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Managerial incentives and risk-taking ☆

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Abstract

We provide empirical evidence of a strong causal relation between managerial compensation and investment policy, debt policy, and firm risk. Controlling for CEO pay-performance sensitivity (delta) and the feedback effects of firm policy and risk on the managerial compensation scheme, we find that higher sensitivity of CEO wealth to stock volatility (vega) implements riskier policy choices, including relatively more investment in R&D, less investment in PPE, more focus, and higher leverage. We also find that riskier policy choices generally lead to compensation structures with higher vega and lower delta. Stock-return volatility has a positive effect on both vega and delta.

JEL Classification: G31; G32; G34; J33

Keywords: Executive compensation; Managerial incentives; Risk taking; Investment policy; Financing policy

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1. Introduction and motivation

This paper provides empirical evidence of a strong causal relation between an important organizational feature, the structure of managerial compensation and corresponding incentives, and value-critical managerial decisions, specifically, those derived from both investment policy and debt policy. The primary characteristic of compensation that we consider is the sensitivity of CEO wealth to stock return volatility, or vega. Controlling for CEO pay-performance sensitivity, and applying modeling and econometric remedies for the endogenous feedback effects of firm risk and policy choices on the structure of compensation, we find that higher prior vega implements riskier policy choices, including relatively more investment in research and development, less investment in property, plant, and equipment, greater focus on fewer lines of business, and higher leverage. This evidence provides support for the hypothesis that higher sensitivity to stock volatility in the managerial compensation scheme gives executives an incentive to both invest in riskier assets and implement more aggressive debt policy.

Such real implications of the compensation structure are particularly important given that the use of equity-based compensation, in the form of stock and options, has grown so rapidly in recent years (Murphy, 1999; Perry and Zenner, 2000). One effect of this growth has been a substantial increase in the sensitivity of CEO wealth to stock price (compare Hall and Liebman, 1998; and Jensen and Murphy, 1990). The sensitivity of CEO wealth to stock price, or delta, is seen as aligning the incentives of managers with the interests of shareholders. Higher delta can mean that managers will work harder or more effectively because managers share gains and losses with shareholders. Of course, another effect of increased delta is to expose managers to more risk. To the extent that managers are undiversified with respect to firm-specific wealth, they are exposed to more risk than diversified shareholders. Accordingly, it is possible that managers will forgo some positive net present value (NPV) projects if those projects are very risky.[1] A second aspect of the increase in equity-based compensation potentially offsets this tendency. Associated with the increase in option grants and holdings has been the increase in vega. Option-based compensation, by providing convex payoffs, can potentially reduce aversion to risky policies that arise from high delta.

Obvious empirical questions are whether higher vega implements riskier investment policy, riskier debt policy, and higher volatility of stock returns. Recent work provides evidence of associations among some of these variables. For example, Guay (1999, p. 43) finds that "…stock-return volatility is positively related to the convexity provided to managers, suggesting convex incentive schemes influence investing and finance decisions." Along these lines, prior studies that use vega as the

[1]See Holmstrom (1979), Mirrlees (1976), Holmstrom and Milgrom (1987), as well as the survey of Murphy (1999), for various interpretations of the principal-agent problem. See Amihud and Lev (1981), Smith and Stulz (1985), Schrand and Unal (1998), and Guay (1999) on increased exposure to risk. Amihud and Lev (1981) and Smith and Stulz (1985) discuss forgoing risky projects, an effect which is similar to the underinvestment problem described by Myers (1977).

independent variable find a positive association between vega and both leverage (e.g., Cohen et al., 2000) and stock return volatility (Cohen et al., 2000; Guay, 1999). When vega is used as the dependent variable, there is a positive association between vega and firm size, investment opportunities, and R&D intensity (Guay, 1999). In a similar manner, other papers examine the connection between delta and policy choices. Some studies use delta as the dependent variable (e.g., Bizjak et al., 1993; Core and Guay, 1999, examine delta as a function of firm characteristics), while others use delta as the independent variable (e.g., Aggarwal and Samwick, 2002a, regress capital expenditures on delta). An obvious conclusion from this literature is that causation is likely to run in both directions for both vega and delta. That is, these parallel but relatively independent segments of the literature suggest that it is critical to account for how policy choices and characteristics of the managerial compensation scheme are jointly determined.

To be more specific, we suppose that shareholders choose a combination of delta and vega to implement second-best, value-maximizing investment and financial policies. For example, as mentioned above, firms with growth opportunities stand to gain if risk-averse managers can be motivated to invest in high risk, positive NPV projects (Guay, 1999). In turn, investment and financial policies determine the probability distribution of a firm's cash flows and stock returns. Of course, in selecting optimal delta and vega, shareholders will account for how the end result, the implemented policies and implied risk profile of the firm, feed back through the structure of the managerial compensation scheme to affect managerial utility. For example, firms for which it is optimal to implement risky policies could determine that it is efficient to increase vega somewhat in order to increase the exposure of the manager to volatility.

Thus, in order to avoid spurious inferences and to isolate causation, the empirical design needs to disentangle how compensation and incentives affect policy and risk from how policy and the corresponding risk profile of the firm's assets affect the compensation scheme of a risk-averse manager. Accordingly, among the several advances we make relative to prior studies, our primary contribution is to use appropriate models and statistical methods to extract evidence from the data on (1) how vega (controlling for delta) implements investment and financial policies and determines riskiness of the firm, and (2) the effect of investment policy, debt policy, and firm risk (stock return volatility) on the choice of vega (as well as delta) in the managerial compensation scheme.

In terms of investment policy, there is strong evidence that higher vega implements riskier policy choices. In particular, higher vega implies significantly higher R&D expenditures, less investment in property, plant, and equipment, and an increased focus as measured by both the Herfindahl index (for sales across segments) and the number of business segments. All of these results are based on specifications that control for the effect of investment policy on compensation structure.

We also examine financial policy. In our data, controlling for the effect of leverage on compensation structure, higher vega appears to implement higher book leverage and market leverage.

We measure the extent to which financial policy, investment policy, and firm diversification affect stock volatility. Total stock return volatility is positively related to R&D investment and leverage, and is negatively related to investment in property, plant, and equipment. While these specific policy decisions have significant power to explain stock volatility, in some cases we find evidence that vega continues to provide additional explanatory power and, thus, also operates through other avenues to increase firm risk.

In contrast to the results on vega, higher delta provides a strong incentive to decrease R&D expenditures, increase capital expenditures, and decrease leverage. As with the results on vega, firm focus and stock return volatility increase in delta.

Finally, to isolate causation that flows in the other direction, we examine the effects of policy choice and firm risk on vega and delta. Controlling for the effect of managerial incentives on policy choices and risk, we find that riskier investment policy (higher R&D, lower capital expenditures, higher leverage) and higher volatility of stock returns cause a higher vega. Delta, on the other hand, increases as policy choices become less risky (lower R&D, higher capital expenditures, and lower leverage). We also find that higher firm risk generally tends to increase pay-performance sensitivity, which is consistent with Demsetz and Lehn (1985) and Core and Guay (2002b), but is inconsistent with Aggarwal and Samwick (1999, 2002b), Himmelberg et al. (1999), and Jin (2002).

The remainder of the paper is organized as follows. Section 2 provides additional discussion of the literature and hypotheses, while Section 3 discusses construction of the sample and outlines the various methods we use to control for endogeneity and to isolate causation. Section 4 provides evidence on the relation between incentives and the allocation of resources among different types of investments. Section 5 presents evidence on corporate diversification, while Section 6 provides results for leverage. Section 7 provides additional evidence on the relation between incentives and risk taking. Section 8 examines the relation between incentives and stock return volatility. Section 9 concludes.

2. Discussion of the literature, hypotheses development, and contributions

2.1. Prior literature

Much of the existing empirical work on compensation policy is related only indirectly to how compensation structure affects observable managerial decisions. For example, one branch of the literature examines how various characteristics of firms are associated with various compensation schemes. The idea, in part, is that characteristics of product markets, the nature of the asset base (e.g., growth opportunities versus other assets), the presence of other monitoring and incentive alignment mechanisms (e.g., board composition), and legal rules and institutions (e.g., Delaware corporation law or Pennsylvania Senate Bill 1310) affect the value-maximizing structure of managerial compensation. See Smith and Watts (1992), Bizjak et al. (1993), Yermack (1995), Holderness et al. (1999), Core and Guay (1999), Guay (1999), Aggarwal and Samwick (1999), Coles et al. (2000), Deli (2002), and others. Another branch connects the form of the compensation scheme to firm performance. The claim is that if a particular compensation policy induces decisions by managers that are good for shareholders, we should observe a relation between the structure of the compensation scheme and firm performance. For example, there is evidence that Tobin's q and managerial performance sensitivity (through ownership) are related—see Morck et al. (1988), McConnell and Servaes (1990), and many successors. Of course, these two strands of the literature, particularly given that they are generally independent of each other, suggest the presence of endogeneity and causation problems in the empirical design.

Several studies attempt to go more directly to our question of whether managerial incentives have observable operational and policy implications. For example, it is common to argue that convex payoffs should be given to CEOs to mitigate the effect of CEO risk aversion and provide the CEO with increased incentives to take on risky projects.[2] Despite the intuitive appeal of this argument, its validity depends on the managerial utility function. As illustrated in Guay (1999), convexity of the payoff structure (e.g., from options) can be more than offset by concavity of the utility function of the risk-averse manager. Along the same lines, Ross (2004) proves that there exists no incentive schedule that will make all expected utility maximizers less risk averse. Ju et al. (2002), analyze the role of options in managerial compensation and demonstrate that a call option contract can induce either too much or too little corporate risk taking, depending on managerial risk aversion and the underlying investment technology. Lewellen (2003) suggests that options, especially if they are in the money, could discourage risk taking.[3]

On the empirical side, Mehran (1992, 1995), Tufano (1996), Berger et al. (1997), Esty (1997a,b), Jolls (1998), Schrand and Unal (1998), and Rogers (2002) explore the association between managerial stock and/or option holdings and financial strategy (such as leverage, repurchase, or the extent of derivatives usage and hedging), but with differing conclusions. Similarly, and again with varying results, several studies, including May (1995), Denis et al. (1997), and Anderson et al. (2000), examine the connection between managerial holdings and corporate focus. Ryan and Wiggins (2002) use 1997 data and find that the value of options granted has power to explain contemporaneous R&D.

