEO Cash Compensation is the sum of salary and bonus. Sales (ln) is the natural logarithm of the firm's net turnover over the fiscal year. M2B is the market-to-book ratio. R&D is research and development expenditure scaled by assets. CAPEX is capital expenditure net of sales of property, plant, and equipment, scaled by assets. Leverage is total debt scaled by assets. All regressions include firm and year fixed effects. Intercepts are not reported. The *p*-values are reported in square brackets. Statistical significance is based on heteroskedasticity robust firm-clustered standard errors. ** and * indicate significance at the 1% and 5% levels, respectively.

	Total Risk (ln)		Systematic Risk (ln)		Unsystematic Risk (ln)	
Independent Variables	Low	High	Low	High	Low	High
$Vega_{t-1}$	−0.030**	−0.002	−0.038**	−0.035**	−0.035**	0.001
	[0.007]	[0.758]	[0.001]	[0.000]	[0.004]	[0.829]
$Delta_{t-1}$	0.005**	0.003**	0.007**	0.005**	0.004**	0.003**
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
CEO Tenure	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001
	[0.708]	[0.499]	[0.795]	[0.598]	[0.746]	[0.732]
CEO Cash Compensation	−0.029*	−0.071**	0.005	−0.071**	−0.041**	−0.073**
	[0.036]	[0.000]	[0.752]	[0.000]	[0.003]	[0.000]
Sales (ln)	−0.192**	−0.091**	−0.058	0.022	−0.209**	−0.108**
	[0.000]	[0.001]	[0.131]	[0.577]	[0.000]	[0.000]
M2B	−0.014	−0.008	0.048**	0.050**	−0.024**	−0.023**
	[0.091]	[0.184]	[0.000]	[0.000]	[0.007]	[0.000]
R&D	1.032*	0.103	−0.943	−0.281	1.434**	0.187
	[0.017]	[0.787]	[0.130]	[0.657]	[0.001]	[0.602]
CAPEX	−0.548*	0.912**	−0.058	1.076**	−0.629**	0.989**
	[0.022]	[0.000]	[0.858]	[0.005]	[0.009]	[0.000]
Leverage	0.232*	0.080	0.015	−0.053	0.255*	0.126
	[0.019]	[0.327]	[0.894]	[0.669]	[0.013]	[0.137]
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	5,580	5,751	5,580	5,751	5,578	5,751
R^2	48.6%	59.0%	44.1%	47.0%	47.8%	59.2%

negative and significant. Also, the vega coefficients for non-investment grade firms are significantly larger compared to those for the investment grade firms. For example, when we test the relationship between risk-taking incentives and total risk, the vega coefficient is -0.009 ($p = 0.051$) for investment grade firms compared to -0.075 ($p = 0.011$) for non-investment grade ones. The differences in the coefficients for all specifications are significant at the 1% level. In further robustness checks, we use Altman's Z-score and interest coverage as alternative proxies for default probability. Following Brockman et al. (2010), we classify into low (high) any firm with a Z-score below (above) 1.81. Low (high) Z-score firms have high (low) default probability. Interest coverage is the pretax interest coverage ratio. Low (high) interest coverage indicates below- (above-) median interest coverage firms. Low interest coverage firms have higher probability of default. All the results are consistent with our prediction of a negative association between vega and risk in firms with high default probability (untabulated results).

In addition, we repeat the analysis presented in Table 4 using D2D portfolios instead of leverage ones. Our results remain unchanged (untabulated results).

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D. Vega, Risk, and Debt Governance

Following Brockman et al. (2010), who present evidence on the importance of debt maturity in risk shifting (i.e., asset substitution), we next examine whether our results are driven by debt governance instead of CEO risk aversion. If managerial risk aversion drives our results, then good debt governance will not affect managerial risk preferences unless it impacts managers' career concerns (e.g., through an increase in the firm's probability of default or bankruptcy). We expect debt governance to be effective, in this sense, only in firms with high debt levels. To test this argument, for each year in our sample we double sort our firms using debt levels and the proportion of short-term debt. We classify firms with above-median ST3 (i.e., the proportion of debt maturing within 3 years) and leverage, "high-high" firms, into one portfolio. The comparison group consists of firms with above-median ST3 but below-median debt levels, "high-low" firms. Using prior-year values ($t - 1$) for ST3 and leverage, we split our sample into the two portfolios and run our analysis separately for these portfolios. We expect the refinancing needs of the "high-high" firms to have the greatest impact. In contrast, we expect no effect for firms in the "high-low" portfolio.