DeFusco et al. (1990) find that firms that approved stock option plans between 1978 and 1982 exhibited a stock return variance increase and Agrawal and Mandelker (1987) find (univariate) that firms with higher stock plus option ownership take on more variance-increasing acquisitions. Guay (1999), using data on a 1993 sample of 278 CEOs, shows that the standard deviation of returns is

[2]For example, see Jensen and Meckling (1976), Myers (1977), Smith and Stulz (1985), Haugen and Senbet (1981), Smith and Watts (1992), Gaver and Gaver (1993), Bizjak et al. (1993), Guay (1999), and Core and Guay (1999).

[3]Also on the theoretical side, Parrino et al. (2005) find that options induce better risk-taking behavior than restricted stock and that options issued in the money make managers more risk averse compared to options issued at or out of the money. Carpenter (2000) examines the optimal investment policy for a risk-averse fund manager compensated with call options.

associated contemporaneously with vega. Rajgopal and Shevlin (2002) find that oil exploration risk is positively related to lagged vega, and Knopf et al. (2002) show that the use of derivatives is negatively (positively) related to vega (delta). Finally, Cohen et al. (2000) find that leverage and stock return volatility are both positively associated with the elasticity of CEO wealth in stock return volatility.

2.2. Hypotheses

While the literature provides considerable evidence of an association between firm risk/policy and compensation structure, in almost no case does the empirical design allow estimation of the underlying causal relations (though see Rogers, 2002). For example, does a positive association between stock return volatility and vega indicate that vega is used to implement high-risk decisions, or does it suggest that some underlying and omitted primitive factor drives the association between vega and volatility? Similarly, R&D intensity appears to be positively correlated with vega, and two plausible explanations are that vega implements high R&D, or, some other factor drives both R&D and vega together. Similar questions arise for the association between vega and investment in hard assets, leverage, firm focus, and other managerial decisions. In all of these examples, endogeneity implies that regression coefficients are likely to be biased and empirical methods are unlikely to quantify the magnitude of the economic effects of interest.

To address such difficulties, we suppose that shareholders choose vega, along with delta, to implement second-best, value-maximizing investment decisions and financial policy. In turn, optimal investment and financial policies should depend on the pre-determined characteristics of the firm such as general and firm-specific human capital, production technology, asset tangibility and growth opportunities, industry, the extent of differentiation of end products, the nature of the supply chain, and applicable legal rules and institutions. These primitives, along with the implementation (using vega and delta) of investment and financial policies that match these primitives, determine the probability distribution of firm cash flows and stock returns. In particular, because convexity in compensation makes risk more valuable to managers, higher vega should implement riskier investment and financial policies and higher return volatility.

For instance, R&D expenditures are typically viewed as high risk investments compared to capital expenditures on property, plant, and equipment (e.g., Bhagat and Welch, 1995; Kothari et al., 2001). If, through vega, the CEO is provided with incentives to take on more risk, one way to increase risk would be to reallocate investment dollars away from tangible assets, such as capital expenditures, toward intangible assets, such as R&D. Another avenue through which the firm could alter risk is by changing the level of diversification. Managerial risk aversion as a motive for diversification is suggested in Amihud and Lev (1981), May (1995), and Tufano (1996). To the extent that diversification decreases firm risk (Comment and Jarrell, 1995), we expect that higher vega will implement lower levels of diversification or increased firm focus. Finally, CEOs can increase firm risk by altering financial policy, or more specifically, by increasing leverage. Thus, higher vega will implement higher leverage.

In summary, our primary hypotheses are that higher vega should lead to higher investment in R&D expenditures, lower investment in capital expenditures, increased firm focus, higher leverage, and higher stock return volatility.

While we use delta mainly as a control variable, the effects of delta on policy choices and firm risk are of some interest. These effects, however, are unclear. John and John (1993) suggest that higher delta increases the incentive to shift risk to debtholders. In addition, if higher NPV projects tend to be relatively risky, increased delta could provide the incentive to implement higher risk projects. On the other hand, higher delta exposes the manager to more risk, in which case managers could choose less risky projects (Guay, 1999).

For causation in the other direction, in selecting optimal vega (and delta) shareholders will account for how the end result, the implemented policies and implied risk profile of the firm, feed back through the structure of the managerial compensation scheme to affect managerial utility. Firms for which it is optimal to implement risky policies are likely to determine that it is efficient to provide higher vega. Thus, we hypothesize that vega should increase with R&D expenditures, firm focus, leverage, and stock return volatility, and decrease with capital expenditures. To the extent that higher delta causes managers to implement less risky policies, we hypothesize that delta should decrease with R&D expenditures, firm focus, leverage, and stock return volatility, and increase with capital expenditures.

If there is a relation between vega incentives and managerial decisions, it is likely to be observable in both the cross-section and through time. Cross-sectional differences among firms in the fundamental characteristics of the firm such as production technology, growth opportunities, and market power should imply cross-sectional differences in optimal policy and compensation structure to implement that policy. Through time, as those characteristics either change or remain constant, so will vega and delta and the implemented policy will change or remain constant.

In summary, our story is that managerial incentives and investment and financial policies are likely to be jointly determined. Accordingly, we apply standard modeling and econometric approaches, including simultaneous equations, suitable control variables, industry and firm fixed effects, and instrumental variables, so as to isolate how vega implements investment and financial policies and determines firm risk. In doing so, we also estimate the effects of investment policy, debt policy, and firm risk (stock return volatility) on the choice of vega (as well as delta) in the managerial compensation scheme.

2.3. Additional contributions to the literature

Our primary contributions are outlined in the introduction and just above. In addition, we advance the literature in several other ways.

First, by including both vega and delta in our regressions, we are able to isolate the effect of each of these incentives on risk taking. With the exception of Rogers (2002) and Nam et al. (2003), prior studies tend to focus on one dimension of compensation structure, such as delta or vega, without controlling for the other. The mix of vega and delta likely varies substantially across firms (Guay, 1999), and both affect risk-taking behavior. Therefore, any attempt to isolate the relation between firm risk and vega or policy choices and vega should also control for delta.

Second, nearly all prior empirical experiments use a relatively rudimentary representation of compensation structure as the basis for explanatory variables. Such right-hand side variables include transformed, scaled, unscaled, and/or untransformed measures of number of options held, value of options held, number of options granted (often in the most recent year), value of options granted, stock held, stock vested, stock grants, the sum of some of these, etc. These measures are disconnected from the characteristics of compensation, specifically vega and delta, that theoretical models suggest are important. At the very best, such measures are noisy proxies for vega and delta (Core and Guay, 2002a).[4] Indeed, only a few of these studies measure incentives with delta (e.g., Anderson et al., 2000), vega (e.g., Cohen et al., 2000; Knopf et al., 2002), or both (e.g., Rogers, 2002; Rajgopal and Shevlin, 2002). By estimating vega and delta for the manager's entire portfolio of stock and options, we obtain a more precise measure of the incentives faced by managers rather than rely on potentially noisy proxies such as the number or value of options or stock held or granted. Specifically, we use the method of Core and Guay (2002a) to estimate both the sensitivity of CEO wealth to stock price and the sensitivity of CEO wealth to stock volatility.

Finally, many studies examine specific events, such as acquisitions (e.g., Datta et al., 2001), or a specific industry (e.g., Rajgopal and Shevlin, 2002; Tufano, 1996). Other studies, due to data limitations (e.g., Knopf et al., 2002) or reliance on a limited time period (e.g., Jolls, 1998; Guay, 1999), use small sample sizes. We construct a broad sample of over 1,500 firms from a variety of industries over the period 1992 to 2002—it is over this period that we have seen rapid growth in the use of equity-based executive compensation.

3. Sample collection and variable construction

We use the Standard & Poor's Execucomp database for data on CEO compensation. Execucomp provides data on salary, bonus, and total compensation for the top five executives (ranked annually by salary and bonus) for firms in the S&P 500, S&P Midcap 400, and S&P Smallcap 600, for the period 1992 to 2002. We start with executives who are identified by Execucomp as CEOs. Execucomp indicates the dates at which the CEO assumed office and the CEO quit office. In some cases,

[4]For instance, using the total number of options to measure incentives ignores cross-sectional variation in the characteristics of options such as time-to-maturity, volatility, or exercise price. Using only vested options to measure incentives ignores the incentives provided by the unvested options. Berger et al. (1997) note that it is difficult to evaluate the importance of the option variable without having data on unexercisable option holdings. Similarly, calculating incentives provided only by newly granted options ignores incentives provided by the existing portfolio of options. In fact, the correlation between deltas of newly granted options and previously granted options is low (Core and Guay, 2002a).

Execucomp fails to identify an executive as the CEO even though he or she appears to be the CEO based on these dates. We classify such individuals as CEOs. Similarly, we collect compensation data on the top management team. Consistent with the prior literature, we eliminate finance firms and utilities.

We define delta as the change in the dollar value of the executive's wealth for a one percentage point change in stock price. Vega is the change in the dollar value of the executive's wealth for a 0.01 change in the annualized standard deviation of stock returns. Guay (1999) shows that option vega is many times higher than stock vega. Consequently, in this study, we use the vega of the option portfolio to measure the total vega of the stock and option portfolio. Both Knopf et al. (2002) and Rajgopal and Shevlin (2002) adopt the same approximation.

The vega and delta calculation follows Guay (1999) and Core and Guay (2002a), which use the Black-Scholes (1973) option valuation model as modified by Merton (1973) to account for dividends. This is consistent with numerous recent papers such as Yermack (1995), Hall and Liebman (1998), Aggarwal and Samwick (1999), Core and Guay (1999, 2002a), Guay (1999), Cohen et al. (2000), Datta et al. (2001), and Rajgopal and Shevlin (2002), among others. There is some recent debate, however, as to whether the Black-Scholes (1973) model is suitable for valuing employee stock options since these are nontransferable and employees are risk averse and typically do not hold the options until expiration (see Carpenter, 1998; Hall and Murphy, 2002; Ingersoll, 2002; Bettis et al., 2004). We use the estimates in Bettis et al. (2004) to model how the holding period of stock options varies with volatility, and we find that in general our main inferences continue to hold. Our results also are robust to giving the options a simple "haircut" by assuming that the maturity of all options is 70% of the stated maturity.

We obtain firm-specific information from Compustat, industrial segment data from the Compustat Industrial Segment Tapes, and stock return information from CRSP. Data requirements limit the final sample size to a maximum of 10,687 observations although some specifications use fewer observations due to data limitations. For example, we do not have lagged values of vega and delta for the year 1992 and for years in which there is a new CEO.

Table 1 presents summary statistics on the compensation of the top five executives including the CEO, CEO characteristics, firm characteristics, and investment and financing measures. Consistent with prior literature (Guay, 1999; Core and Guay, 1999), we winsorize vega, delta, cash compensation, and market-to-book ratio at the 1st and 99th percentiles. Mean (median) vega is \$79,586 (\$33,610), mean (median) delta is \$599,609 (\$206,359), and mean (median) cash compensation is \$1,140,249 (\$831,338).

The investment and financial policy variables we consider are: (1) *R&D*, defined as research and development expenditures scaled by assets; (2) *CAPEX*, defined as net capital expenditures (capital expenditures less sales of property, plant, and equipment) scaled by assets; (3) *Segments*, which is the number of different businesses in which the firm operates; (4) *Herfindahl Index*, which captures revenue concentration across segments and is defined as the sum of the square of segment sales divided by the square of firm sales; and (5) *Book Leverage,* defined as total book

Table 1
Summary statistics

Data on executive compensation from 1992 to 2002 are from Execucomp. Vega is the dollar change in the executive's wealth for a 0.01 change in standard deviation of returns. Delta is the dollar change in the executive's wealth for a 1% change in stock price. Cash compensation is the sum of salary and bonus. Management team compensation is cumulated over the top five executives excluding the CEO. 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. Herfindahl index is calculated as the sum of the square of segment sales divided by the square of firm sales. Book (market) leverage is total debt divided by book (market) value of assets. Standard deviation of daily stock returns is given. Market-to-book is the market value of assets divided by their book value. All dollar values are stated in 2002 dollars. Vega, delta, cash compensation, and market-to-book are winsorized at the 1st and 99th percentile levels.

	Mean	Standard deviation	25th percentile	50th percentile	75th percentile
CEO characteristics					
Vega ($000s)	80	116	11	34	92
Delta ($000s)	600	1006	81	206	581
Cash compensation ($000s)	1140	1132	510	831	1385
Tenure (years)	7	8	2	5	10
Age (years)	54	8	49	54	59
Management team compensation					
Vega ($000s)	122	375	17	46	115
Delta ($000s)	787	8546	70	172	455
Cash compensation ($000s)	2538	1,870	1,298	1,983	3,198
Policy measures					
R&D	0.04	0.08	0.00	0.00	0.05
CAPEX	0.07	0.06	0.03	0.05	0.09
Herfindahl Index	0.83	0.25	0.62	1.00	1.00
Segments	1.76	1.24	1.00	1.00	2.00
Book leverage	0.23	0.19	0.06	0.21	0.34
Market leverage	0.15	0.15	0.02	0.12	0.24
Standard deviation (%)	3.05	1.53	1.97	2.71	3.74
Firm characteristics					
Sales ($ millions)	3,819	11,520	330	887	2,724
Market-to-book	2.24	1.73	1.24	1.66	2.49

debt scaled by book value of assets. The effect of these policy variables should be captured in stock return volatility (*Firm Risk*), which we define as the logarithm of the variance of daily stock returns.

The control variables that we use as determinants of the policy measures and incentives are all based on existing literature. Specifically, we use: (1) Logarithm of sales to proxy for *firm size*; (2) *Market-to-Book*, defined as market value of assets to book value of assets, as a proxy for investment opportunities; (3) *Surplus Cash*, defined as the amount of cash available to finance new projects, scaled by assets (see

Richardson, 2002); (4) *Sales Growth*, defined as the logarithm of the ratio of sales in the current year to the sales in the previous year; (5) *Stock Return*, which is the return over the fiscal year; (6) *ROA*, defined as EBITDA scaled by assets; (7) *Dividend Cut*, an indicator variable that takes the value of one if there was a decrease in the annual dividend, and zero otherwise; (8) *CEO Turnover*, an indicator variable that takes the value of one if the identity of the CEO changes, and zero otherwise; (9) *Net PPE*, defined as investment in property, plant, and equipment scaled by assets; and (10) *Z-Score* (Altman, 1968) to proxy for the probability of bankruptcy. Consistent with the existing literature, we use CEO *Tenure* and CEO *Cash Compensation* (salary plus bonus) to proxy for the CEO's level of risk aversion. For instance, Berger et al. (1997) argue that CEOs with longer tenures and higher cash compensation are more likely to be entrenched and will seek to avoid risk. Guay (1999) argues that CEOs with higher total cash compensation are better diversified, as they have more money to invest outside the firm and, therefore, are less risk averse. The Appendix provides additional details on the construction of these variables from Compustat data items.

Table 1 provides summary statistics for the key policy and compensation variables. Given space limitations, we do not report summary statistics on control variables. All numbers are similar to values reported in related studies, such as Guay (1999), Core and Guay (1999), Barclay et al. (2003), and Richardson (2002). As an additional data check, we use our data to replicate some of the analyses in these studies. We obtain similar results.

4. Investment policy and CEO incentives

4.1. R&D, CAPEX, and vega

In this section we examine the extent to which vega induces managers to implement risky investment policy. As stated earlier, we expect that higher vega will result in higher R&D and lower CAPEX. Table 2 reports estimates from regressing R&D and CAPEX on lagged vega, lagged delta, and contemporaneous control variables. As in other studies, we set R&D equal to zero when it is missing from Compustat. Here and throughout, reported *t*-statistics and *p*-values are based on robust standard errors.

While we focus on vega as the primary explanatory variable, here and in subsequent sections our specifications include both delta and control variables based on evidence elsewhere in the literature. Accordingly, our specifications control for market-to-book, the growth rate of sales, surplus cash, book leverage, stock return, ROA, and the logarithm of annual sales (Servaes, 1994; Bhagat and Welch, 1995; and Opler et al., 1999). An important reason to include control variables is to represent forces that drive both vega and delta together with investment (or financial) policy. To address the possibility that there are other omitted variables, all specifications throughout include either firm or industry (two-digit SIC) fixed effects. Furthermore, as instruments for vega and delta, we use either the lagged values of vega and delta or the vega and delta predicted from regressions. The regression

Table 2
Regressions of R&D and capital expenditures on CEO incentives

The dependent variables are research and development expenditures scaled by assets (R&D) and net capital expenditures scaled by assets (CAPEX), where net capital expenditures is the capital expenditures net of sales of property, plant, and equipment. Vega is the dollar change in the CEO's wealth for a 0.01 change in standard deviation of returns. Delta is the dollar change in the CEO's wealth for a 1% change in stock price. Predicted and residual incentives are the predicted values and residuals from regressions of vega and delta on endogenous and control variables. Control variables are as described in the appendix. The predicted signs for the variables of interest are given to the left of the coefficient. Dollar values are in millions of 2002 dollars. Intercepts not reported. t-statistics based on robust standard errors are within parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Predicted signs are indicated in parentheses.

	Panel A: R&D					Panel B: CAPEX				
Independent variables		Industry FE	Firm FE	Predicted	Predicted + residuals		Industry FE	Firm FE	Predicted	Predicted + residuals
Vega $_{t-1}$	(+)	0.080***	0.006			(−)	−0.038***	−0.039***		
		(13.3)	*(1.1)*				*(−6.8)*	*(−6.0)*		
Predicted vega $_{t-1}$	(+)			0.685***	0.696***	(−)			−0.262***	−0.275***
				(10.2)	*(10.5)*				*(−9.6)*	*(−10.4)*
Residual vega $_{t-1}$	(+)				0.031***	(−)				−0.029***
					(4.2)					*(-4.7)*
Delta $_{t-1}$	(±)	−0.002***	−0.001			(±)	0.005***	0.008***		
		(−3.5)	*(−1.2)*				*(6.6)*	*(8.6)*		
Predicted delta $_{t-1}$	(±)			−0.058***	−0.059***	(±)			0.036***	0.037***
				(−7.4)	*(−7.6)*				*(10.7)*	*(11.1)*
Residual delta $_{t-1}$	(±)				−0.003***	(±)				0.003***
					(−3.4)					*(4.3)*