Panel A of Table 6 presents the regression results. The results confirm our prediction that CEO career concerns lead to risk reduction in firms with high refinancing needs and high leverage, even in the presence of risk-taking incentives. The estimated coefficient on vega is negative and highly significant for this group (-0.041, $p < 0.000$). A 1-standard-deviation increase in vega is associated with a reduction of 1% in firm total risk (a decrease of 6% compared to the mean total risk of 17.6%). Consistent with prior results, this relationship is mainly driven by unsystematic risk (-0.043, $p < 0.000$). The estimated coefficient for the "high-low" firms when unsystematic risk is the dependent variable is positive and insignificant (0.008, $p = 0.217$). The relationship between vega and systematic risk, in contrast, is again negative and significant for all firms, although the estimated coefficient for the "high-high" firms is significantly larger than that for the comparison group (-0.071 vs. -0.024). As a robustness test, we rerun this analysis using the proportion of debt maturing within 5 years (ST5) as a proxy for short-term debt. Our results (untabulated) remain qualitatively the same.

As an alternative proxy for debt governance, we employ the intensity of a firm's debt covenants. Higher debt covenant intensity is associated with better debt governance. In Panel B of Table 6, we repeat the analysis applied on debt maturity using debt covenant intensity instead. In particular, for each year in our sample we double sort our firms using debt levels and an index of debt covenant intensity. The intersection of firms with above-median covenant intensity and leverage are classified into one portfolio. The comparison group consists of firms with above-median covenant intensity but below-median debt levels. Using prior-year values ($t - 1$) for covenant intensity and leverage, we split our sample into the two portfolios and separately run our analysis. We expect the risk-aversion effect to dominate only in highly levered firms with high debt covenant intensity, as in these firms a breach of covenants will increase the probability of default and in turn managerial career concerns. In contrast, a covenant violation

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in firms with low debt levels has little impact on managerial career concerns, and thus we expect covenant intensity to have little, if any, effect on managerial risk choices. The results presented in Panel B indicate that, indeed, covenant intensity affects managerial risk choices only for highly levered firms. The magnitudes of the coefficients are identical to those reported in Panel A, further strengthening our inference that the results are mainly driven by firms' debt levels.

Taken together, the results in this section highlight that the risk-aversion effect has greater influence over managerial choices than any ex ante contractual restrictions.

TABLE 6

Vega, Risk, and Debt Governance

Table 6 presents panel-data regression results on the vega-risk relationship for firms with high/low levels of risky debt and high debt governance. In Panel A (Panel B), we use debt maturity (covenant intensity) as the proxy for the quality of debt governance. In Panel A, Low (High) models report results for firms with low (high) refinancing needs, that is, the majority of debt is short-term but there are different overall levels of risky debt. We classify a firm as having high refinancing needs if ST3 and Leverage are above the sample median for that fiscal year. We classify a firm as having low refinancing needs if ST3 is above the sample median but Leverage is below the sample median for that fiscal year. In Panel B, Low (High) models report results for firms with low (high) debt covenant impact, that is, all firms have above-median covenant intensity index but there are differences in the overall levels of risky debt. We classify a firm into the low debt covenant impact group if the Covenant Intensity index is above sample median but Leverage takes below-median values for that fiscal year. We classify a firm into the high debt covenant impact group if the Covenant Intensity index and Leverage are above the sample median for that fiscal year. The dependent variables are the level and composition of firm risk. Total Risk (ln) is the natural logarithm of the annualized variance of daily stock returns over a firm's fiscal year. Systematic Risk (ln) is the natural logarithm of the annualized variance of the predicted portion of the market model. Unsystematic Risk (ln) is the natural logarithm of the annualized variance of the residuals of the market model. Vega is the change in value of a CEO's option portfolio for a 1% change in the firm's stock return volatility. Delta is the change in value of a CEO's stock and option portfolio for a 1% change in the firm's stock price. CEO Tenure is the number of years the CEO has served in the position. CEO Cash Compensation is the sum of salary and bonus. Sales (ln) is the natural logarithm of the firm's net turnover over the fiscal year. M2B is the market-to-book ratio. R&D is research and development expenditure scaled by assets. CAPEX is capital expenditure net of sales of property, plant, and equipment, scaled by assets. Leverage is total debt scaled by assets. ST3 is the proportion of total debt maturing within 3 years. Covenant Intensity is the arithmetic mean of a firm's 15 covenant indicator variables, as per Billett et al. (2007). All regressions include firm and year fixed effects. Intercepts are not reported. The *p*-values are reported in square brackets. Statistical significance is based on heteroskedasticity robust firm-clustered standard errors. ** and * indicate significance at the 1% and 5% levels, respectively.