Tenure	−0.001***	0.000	0.001***	0.002***	−0.000	−0.000	−0.001***	−0.001***
	(−7.9)	*(0.1)*	*(4.9)*	*(5.1)*	*(−1.2)*	*(−1.1)*	*(−8.8)*	*(−9.1)*
Cash compensation	0.004***	0.000	−0.009***	−0.009***	−0.002***	−0.001**	0.004***	0.004***
	(5.6)	*(0.2)*	*(−6.0)*	*(−6.2)*	*(−4.0)*	*(−2.1)*	*(4.4)*	*(4.5)*
Log (sales)	−0.017***	−0.012***	−0.023***	−0.023***	0.000	−0.006***	−0.001	−0.001
	(−4.3)	*(−1.9)*	*(−12.2)*	*(−12.3)*	*(0.1)*	*(−5.0)*	*(−0.8)*	*(−0.6)*
Market-to-book	0.006***	0.001*	0.013***	0.013***	0.003***	0.004***	−0.000	−0.001
	(6.3)	*(1.7)*	*(6.8)*	*(6.9)*	*(6.5)*	*(8.7)*	*(−0.6)*	*(−0.8)*
Surplus cash	0.092***	0.053***	0.102***	0.100***	0.040***	0.021***	0.040***	0.041***
	(5.3)	*(9.7)*	*(5.3)*	*(5.3)*	*(5.7)*	*(3.5)*	*(5.4)*	*(5.6)*
Sales growth	0.006**	−0.002***	0.008***	0.008***	0.001	0.001**	0.001	0.001
	(2.6)	*(−4.1)*	*(2.7)*	*(2.7)*	*(1.0)*	*(2.4)*	*(1.0)*	*(0.9)*
Stock return	−0.001	−0.000	−0.015***	−0.015***	−0.000*	−0.001***	−0.001	−0.001
	(−1.6)	*(−1.0)*	*(−7.0)*	*(−6.9)*	*(−1.7)*	*(−3.7)*	*(−0.6)*	*(−0.6)*
Book leverage	0.003	0.026***	−0.014	−0.014	−0.006	−0.010**	0.001	0.001
	(0.3)	*(6.6)*	*(−1.4)*	*(−1.5)*	*(−1.6)*	*(−2.2)*	*(0.2)*	*(0.3)*
Firm fixed effects		YES				YES		
2-digit SIC controls	YES		YES	YES	YES		YES	YES
Observations	9551	9551	8403	8403	9422	9422	8373	8373
R^2	39%	3%	45%	45%	29%	4%	32%	32%

specifications used to predict vega and delta closely follow those in Guay (1999) and Core and Guay (1999).[5] We include all of our endogenous variables (e.g., R&D, CAPEX, leverage, firm risk) on the right-hand side. We calculate the predicted values of lagged vega and lagged delta for a firm in a given year by using the estimated regression coefficients. Residual lagged vega (or lagged delta) is the actual value minus the predicted value.

Table 2 indicates that the estimated coefficients on vega are significant at 1% in all specifications with one exception (the firm fixed effects specification for R&D).[6] For R&D, the coefficient on vega is positive, and for CAPEX, the estimate is negative, which implies that higher vega is associated with higher R&D and lower capital expenditures. This represents a re-allocation of investment dollars to riskier assets. CEOs with higher vega allocate investment dollars away from less risky capital expenditures to more risky R&D.

From the last column of Panels A and B, it can be seen that the estimated coefficients on residual vega and delta have the same signs as those on predicted vega and delta and are statistically significant at 1%. Thus, the components of vega and delta that are orthogonal to the other right-hand side variables have explanatory power. This raises several possibilities. First, the coefficient on the residual could represent (a) the effect of a transitory departure in vega or delta from normal levels that results from either transaction costs or an imperfect ability to track perfectly normal levels due to discretionary portfolio adjustments by the CEO, or (b) the effects of a purposeful but short-term effort by the board of directors to alter investment policy. Both interpretations assume that the coefficient on the predicted value represents the permanent or intentional (driven by the right-hand side determinants in the predictive regression) effect of vega or delta on investment policy. Second, the model predicting vega and delta could be incomplete, in which case the residual captures the effect of omitted variables which contribute to the association between compensation structure and investment composition. Third, given that predicted vega and delta are included on the right-hand side, the significant coefficients on residual values could reflect causation flowing the other direction, from investment policy to compensation structure. These last two possibilities provide a strong impetus to specify and estimate simultaneous equations models.

[5] Our specifications are very similar but not identical. Differences are driven by the need to impose identifying restrictions in simultaneous equations specifications of policy, vega, and delta.

[6] One possible reason for slightly weaker results using firm fixed effects is that the relation between firm investment policy and vega is strong in the cross-section but not very prominent in the time series. This is plausible if, for a given firm, CEO turnover is infrequent and value-maximizing vega and delta are relatively stable. Perhaps unobserved heterogeneity at the firm level is important and the use of firm fixed effects is likely to appreciably affect test power. That is, firm fixed effects weaken the explanatory power of vega, but fixed-effects may be a poor match for this empirical context (Zhou, 2001) because most of the variation arises in the cross-section rather than in the time series. A second reason could be that managers respond quickly to temporary deviations from optimal incentives, which implies that the effect of incentives on policy could be found in only one or two years of the sample period of ten years. This reduces the power of the fixed effects model to detect a significant relation between incentives and future risk taking.

4.2. Simultaneous equations: Investment composition, vega, and delta

Our premise is that managerial incentives (vega and delta) and policy choices are jointly determined. Parameter estimates, from ordinary least squares (OLS) for example, will be biased when the regressors are endogenously determined along with the dependent variable. Our empirical analysis, to this point, addresses the issue by using numerous control variables, lagged values of vega and delta as instruments, fixed effects, and predicted values of vega and delta as instruments. To further reduce the likelihood that our results are spurious and to isolate the effects of incentives on investment policy and financial policy on compensation structure, we approach the data with simultaneous equations models.

Table 3 contains two systems specifications. In each case, the jointly determined variables are the investment measure, vega, and delta. We draw independent variables from Table 2 for investment, and from the prior literature (e.g., Bizjak et al., 1993; Guay, 1999; Core and Guay, 1999) for vega and delta. To conform to the underlying reasoning for simultaneous equations, both here and in the other empirical experiments that follow (on focus and leverage), we use contemporaneous rather than lagged values of vega and delta. The identifying restrictions we impose should be clear from the tables. We estimate the systems using three-stage least squares (3SLS).

For R&D, the estimated coefficient on vega is positive and significant at 1%, while for CAPEX the estimated coefficient on vega is negative and significant at 5%. The results indicate that higher vega implements an allocation of investment dollars to riskier assets.

To gauge the economic significance of these estimates, we calculate the effect on investment of a one standard deviation change in vega. Recall that we scale investment expenditures by total assets. Based on the coefficient estimates from the models in Table 3, the effect of a one standard deviation increase in vega is to increase R&D by about 0.060 (an increase of 158% versus the mean R&D of 0.038). In contrast, the same increase in vega decreases CAPEX by about 0.010 (a decrease of 15% versus the mean CAPEX of 0.068). The effect of vega on investment policy appears to be large and economically significant.

Turning to the 3SLS estimates on the control variables, the coefficients are generally as expected (for example, Gibbons and Murphy, 1992a,b; Bizjak et al., 1993; Brickley et al., 1999). Table 3 also provides results on the determinants of delta and vega. We estimate additional simultaneous systems later in the paper that include vega and delta as endogenous variables, namely, 3SLS regressions of firm focus, vega, and delta (Section 5.2) and 3SLS regressions of leverage, vega, and delta (Section 6.2). Since the results on determinants of vega and delta are similar across all the specifications, rather than discuss the results in each subsection separately, we provide a consolidated discussion in Section 7.4.

4.4. Further robustness checks

We try several other approaches to test for robustness of the results in Table 2. We estimate the R&D regressions using Tobit since a large number of firms have zero R&D. In addition, we estimate median regressions (which minimizes the impact of

Table 3
Simultaneous equations (3SLS): R&D, capital expenditures, and CEO incentives

Simultaneous regressions of investment measures, vega, and delta are reported. In Panel A, the investment measure is research and development expenditures scaled by assets (R&D). In Panel B, the investment measure is net capital expenditures scaled by assets (CAPEX), where net capital expenditures is the capital expenditures net of sales of property, plant, and equipment. Vega is the dollar change in the value of the CEO's wealth for a 0.01 change in standard deviation of returns. Delta is the dollar change in the value of the CEO's wealth for a 1% change in stock price. Control variables are as described in the appendix. The predicted signs for the variables of interest are given to the left of the coefficient. Dollar values are in millions of 2002 dollars. Intercepts not reported. *t*-statistics based on robust standard errors are within parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Predicted signs are indicated in parentheses.

	Panel A				Panel B			
Independent variables		R&D	Vega	Delta		CAPEX	Vega	Delta
Vega $_t$	(+)	0.517***		2.340***	(−)	−0.089**		5.355***
		(6.2)		*(3.4)*		*(−2.1)*		*(7.6)*
Delta $_t$	(±)	0.040**	0.002		(±)	−0.015	−0.000	
		(2.0)	*(0.5)*			*(−1.4)*	*(−0.1)*	
Tenure		−0.002***		0.040***		0.001*		0.032***
		(−2.7)		*(17.3)*		*(1.8)*		*(16.5)*
Cash compensation		−0.016***	0.030***			0.002**	0.031***	
		(−9.3)	*(25.7)*			*(2.0)*	*(24.0)*	
Log (sales)		−0.036***	0.034***	0.227***		0.004***	0.034***	0.017
		(−19.3)	*(33.8)*	*(3.5)*		*(3.5)*	*(33.7)*	*(0.8)*

Market-to-book	−0.011***		0.009***		0.171***	0.008***		0.009***		0.122***
	(−2.9)		*(7.8)*		*(18.4)*	*(3.7)*		*(6.9)*		*(3.7)*
Surplus cash	0.151***				−1.890***	0.033***				−0.825***
	(13.1)				*(−3.6)*	*(4.9)*				*(−2.9)*
Sales growth	0.002					0.002***				
	(1.4)					*(3.4)*				
Stock return	−0.000					−0.000				
	(−0.5)					*(−0.9)*				
Book leverage	0.006	(+)	−0.003	(−)	−0.156**	−0.010***	(+)	−0.003	(−)	−0.106
	(0.9)		*(−0.6)*		*(−2.3)*	*(−2.7)*		*(−0.4)*		*(−1.2)*
R&D		(+)	0.131**	(−)	10.317***		(+)	0.072***	(−)	−0.940***
			(2.0)		*(2.9)*			*(5.1)*		*(−4.9)*
CAPEX		(−)	−0.047***	(+)	0.736***		(−)	0.179	(+)	15.670**
			(−2.8)		*(3.7)*			*(0.73)*		*(2.1)*
Firm risk		(+)	0.022***	(±)	−0.130***		(+)	0.024***	(±)	0.035
			(13.8)		*(−2.7)*			*(14.3)*		*(1.6)*
2-digit SIC controls	YES		YES		YES	YES		YES		YES
Observations	10687		10687		10687	10687		10687		10687

outliers), and we adjust for serial correlation in the error terms. In all cases, the results on vega are qualitatively similar.

Additionally, for the regressions in both Tables 2 and 3, we use CEO age as an additional explanatory variable, we include year dummy variables, and we use logarithmic values of vega and delta rather than the raw values. The results on vega are robust to all these alternative specifications with one exception, namely, the coefficient on vega is insignificant in the 3SLS regression of CAPEX when year dummies are included.

5. Firm focus and CEO incentives

In Tables 4 and 5 we present results on whether compensation structure affects the decision to focus on a small number of businesses or diversify across many lines of business. To the extent that diversification decreases firm risk, we expect that higher vega will implement increased focus.

We use two measures of focus, the Herfindahl index of the concentration of sales across the various business segments and the logarithm of the number of reported business segments. Increased focus is represented by a higher Herfindahl Index and fewer segments. Thus, we predict that the Herfindahl index (number of segments) should be positively (negatively) related to vega. Our choice of control variables used in the regressions of the Herfindahl index and number of segments is influenced primarily by Berger and Ofek (1999).

Our analysis of firm focus is based on a smaller number of observations. We use Compustat segment data only through 1997 because in 1998 FASB introduced SFAS 131, which significantly changed the reporting requirements for segment data.

5.1. *Firm focus and vega*

With the exception of the industry fixed effects specification, the coefficient estimates in Table 4 indicate that higher vega implements greater focus ($p<0.01$). The Herfindahl index depends positively on both lagged and fitted vega, while the logarithm of the number of segments depends negatively on both lagged and fitted vega. Residual vega, in contrast, has little explanatory power.[7] These results are consistent with the hypothesis that higher vega implements increased focus.

5.2. *Simultaneous equations: firm focus, vega, and delta*

Table 5 presents 3SLS parameter estimates.[8] In both systems, the estimated coefficient on vega is significant at 1%. Vega has a positive effect on the Herfindahl

[7]CEO turnover cannot be included in the last two specifications. These specifications include predicted values of lagged incentives and we do not have predicted lagged incentives in the turnover year.

[8]Note that we do not include Herfindahl index and log(Segments) as right-hand side variables in the delta and vega regressions. This is to ensure that the same set of variables is used throughout all our

index and a negative effect on the number of segments. Moreover, vega has a substantial impact in economic terms. For example, increasing vega by one standard deviation implies a 52% increase (change of 0.43 relative to an average of 0.83) in the Herfindahl index and an 85% decrease in the number of segments.

Of the control variables, focus is positively related to delta and ROA, and negatively related to sales, market-to-book, CEO tenure, CEO cash compensation, and stock return.

5.3. Further robustness checks

Denis et al. (1997) is the only other paper to our knowledge that explores determinants of the number of segments. They include R&D as an additional explanatory variable. When we do the same, the results in Table 4 relating to vega remain. Further, when we adjust for serial correlation in the error terms, the results are qualitatively similar.

As with the investment measures, we try several other approaches to test for robustness of the results in Tables 4 and 5. We include CEO age as an additional explanatory variable, we include year dummy variables, and we use logarithmic values of vega and delta rather than the raw values. The results on vega are robust to all these alternative specifications.

6. Debt policy and CEO incentives

6.1. Leverage and vega

One way to increase firm risk is to increase leverage. Thus, higher vega should imply higher leverage. In Table 6, the primary explanatory variables are lagged actual, residual, or predicted values of vega. All specifications include either industry (two-digit SIC) or firm fixed effects. Consistent with existing studies on leverage, we use as control variables the logarithm of firm sales, market-to-book ratio, ROA, net fixed assets, R&D, and *Z*-score (Altman, 1968), among others. Our choices for control variables reflect the extensive literature on the determinants of capital structure. An incomplete list includes Mackie-Mason (1990), Rajan and Zingales (1995), Jung et al. (1996), Barclay et al. (2003), and Welch (2004).

Our choice of book (rather than market) leverage as the dependent variable is influenced by Welch (2004), who points out that market leverage may change passively simply because of changes in stock price performance, and may not be an active managerial choice. On the other hand, market leverage may more directly affect the CEO's incentives through its effect on stock price volatility. Thus, there is a

(*footnote continued*)
simultaneous systems (in Tables 3, 5, and 7), and including Herfindahl index and Segments would dramatically reduce the number of observations. For completeness, however, we estimate the system with the corresponding risk measure included and the results are similar.

Table 4
Regressions of firm focus measures on CEO incentives

The dependent variables are Herfindahl Index and log of number of business segments. Herfindahl Index is calculated as the sum of the square of segment sales divided by the square of firm sales. Vega is the dollar change in the value of the CEO's stock and option portfolio for a 0.01 change in standard deviation of returns. Delta is the dollar change in the value of the CEO's stock and option portfolio for a 1% change in stock price. Predicted and residual incentives are the predicted values and residuals from regressions of vega and delta on endogenous and control variables. Control variables are as described in the Appendix. The predicted signs for the variables of interest are given to the left of the coefficient. Intercepts not reported. Dollar values are in millions of 2002 dollars. t-statistics based on robust standard errors are within parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Predicted signs are indicated in parentheses.

	Panel A: Herfindahl index					Panel B: Log (segments)				
Independent variables		Industry FE	Firm FE	Predicted	Predicted + residuals		Industry FE	Firm FE	Predicted	Predicted + residuals
Vega $_{t-1}$	(+)	0.051	0.130***			(−)	−0.140	−0.422***		
		(0.9)	*(4.7)*				*(−1.1)*	*(−6.2)*		
Predicted vega $_{t-1}$	(+)			1.051***	1.049***	(−)			−2.007***	−2.021***
				(4.1)	*(4.0)*				*(−3.8)*	*(−3.7)*
Residual vega $_{t-1}$	(+)				0.015	(−)				−0.083
					(0.3)					*(−0.7)*
Delta $_{t-1}$	(±)	0.020***	−0.005			(±)	−0.039***	0.028***		
		(4.5)	*(−1.4)*				*(−3.7)*	*(3.0)*		
Predicted delta $_{t-1}$	(±)			0.069***	0.071***	(±)			−0.116**	−0.124***
				(3.2)	*(3.3)*				*(−2.4)*	*(−2.6)*
Residual delta $_{t-1}$	(±)				0.012**	(±)				−0.027***
					(2.6)					*(−2.6)*

Tenure	0.000	0.000	−0.002***	−0.003***	0.002*	−0.001	0.005***	0.006***
	(−0.9)	(0.3)	(−2.6)	(−2.7)	(1.7)	(−0.7)	(2.6)	(2.7)
Cash compensation	−0.008*	−0.001	−0.023**	−0.025**	0.014	0.002	0.041**	0.046**
	(−1.7)	(−0.4)	(−2.3)	(−2.5)	(1.3)	(0.3)	(2.0)	(2.2)
Log (sales)	−0.054***	−0.026***	−0.094***	−0.093***	0.131***	0.073***	0.207***	0.205***
	(−17.3)	(−5.6)	(−16.1)	(−15.9)	(19.2)	(6.3)	(16.3)	(16.1)
Market-to-book	0.015***	0.006***	−0.007	−0.007*	−0.028***	−0.023***	0.012	0.013
	(5.8)	(2.6)	(−1.6)	(−1.7)	(−4.7)	(−4.2)	(1.2)	(1.4)
ROA	0.200***	0.009	0.237***	0.236***	−0.565***	−0.008	−0.645***	−0.645***
	(7.4)	(0.4)	(7.4)	(7.3)	(−9.0)	(−0.1)	(−8.5)	(−8.5)
Stock return	−0.013*	−0.005	0.019*	0.019*	0.032*	0.020**	−0.024	−0.026
	(−1.8)	(−1.4)	(1.8)	(1.9)	(1.9)	(2.4)	(−1.1)	(−1.2)
Sales growth	0.006*	−0.000	0.009***	0.009***	−0.011*	0.000	−0.017**	−0.017**
	(1.8)	(−0.3)	(2.6)	(2.5)	(−1.8)	(0.1)	(−2.5)	(−2.4)
Dividend cut	−0.005	0.011**	−0.001	−0.002	0.027	−0.026**	0.024	0.026
	(−0.4)	(2.3)	(−0.1)	(−0.1)	(1.0)	(−2.2)	(0.8)	(0.9)
CEO turnover	−0.026*	0.002			0.066**	−0.008		
	(−1.8)	(0.4)			(2.1)	(−0.6)		
Book leverage	−0.036*	0.034*	0.003	0.030	0.100**	−0.079*	0.053	0.052
	(−1.7)	(1.9)	(0.1)	(0.1)	(2.1)	(−1.8)	(1.0)	(1.0)
Firm fixed effects		YES				YES		
2-digit SIC controls	YES		YES	YES	YES		YES	YES
Observations	4219	4219	3596	3596	4220	4220	3597	3597
R^2	29%	2%	30%	30%	32%	3%	32%	32%

Table 5
Simultaneous equations (3SLS): Firm focus and CEO incentives

Simultaneous regressions of focus, vega, and delta are reported. In Panel A, we consider Herfindahl Index, calculated as the sum of squared segment sales divided by the square of firm sales. In Panel B, we consider Log(Segments). Vega is the dollar change in the value of the CEO's stock and option portfolio for a 0.01 change in standard deviation of returns. Delta is the dollar change in the value of the CEO's stock and option portfolio for a 1% change in stock price. Control variables are as described in the Appendix. The predicted signs for the variables of interest are given to the left of the coefficient. Intercepts not reported. Dollar values are in millions of 2002 dollars. *t*-statistics based on robust standard errors are within parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Predicted signs are indicated in parentheses.