	Total Risk (ln)		Systematic Risk (ln)		Unsystematic Risk (ln)	
Independent Variables	Low	High	Low	High	Low	High
Panel A. Debt Maturity						
$Vega_{t-1}$	0.006	−0.041**	−0.024**	−0.071**	0.008	−0.043**
	[0.351]	[0.000]	[0.009]	[0.000]	[0.217]	[0.000]
$Delta_{t-1}$	0.002**	0.004**	0.004**	0.007**	0.001	0.003*
	[0.001]	[0.001]	[0.000]	[0.000]	[0.105]	[0.017]
CEO Tenure	−0.002	−0.001	−0.001	−0.004	−0.002	0.001
	[0.342]	[0.660]	[0.826]	[0.205]	[0.286]	[0.763]
CEO Cash Compensation	−0.058**	−0.055**	−0.034	−0.037*	−0.066**	−0.064**
	[0.000]	[0.001]	[0.089]	[0.043]	[0.000]	[0.000]
Sales (ln)	−0.164**	−0.118**	−0.014	−0.011	−0.190**	−0.131**
	[0.000]	[0.004]	[0.751]	[0.831]	[0.000]	[0.002]
M2B	−0.009	−0.001	0.045**	0.072**	−0.019**	−0.018
	[0.079]	[0.920]	[0.000]	[0.000]	[0.001]	[0.203]
R&D	0.504	−0.749	−1.125*	−2.554*	0.811**	−0.184
	[0.078]	[0.324]	[0.015]	[0.032]	[0.004]	[0.806]
CAPEX	0.596*	−0.752**	1.292**	−0.340	0.561*	−0.776**
	[0.024]	[0.008]	[0.000]	[0.362]	[0.041]	[0.008]
Leverage	0.264*	0.437**	−0.015	0.250	0.339**	0.462**
	[0.015]	[0.000]	[0.924]	[0.074]	[0.003]	[0.000]
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	4,602	4,434	4,602	4,434	4,602	4,430
R^2	53.5%	50.9%	43.0%	45.3%	53.0%	50.3%

(continued on next page)

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TABLE 6 (continued)
Vega, Risk, and Debt Governance

	Total Risk (ln)		Systematic Risk (ln)		Unsystematic Risk (ln)	
Independent Variables	Low	High	Low	High	Low	High
Panel B. Covenant Intensity						
$Vega_{t-1}$	0.004	−0.043**	−0.024*	−0.074**	0.007	−0.044**
	[0.534]	[0.000]	[0.022]	[0.000]	[0.369]	[0.000]
$Delta_{t-1}$	0.003**	0.004**	0.005**	0.007**	0.002**	0.003*
	[0.000]	[0.002]	[0.000]	[0.000]	[0.007]	[0.010]
CEO Tenure	−0.003	−0.002	−0.004	−0.004	−0.003	−0.001
	[0.205]	[0.526]	[0.187]	[0.280]	[0.205]	[0.825]
CEO Cash Compensation	−0.057**	−0.053**	−0.033	−0.028	−0.065**	−0.062**
	[0.000]	[0.005]	[0.118]	[0.195]	[0.000]	[0.001]
Sales (ln)	−0.176**	−0.152**	−0.070	−0.086	−0.191**	−0.162**
	[0.000]	[0.000]	[0.141]	[0.105]	[0.000]	[0.000]
M2B	−0.002	−0.012	0.076**	0.066**	−0.018	−0.027
	[0.861]	[0.470]	[0.000]	[0.003]	[0.061]	[0.112]
R&D	0.288	−0.680	−1.782*	−2.950*	0.702	0.031
	[0.473]	[0.421]	[0.017]	[0.028]	[0.066]	[0.970]
CAPEX	0.641*	−0.944**	1.247**	−0.644	0.626*	−0.946**
	[0.033]	[0.004]	[0.002]	[0.112]	[0.044]	[0.005]
Leverage	0.106	0.450**	0.003	0.230	0.133	0.463**
	[0.324]	[0.001]	[0.982]	[0.133]	[0.260]	[0.001]
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	3,605	4,083	3,605	4,083	3,605	4,079
R^2	55.1%	50.0%	44.2%	45.6%	54.5%	49.6%

V. Robustness Checks

As we discuss in Section III, we run panel data regressions with firm and year fixed effects to account for omitted variables at both the firm and the market level. The reported *p*-values are based on robust firm-clustered standard errors. We test the importance of these modeling choices below. We then discuss additional robustness tests that we conduct. In particular, we test whether multicollinearity drives our results and whether our lagged variables are valid instruments. Finally, we discuss further robustness checks based on asset vega and asset delta, as opposed to equity vega and equity delta that we use in our tabulated analysis.

The inclusion of year effects in our model specifications is important because they control for cross-sectional dependence. Given that our dependent variables are market-based proxies of firm risk, we expect marketwide effects to influence the level and composition of risk. This is particularly important, since our sample period covers the 2000 market crisis. Indeed, we plot each of our proxies for firm risk and find that it displays obvious time trends (untabulated result). Both total and unsystematic risk peak during the market crisis of 2000. This marketwide risk inflation contributes to the positive relationship between vega and firm risk identified in prior studies, as we explain in Section IV.A. Thus, we argue that it is important to include year dummy variables in all specifications.

Firm fixed effects capture omitted time-invariant firm characteristics. All of our specifications reject the hypothesis that the unobservable company-specific

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error equals 0 ($u_i = 0$). Also, most specifications reveal a substantial correlation between the error term and the coefficients on the independent variables in the model. This implies that ordinary least squares (OLS) will not give unbiased coefficients, and thus it is important to control for firm fixed effects. To formally test this, we first run the Breusch and Pagan (1980) Lagrange multiplier test to identify the existence of random effects. The test is highly significant (χ^2: 16,107, $p < 0.000$), indicating that we can safely reject the null hypothesis that the variation in the random firm effects is equal to 0 (var(u) = 0). The OLS coefficients are thus biased. We next run a Hausman (1978) test, which reveals that the fixed effects specification is more efficient than the random effects specification, that is, we strongly reject the hypothesis of nonsystematic differences in coefficients ($\chi^2 : 114$, $p < 0.000$). We conclude that the most robust specification is the firm fixed effects one (untabulated results).

We also include in all specifications heteroskedasticity-robust standard errors clustered at the firm level. Clustering the errors at the firm level allows us to control for time-series dependence. For robustness, we rerun all our analyses allowing for clustering of standard errors at the industry level (2-digit Standard Industrial Classification (SIC)). Our results remain unchanged (untabulated results).

In our next test, we confirm that our results are not driven by multicollinearity. A variance inflation factor (VIF) analysis reveals moderate problems only with our proxy for firm size (i.e., sales). When we substitute sales with other proxies for firm size commonly used in the literature (e.g., market value of equity or assets, or book value of assets), we find that these measures fare even worse (untabulated results). However, even if we remove sales, the results remain unchanged.

Coles et al. (2006) argue that the causality between CEO incentives and firm risk can run in both directions. In order to isolate the direction of causality and avoid capturing endogenous feedback effects, they use the lagged values of vega and delta as exogenous variables. This practice is common in related studies (e.g., Rajgopal and Shevlin (2002)). Following this approach, we use lagged vega and delta in all of our specifications. To formally test the validity of this approach, we run panel-data instrumental variable regressions. In line with Coles et al., apart from the exogenous variables of the main model, we also include in our first-stage least squares regressions the lagged values of CEO characteristics that the literature identifies as determinants of vega and delta: CEO tenure, cash compensation, age, and ownership. We rerun the analysis presented in Panel A of Table 2, but now use the predicted values of lagged vega and delta in the main model (untabulated results). We run an endogeneity test on the lagged vega and delta. This test is formally defined as the difference between two Sargan-Hansen statistics, one for the equation when lagged vega and delta are treated as endogenous and another for the equivalent equation with assumed exogenous lagged vega and delta (see Hayashi (2000)). In all three models, we cannot reject the null hypothesis that the specified endogenous regressors, that is, lagged delta and vega, can be treated as exogenous (untabulated results). We conclude that lagged vega and delta are valid instruments. We also run the same specification on the contemporaneous values of delta and vega. For two out of the three specifications, we reject the null hypothesis. Therefore, we cannot assume the contemporaneous values to

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be exogenous. This further highlights the importance of using lagged incentive values in our specifications.