	Panel A				Panel B			
Independent variables		Herfindahl index	Vega	Delta		Log (segments)	Vega	Delta
Vega $_t$	(+)	3.749***		6.744***	(−)	−7.314***		6.722***
		(4.4)		*(12.4)*		*(−4.2)*		*(12.4)*
Delta $_t$	(±)	0.340***	0.001		(±)	−0.691***	0.001	
		(4.9)	*(0.2)*			*(−4.9)*	*(0.2)*	
Tenure		−0.011***		0.033***		0.024***		0.033***
		(−4.5)		*(19.5)*		*(4.7)*		*(19.5)*
Cash compensation		−0.163***	0.026***			0.321***	0.026***	
		(−6.6)	*(15.7) (25.1)*			*(6.4)*	*(15.7) (25.1)*	
Log (sales)		−0.161***	0.021***	−0.001		0.343***	0.021***	−0.000
		(−9.4)	*(18.4)*	*(−0.0)*		*(9.8)*	*(18.4)*	*(−0.0)*
Market-to-book		−0.086***	0.005***	0.183***		0.174***	0.005***	0.184***
		(−5.3)	*(3.6)*	*(17.0)*		*(5.2)*	*(3.5)*	*(17.0)*
ROA		0.306***				−0.765***		
		(5.2)				*(−6.1)*		

Stock return	−0.020*					0.045**				
	(−2.0)					*(2.1)*				
Sales growth	0.001					−0.000				
	(0.2)					*(0.1)*				
Dividend cut	0.020					−0.018				
	(1.5)					*(−0.7)*				
CEO turnover	−0.019					0.038				
	(−1.6)					*(1.4)*				
Book leverage	0.015	(+)	0.008	(−)	−0.237***	0.000	(+)	0.008	(−)	−0.237***
	(0.3)		*(1.0)*		*(−2.7)*	*(0.0)*		*(1.1)*		*(−2.7)*
R&D		(+)	0.106***	(−)	−1.352***		(+)	0.113***	(−)	−1.341***
			(6.8)		*(−6.3)*			*(7.1)*		*(−6.2)*
CAPEX		(−)	−0.039**	(+)	1.375***		(−)	−0.030	(+)	1.381***
			(−2.1)		*(5.7)*			*(−1.6)*		*(5.7)*
Firm risk		(+)	0.011***	(±)	0.042*		(+)	0.011***	(±)	0.042*
			(5.7) *(15.3)*		*(1.9)*			*(5.6)* *(15.3)*		*(1.9)*
Surplus cash					0.063					0.054
					(0.5)					*(0.4)*
2-digit SIC controls	YES		YES		YES	YES		YES		YES
Observations	4301		4301		4301	4301		4301		4301

Table 6
Regressions of book leverage on CEO incentives

The dependent variable is book leverage defined as book debt divided by book value of total assets. Vega is the dollar change in the CEO's wealth for a 0.01 change in standard deviation of returns. Delta is the dollar change in the CEO's wealth for a 1% change in stock price. Predicted and residual incentives are the predicted values and residuals from regressions of vega and delta on endogenous and control variables. Control variables are as described in the Appendix. The predicted signs for the variables of interest are given to the left of the coefficient. Dollar values are in millions of 2002 dollars. Intercepts not reported. t-statistics based on robust standard errors are within parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Predicted signs are indicated in parentheses.

		Dependent variable: book leverage			
Independent variables		Industry FE	Firm FE	Predicted	Predicted + residuals
Vega $_{t-1}$	(+)	0.056***	0.024		
		(2.8)	(1.3)		
Predicted vega $_{t-1}$	(+)			0.556***	0.576***
				(5.2)	(5.5)
Residual vega $_{t-1}$	(+)				0.047**
					(2.1)
Delta $_{t-1}$	(±)	−0.008***	−0.010***		
		(−2.8)	(−3.6)		
Predicted delta $_{t-1}$	(±)			−0.087***	−0.088***
				(−6.5)	(−6.6)
Residual delta $_{t-1}$	(±)				−0.003
					(−1.0)
Tenure		−0.001**	−0.000	0.002***	0.002***
		(−2.2)	(−0.4)	(4.6)	(4.7)
Cash compensation		−0.004**	−0.008***	−0.013***	−0.013***
		(−2.0)	(−4.6)	(−4.6)	(−4.7)
Log (sales)		0.013***	0.046***	0.013***	0.013***
		(7.3)	(13.4)	(4.1)	(4.0)
Market-to-book		−0.002	−0.000	0.004	0.005*
		(−0.7)	(−0.2)	(1.6)	(1.7)
ROA		−0.382***	−0.412***	−0.364***	−0.362***
		(−9.3)	(−20.6)	(−8.8)	(−8.7)
Net PPE		0.073***	0.004	0.066***	0.067***
		(5.0)	(0.2)	(4.6)	(4.7)
R&D		−0.350***	−0.012	−0.435***	−0.437***
		(−5.9)	(−0.3)	(−6.6)	(−6.6)
Z-Score ($\times 10^{-6}$)		−1.25**	−1.310**	−0.918**	−0.915**
		(−2.1)	(−4.5)	(−2.0)	(−2.0)
Firm fixed effects			YES		
2-digit SIC controls		YES		YES	YES
Observations		8865	8865	7396	7396
R^2		18%	9%	21%	21%

tradeoff between the measure of interest to the CEO (market leverage), and the measure that is, perhaps, a less noisy reflection of the CEO's decision making (book leverage). In any case, if we use market leverage instead (in all the tables and all robustness checks), there is no change in our inferences.

The regression results in Table 6 are consistent with our predictions. The estimated coefficient on (actual or predicted) vega is always positive and is significant at the 1% level in three of the four specifications, while the coefficient on residual vega is significant at the 5% level. Leverage depends positively on both vega and residual vega.

6.2. Simultaneous equations: Leverage, vega, and delta

Despite our attempts above to address the endogeneity problem, using fixed effects and instruments for vega and delta (lagged and predicted), the issue of causation may still be a concern. Certainly there are hypotheses that suggest leverage causes compensation or compensation policy. For example, one possibility is that shareholders of firms with high leverage will structure managerial compensation to have low vega, so that managers choose low risk projects and shareholders bear lower costs of indirect financial distress (John and John, 1993). In addition, firms with more growth opportunities have lower debt in their capital structure (Bhagat and Welch, 1995; Rajan and Zingales, 1995), but may provide their CEOs with higher vega (Guay, 1999). These results suggest that leverage and vega should be negatively related. Also, if leverage and delta are substitute incentive alignment devices, higher leverage will imply lower delta.

To account further for the possibility that financial policy and the structure of compensation are jointly determined, we estimate simultaneous systems of equations (3SLS) in which the jointly determined variables are leverage, vega, and delta. Once again, we use contemporaneous rather than lagged values of vega and delta to accommodate the logic of the simultaneous equations approach.

As Table 7 reports, the results for vega continue to hold. The estimated coefficient on vega is positive and significant at 1%. Vega has an economically significant effect on leverage: A one standard deviation change in vega increases book leverage by 65% (a change of 0.15 relative to a mean value of 0.23).

In contrast, controlling for the effect of leverage on vega, higher delta implements lower leverage. The coefficients on the other control variables are generally qualitatively similar to those estimated in earlier studies (e.g., Rajan and Zingales, 1995; Barclay et al., 2003).

6.3. Further robustness checks

We check for robustness in several ways. We include additional explanatory variables, such as investment tax credit to total assets, an indicator variable that takes the value of one if the firm does not pay dividends in the current year, free cash flow to assets, and an indicator variable that takes the value of one if the firm had a CEO turnover that year. We also estimate both Tobit regressions and median regressions, and adjust for serial correlation in the error terms. In all cases, our inferences in Table 6 regarding vega remain.

As with the investment and focus measures, we try several other approaches to test for robustness of the results in Tables 6 and 7 on leverage. We include CEO

Table 7
Simultaneous equations (3SLS): Book leverage and CEO incentives

Simultaneous regressions of book leverage, vega, and delta are reported. Book leverage is book debt divided by total assets. Vega is the dollar change in the CEO's wealth for a 0.01 change in standard deviation of returns. Delta is the dollar change in the CEO's wealth for a 1% change in stock price. Control variables are as described in the Appendix. The predicted signs for the variables of interest are given to the left of the coefficient. Dollar values are in millions of 2002 dollars. Intercepts not reported. *t*-statistics based on robust standard errors are within parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Predicted signs are indicated in parentheses.

Independent variables		Book leverage		Vega		Delta
Vega_t	(+)	1.322***				5.203***
		(3.9)				*(18.2)*
Delta_t	(±)	−0.233***		0.013***		
		(−3.8)		*(3.6)*		
Tenure		0.007***				0.031***
		(3.2)				*(27.2)*
Cash compensation		−0.003		0.028***		
		(−0.5)		*(24.0)*		
Log (sales)		0.000		0.032***		−0.024
		(0.0)		*(32.1)*		*(−1.3)*
Market-to-book		0.033**		0.008***		0.165***
		(2.5)		*(7.1)*		*(22.1)*
ROA		−0.179***				
		(−5.3)				
Net PPE		0.073***				
		(3.3)				
R&D		−0.512***	(+)	0.088***	(−)	−1.239***
		(−5.6)		*(5.6)*		*(−8.9)*
Z-Score ($\times 10^{-6}$)		−0.841**				
		(−2.0)				
Book leverage			(+)	0.038*	(−)	−1.232**
				(1.7)		*(−2.5)*
CAPEX			(−)	−0.061***	(+)	0.721***
				(−3.3)		*(4.1)*
Firm risk			(+)	0.022***	(±)	−0.019
				(15.1)		*(−1.2)*
Surplus cash						0.036
						(0.2)
2-digit SIC controls		YES		YES		YES
Observations		9438		9438		9438

age as an additional explanatory variable, year dummy variables, and logarithmic values of vega and delta rather than the raw values. The results on vega are generally similar.

To conclude, our results on higher vega implementing higher leverage are consistent with the association documented in Cohen et al. (2000). Since we apply various corrections for endogeneity, including the use of simultaneous equations in Table 7, we are more likely to isolate the direction and magnitude of the causal effects of vega on leverage, and vice versa. Higher vega implements higher leverage and, in both statistical and economic terms, the effect is substantial.