Throughout our analysis we use the Core and Guay (2002) approximation method to estimate the (equity) vega and delta. This method ignores the effect of leverage on stock compensation, that is, levered-stock compensation provides a convex payoff to the manager, similar to the option portfolio payoff structure, and therefore potentially a nontrivial vega. Therefore, we could be significantly underreporting vega. In order to address this issue, we calculate the asset vega and asset delta. We follow the methodology developed in Chesney et al. (2011) and treat stocks (stock options) as options (compound options) on the underlying asset value of the firm. Asset vega is the sensitivity of the value of the CEO stock and option portfolio to firm asset return volatility, and asset delta is the sensitivity of the value of the CEO stock and option portfolio to firm asset value. Asset values, returns, and volatility are estimated following Vassalou and Xing (2004). The median values for asset vega and asset delta are directly comparable to the median values for (equity) vega and delta presented in Panel A of Table 1 (untabulated result). The correlation coefficient for the asset and equity vega measures is 88%, and for the asset and equity delta measures it is 71%; both are highly statistically significant. We argue that this high correlation illustrates that there are only substantial differences between equity and asset vega and delta for "extreme" values of leverage, like those reported in Chesney et al. (2011). This rationale is consistent with the observation by Geske (1979) that the compound option price converges to the Black and Scholes (1973) price when the firm's debt goes to 0. We conclude that in our sample of nonfinancial firms, the observed leverage levels do not lead to substantial differences between equity and asset vega and delta. Still, we rerun our main analysis, but now regress asset vega and asset delta on firm asset volatility; our results remain unchanged (untabulated results).

VI. Conclusions

In this paper we provide empirical evidence of a negative relationship between risk-taking incentives and firm risk in firms with high leverage, or high default probability. Based on early theoretical work (e.g., Pratt (1964)), we argue that managerial preferences are determined by the relative size of managers' risk-aversion effect versus wealth effect. Following recent theoretical studies (Cadenillas et al. (2004), Berk et al. (2010), and Carlson and Lazrak (2010)), we predict the CEO risk-aversion effect to dominate in highly levered firms or firms with high default probability. Our findings are consistent with the hypothesis that when CEOs face increased career concerns, they proactively reduce firm risk, even in the presence of strong risk-taking incentives. When we control for the sensitivity of CEO wealth to changes in a firm's stock price, that is, compensation delta, other determinants of firm risk, endogenous feedback effects of firm risk on CEO incentives, and unobserved effects at the firm and market levels, we find a negative relationship between compensation vega (i.e., the sensitivity of CEO wealth to firm risk) and firm risk only for firms with high debt levels or high default risk. Furthermore, the effect of CEO risk aversion is economically

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significant. Our findings strongly support a nonmonotonic relation between compensation incentives and firm risk, consistent with recent theoretical predictions (Cadenillas et al. (2004), Carlson and Lazrak (2010)).

Our study extends the literatures on executive compensation, the agency costs of debt, and the effect of career concerns. First, we provide new evidence that adding convexity to CEOs' payoff structure does not necessarily increase their risk-taking behavior. Specifically, when the risk-aversion effect dominates, it leads to the opposite result. This evidence complements prior studies that mainly concentrate on wealth effects and risk taking. Second, the literature on the agency costs of debt argues that debt contracting can *partially* mitigate the effect of risk-taking incentives on CEO behavior. Our evidence suggests the CEO risk aversion may be more powerful in constraining risk-taking behavior than debt contracting. Third, recent studies such as Peters and Wagner (2014) highlight the role of industry risk in increasing career concerns. We confirm this result by showing a negative relationship between vega and firm risk in high industry risk firms, and we extend this literature by highlighting the role of risky debt in increasing career concerns.

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