7. Additional evidence on the relation between incentives and policy choices

7.1. Changes in incentives imply changes in policy and risk

While using lagged, predicted, and residual values of incentives should all help control for endogeneity, to demonstrate further evidence of causality, we also estimate regressions of changes in policy measures on lagged changes in incentives and residual incentives. Our specifications are similar to industry fixed effects regression in Tables 2, 4, and 6, but with minor changes. We include the control variables that are already reflective of changes in underlying variables, such as stock return, surplus cash, sales growth, ROA, dividend cut, and CEO turnover. The control variables that are levels, such as CEO cash compensation, book leverage, R&D, firm risk, net PPE, and Z-score, are included as first-differences. Log(sales) and market-to-book, as primitives, are the only variables that are not included in change form. We do not use tenure in the change regressions because change in tenure equals one for all observations.

The results, which we do not report here, indicate that changes in riskier policy measures such as R&D and Herfindahl index are positively related to lagged change in vega (p-values of 0.005 and 0.019, respectively). We find that change in book leverage is not significantly related to change in vega, but change in market leverage is weakly and positively related to change in vega ($p = 0.104$). Changes in safer policy choices such as CAPEX and segments are negatively related to lagged change in vega ($p = 0.017$ and 0.033, respectively). We also consider a change-in-focus measure, REFOCUS. Following Berger and Ofek (1999), this variable takes the value of one if the number of Compustat business segments decreases and the Herfindahl index (of concentration in business segments) increases by more than 0.1. As expected, we find that the probability of refocusing is positively related to lagged change in vega ($p = 0.034$).

We also regress policy changes on lagged residual incentives. The idea, in part, is to capture the possibility that residual incentives reflect the board's desire to implement policy changes. Thus, we estimate the same models with policy changes on the left-hand side and lagged values of residual vega and delta on the right-hand side. In unreported results, we find that residual vega has a strong positive effect on change in R&D intensity and change in book leverage, and a strong negative effect on change in CAPEX. In contrast, residual vega has a weak effect on change in focus (in the logit regression of firm refocus, residual vega is positive with a p-value of 0.13).

7.2. Alternative specification of system of equations

Though the 3SLS system used in this study to explore the causal relation between incentives and risk taking is in line with conventional thinking on simultaneous

Table 8
Regressions of risk measures on incentives of top five executives

The dependent variables are the usual risk measures. Management team vega, management team delta, and management team cash compensation are the cumulative vegas, deltas, and cash compensation of the top four executives of the firm other than the CEO, as reported in Execucomp. Vega is the dollar change in the CEO's wealth for a 0.01 change in standard deviation of returns. Delta is the dollar change in the CEO's wealth for a 1% change in stock price. Control variables are as described in the Appendix. The predicted signs for the variables of interest are given to the left of the coefficient. Dollar values are in millions of 2002 dollars. Intercepts not reported. t-statistics based on robust standard errors are within parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Predicted signs are indicated in parentheses.

Independent variables		R&D		CAPEX		Herfindahl index		Log (segments)		Book leverage
CEO vega $_{t-1}$	(+)	0.048***	(−)	−0.015**	(+)	0.130*	(−)	−0.311**	(+)	0.076***
		(7.2)		*(−2.1)*		*(2.0)*		*(−2.1)*		*(2.9)*
Mgmt team vega $_{t-1}$	(+)	0.031***	(−)	−0.024***	(+)	−0.078	(−)	0.184	(+)	−0.010
		(6.4)		*(−5.4)*		*(−1.3)*		*(1.4)*		*(−0.6)*
CEO delta $_{t-1}$	(±)	−0.003***	(±)	0.004***	(±)	0.019***	(±)	−0.033***	(±)	−0.004
		(−4.0)		*(6.0)*		*(3.9)*		*(−3.0)*		*(−1.6)*
Mgmt team Delta $_{t-1}$	(±)	−0.001***	(±)	0.001**	(±)	0.005	(±)	−0.019**	(±)	−0.007***
		(−2.6)		*(2.0)*		*(1.1)*		*(−2.1)*		*(−3.7)*
CEO cash compensation		−0.001		−0.003***		0.001		−0.003		−0.003
		(−1.3)		*(−4.7)*		*(0.2)*		*(−0.2)*		*(−1.4)*
Mgmt team cash compensation		0.007***		0.001		−0.012***		0.023***		−0.001
		(11.1)		*(1.1)*		*(−3.3)*		*(2.9)*		*(−0.7)*
CEO tenure		−0.001***		−0.000		0.000		0.002		−0.001***
		(−7.1)		*(−1.3)*		*(−0.8)*		*(1.4)*		*(−2.8)*
Log (sales)		−0.022***		0.000		−0.047***		0.118***		0.014***
		(−14.9)		*(0.2)*		*(−13.4)*		*(15.3)*		*(6.9)*

Market-to-book	0.005***	0.003***	0.016***	−0.029***	−0.001
	(5.6)	*(6.3)*	*(6.0)*	*(−4.8)*	*(−0.3)*
Book leverage	0.004	−0.006	−0.041*	0.109**	
	(0.4)	*(−1.6)*	*(−1.9)*	*(2.3)*	
Sales growth	0.006**	0.001	0.006*	−0.011*	
	(2.6)	*(1.0)*	*(1.8)*	*(−1.8)*	
Stock return	−0.001	−0.000*	−0.012	0.029*	
	(−1.6)	*(−1.7)*	*(−1.6)*	*(1.8)*	
Surplus cash	0.094***	0.040***			
	(5.5)	*(5.7)*			
Dividend cut			−0.006	0.028	
			(−0.5)	*(1.1)*	
CEO turnover			−0.018	0.052	
			(−1.2)	*(1.6)*	
ROA			0.186**	−0.539***	−0.387***
			(6.8)	*(−8.5)*	*(−9.5)*
R&D					−0.351***
					(−5.9)
Net PPE					0.071***
					(4.9)
Z-Score ($\times 10^{-6}$)					−1.270**
					(−2.1)
2-digit SIC controls	YES	YES	YES	YES	YES
Observations	9551	9422	4219	4220	8865
R^2	40%	30%	30%	32%	18%

systems (where both policy and incentive measures are contemporaneous), an alternate specification used by Rajgopal and Shevlin (2002) merits attention.

$$\text{Policy}_t = \text{function of } \{\text{Vega}_{t-1},\ \text{Delta}_{t-1},\ \text{Controls}_{t-1}\},$$

$$\text{Vega}_{t-1} = \text{function of } \{\text{Policy}_t,\ \text{Delta}_{t-1},\ \text{Controls}_{t-1}\},$$

$$\text{Delta}_{t-1} = \text{function of } \{\text{Policy}_t,\ \text{Vega}_{t-1},\ \text{Controls}_{t-1}\}.$$

This specification allows for the possibility that a firm that wants the CEO to increase risk in the future will provide higher vega today. We estimate five systems corresponding to the five policy choices we have considered thus far. Our inferences, for both the policy equations and the incentive regressions, are robust to using these specifications.

7.3. *Effect of incentives of top management team on policy choice*

Thus far in the paper, we have examined only the effect of CEO incentives on policy choices. While the influence of the CEO is likely to be large, others on the top management team also are likely to affect investment and financing policies. Thus, we examine the influence of vega and delta for the top four executives (other than the CEO) on the firm's decisions.[9]

We define the management team vega as the sum of the vegas of the top four executives other than the CEO. Management team delta and cash compensation are similarly defined. Our specifications are similar to the industry fixed effects regressions in Tables 2, 4, and 6 but with management team incentives included in addition to CEO incentives. As Table 8 indicates, CEO incentives continue to have explanatory power when the specification controls for the incentives of the next four executives on the management team. The coefficients on management team vega are significant only in the R&D and CAPEX regressions, and are in the same direction as the corresponding coefficients on CEO vega. The results suggest that CEO vega is the primary driving force behind firm policy choices and that management team vega has lower explanatory power. In contrast, there is strong evidence that management team delta (in addition to CEO delta) also affects firm policy choices. These results are new to the literature.

7.4. *Determinants of vega and delta*

While the determinants of delta have attracted strong interest in the literature (e.g., Bizjak et al., 1993; Core and Guay, 1999), we know of very little work on the determinants of vega (one exception is Guay, 1999). Existing studies examine the determinants of either delta or vega in an OLS setting without controlling for the fact that both are chosen simultaneously. Moreover, these studies do not correct for endogeneity in policy choices and managerial incentives. Our approach attempts to

[9]To our knowledge, the only other paper that examines team incentives and policy is Aggarwal and Samwick (2002a). They estimate the effect of total management team delta on capital expenditures.

resolve these difficulties. Specifically, in the discussion below, we refer to the vega and delta equations (3SLS) of Tables 3, 5, and 7, as well as the Rajgopal and Shevlin (2002) specification discussed in Section 7.2. In addition, for robustness, we estimate all of these specifications but also include the firm focus measures one at a time.

We can draw a number of general conclusions from this assortment of estimated specifications. First, vega depends positively on firm risk. Second, our results suggest that vega depends negatively on capital expenditure. In contrast, Guay (1999) finds that vega is positively related to investment expenditures (defined as capital expenditures plus acquisitions expenditures). The difference could be driven by the fact that acquisitions can be high risk or low risk, which suggests that it may be important to separate out investment expenditures based on their relative riskiness. Third, the riskiness of the policy choices the firm would like to implement affects the incentive structure. Specifically, vega is positively related to riskier policy choices (R&D and leverage) and negatively related to safer policy choices (CAPEX). In contrast, delta is negatively related to riskier policy choices and positively related to safer policy choices.[10]

Our other results generally accord with the existing literature. Vega is positively related to sales, market-to-book, and CEO cash compensation. Delta is positively related to market-to-book (as in Coles et al., 2003) and CEO tenure. Delta is also positively related to firm risk, which is consistent with Core and Guay (2002b), but not with Aggarwal and Samwick (1999), though firm risk may not be the appropriate measure of uncertainty (Baker and Jorgensen, 2003). In contrast to Guay (1999), we find that vega does not depend on delta.

8. Stock return volatility and CEO incentives

8.1. Firm risk and vega

Above we isolate the effect of compensation structure on policy choices. These same policies serve as some of the channels through which compensation structure can alter firm risk. Decisions about investment composition, firm focus, and leverage should ultimately affect stock volatility. Therefore, we regress firm risk on policy choices but also include vega and delta.

Table 9 presents results for five specifications. In each the dependent variable is the logarithm of the variance of daily stock returns. Consistent with our expectations, higher R&D and higher leverage translate into higher firm risk, while higher CAPEX tends to imply lower firm risk.

[10]In the specifications that include firm focus, we find that vega (delta) depends negatively (positively) on Herfindahl index. This is in contrast with our finding that riskier policy choices lead to higher vega and lower delta. One possible explanation is that diversified firms (lower Herfindahl index) are given higher vega and lower delta to induce the CEO to refocus in order to reduce the diversification discount (Berger and Ofek, 1999). Of course, the validity of this argument depends on the existence of a diversification discount and refocusing taking a longer time to implement. Our inferences are similar if we use log(Segments) to represent firm focus.

Table 9 indicates that, controlling for R&D, CAPEX, and leverage, the coefficients on actual and predicted vega and delta are positive and highly significant. Even when holding policy choices constant, higher vega and delta increase firm risk. These results hold when we include measures of firm focus in the regressions.

Table 9
Regressions of firm risk on firm policy and CEO incentives

The dependent variable is the logarithm of variance of daily stock returns. Vega is the dollar change in the value of the CEO's stock and option portfolio for a 0.01 change in standard deviation of returns. Delta is the dollar change in the value of the CEO's stock and option portfolio for a 1% change in stock price. Predicted and residual incentives are the predicted values and residuals from regressions of vega and delta on endogenous and control variables. Control variables are as described in the Appendix. The predicted signs for the variables of interest are given to the left of the coefficient. Dollar values are in millions of 2002 dollars. Intercepts not reported. t-statistics based on robust standard errors are within parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Predicted signs are indicated in parentheses.

	Dependent variable: firm risk					
Independent variables		Industry FE	Firm FE	Predicted	Predicted + residuals	Residuals only
Vega $_{t-1}$	(+)	1.438***	1.506***			
		(17.2)	*(17.8)*			
Predicted vega $_{t-1}$	(+)			8.612***	8.707***	
				(12.1)	*(12.5)*	
Residual vega $_{t-1}$	(+)				0.421***	0.233**
					(4.6)	*(2.4)*
Delta $_{t-1}$	(±)	0.106***	0.097***			
		(10.8)	*(7.8)*			
Predicted delta $_{t-1}$	(±)			0.424***	0.417***	
				(8.0)	*(8.0)*	
Residual delta $_{t-1}$	(±)				0.012	0.020*
					(1.2)	*(1.9)*
Tenure		−0.007***	−0.01***	−0.019***	−0.019***	−0.002
		(−6.3)	*(−8.0)*	*(−8.5)*	*(−8.6)*	*(−1.5)*
Cash compensation		−0.045***	0.008	−0.175***	−0.181***	−0.003
		(−5.2)	*(1.0)*	*(−7.5)*	*(−7.8)*	*(−0.4)*
Log (sales)		−0.258***	0.117***	−0.541***	−0.541***	−0.207***
		(−37.2)	*(7.7)*	*(−38.2)*	*(−39.0)*	*(−29.2)*
Market-to-book		0.008	−0.010*	−0.076***	−0.076***	0.035***
		(1.5)	*(−1.8)*	*(−9.4)*	*(−9.4)*	*(6.4)*
R&D		1.909***	0.263	0.797***	0.772***	1.904***
		(11.7)	*(1.5)*	*(4.5)*	*(4.4)*	*(11.1)*
CAPEX		−0.877***	−1.501***	−0.847***	−0.830***	−0.854*
		(−6.0)	*(−10.2)*	*(−5.8)*	*(−5.7)*	*(−5.4)*
Book leverage		0.465***	1.051***	0.451***	0.447***	0.427***
		(8.2)	*(18.3)*	*(7.5)*	*(7.5)*	*(7.0)*
Firm fixed effects			YES			
2-digit SIC controls		YES		YES	YES	YES
Observations		9689	9689	8315	8315	8315
R^2		39%	15%	53%	53%	37%

The last column of Table 9 isolates the effect of vega and delta on firm risk beyond their influence through investment and financial policies. Once again, R&D and leverage have a positive effect on firm risk, while CAPEX appears to have a negative effect. The estimated coefficient on residual vega is positive and significant. In sum, the results indicate that, in addition to vega operating to increase firm risk through the avenues of investment and financial policies, vega increases firm risk in other ways as well. While policy decisions have significant power to explain stock volatility, they do not appear to be the only mechanisms through which higher vega implies higher firm risk. An interesting line of inquiry would be to identify the other avenues through which vega affects firm risk. One possibility is that vega reduces the managerial incentive to hedge firm risk (Tufano, 1996; Knopf et al., 2002).

8.2. Further robustness checks and discussion

We perform several robustness checks. We estimate median regressions, adjust for serial correlation in the error terms, use logarithmic values of incentives (instead of raw values), and include additional control variables such as year dummies and CEO age. The policy variables typically continue to be significant and the results for risk, vega, and delta generally hold.

To address the endogeneity and causality issues, another possible approach is to estimate a system of six simultaneous equations, one each for firm risk, vega, delta, R&D, CAPEX, and leverage. Because specification error is more likely to be propagated throughout a large system of equations, we use two-stage least squares (2SLS) instead of 3SLS. That is, we use fitted values for vega, delta, R&D, CAPEX, and book leverage on the right-hand side in addition to the usual control variables. We find that the coefficient on vega is insignificant but delta continues to have a significantly positive effect on firm risk. The policy variables have the expected signs. The coefficients on R&D and leverage are positive, while the coefficient on CAPEX is negative.[11] CEO tenure, firm size, and market-to-book are significantly negatively related to firm risk.

8.3. Comparison of results to the prior literature

Guay (1999) regresses the standard deviation of stock returns on contemporaneous vega, logarithm of assets, leverage, and investment opportunities. Cohen et al. (2000) regress firm stock return volatility on elasticity of CEO wealth to stock return volatility, CEO tenure, CEO age, firm fixed effects, year dummies, and the logarithm of each of option value plus stock value, cash compensation, and firm market value. We augment this evidence by estimating specifications that include instruments for vega and delta, control for policy choices that are likely to affect firm risk, include

[11]We also estimate the regressions with predicted values of firm focus included. We find that the inferences regarding vega are generally the same. The coefficients on the other policy variables (R&D and leverage) have the same signs and are highly significant. In contrast, the coefficient on CAPEX loses power. Possible reasons include fewer observations, firm focus is correlated with CAPEX and usurps explanatory power, and changing CAPEX does not have a material impact on firm risk (when proper control variables are included).

other control variables and either industry fixed effects (two-digit SIC) or firm fixed effects, and isolate causality. Our estimates of the coefficient on vega are positive and significant, which is consistent with the results of these two prior studies.

9. Conclusion

We provide empirical evidence of a strong causal relation between an important organizational feature, the structure of managerial compensation, and value-critical managerial decisions, specifically those derived from investment policy and debt policy. The primary characteristic of compensation that we consider is the sensitivity of CEO wealth to stock volatility, or vega. We also examine the role of the sensitivity of CEO wealth to performance, or delta.

Controlling for CEO delta, and applying modeling and econometric remedies for the endogenous feedback effects of firm risk and policy choices on the structure of compensation, we find that higher vega implements riskier policy choices, including relatively more investment in R&D, less investment in property, plant, and equipment, greater focus on fewer lines of business, and higher leverage. This evidence provides support for the hypothesis that higher sensitivity to stock price volatility in the managerial compensation scheme gives executives the incentive to both invest in riskier assets and implement more aggressive debt policy.

We also find that, as expected, stock price volatility is significantly positively related to R&D expenditures, firm focus, and leverage, and is negatively related to capital expenditures. There is some evidence, however, that the policy choices we analyze are not the only mechanisms through which higher vega implies higher firm risk, which poses interesting possibilities for future research.

Finally, we isolate the effects of policy choice and firm risk on vega and delta after controlling for the feedback effect of incentives on policy and risk. We find that riskier policy (higher R&D, lower capital expenditures, higher leverage), and higher volatility of stock returns cause a higher vega. In contrast, less risky policy choices cause a higher delta. Higher volatility of stock returns generally tends to increase pay-performance sensitivity, which is consistent with Demsetz and Lehn (1985), Core and Guay (1999), and Core and Guay (2002b), but inconsistent with Aggarwal and Samwick (1999, 2002b); Himmelberg et al. (1999), and Jin (2002).

Appendix. Definitions of variables used in the study

This appendix defines the variables used in the study. Compustat data items are defined as data#. Stock return data are taken from CRSP, operating segment data from Compustat, and compensation data from Execucomp.

Policy measures

CAPEX = Net capital expenditure to assets
= (Capital Expenditure – Sale of Property, Plant and Equipment)/Assets
= (data128–data107)/data6

R&D = Research and development expenditure to assets = Max(0,data46)/data6
Segments = Number of operating segments as reported in Compustat segment database
Herfindahl Index = (Sum of squared segment sales)/(squared firm sales)
Book Leverage = (data9 + data34)/data6
Market Leverage = (data9 + data34)/(data6–data60 + data199*data25)
Firm Risk = Stock return volatility = Log(variance of daily returns)
Firm characteristics
Market-to-Book = (data6–data60 + data199*data25)/data6
ROA = Return on Assets = data13/data6
Net PPE = Net Property, Plant, and Equipment to assets = data8/data6
Z-Score = 3.3*data178/data6 + 1.2*(data4–data5)/data6 + data12/data6 + 0.6*data199*data25/(data9 + data34) + 1.4*data36/data6
Net Operating Loss to Assets = data52/data6
Surplus Cash = Cash from assets-in-place to total assets = (data308–data125 + data46)/data6
Sales Growth = Log($Sales_t/Sales_{t-1}$)
Dividend Cut = Indicator variable that takes the value of one if there is a reduction in annual dividend, and zero otherwise
CEO Turnover = Indicator variable that takes the value of one if the CEO was replaced, and zero otherwise
Stock Return = Annual return over the fiscal year
Cash to Assets = data1/data6

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