RISK-RETURN TRADEOFFS AND MANAGERIAL INCENTIVES

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ABSTRACT

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Moral hazard theory posits that managerial risk aversion imposes agency costs on shareholders, and firms respond by providing risk-taking incentives to mitigate these costs. The underlying assumption in this literature is that increasing shareholder value requires increasing risk, yet there is limited empirical evidence supporting this assumption or the role of such risk-return tradeoffs in incentive compensation design. Using measures based on the firm's stock price, I find that shareholder value increases with risk, consistent with managerial risk aversion imposing agency costs on shareholders. I also find that firms provide managers with more risk-taking incentives when this risk-return relation is more positive and thus potential risk-related agency costs are more severe. This finding is strongest among firms where value increases with idiosyncratic rather than systematic risk, consistent with theory that these agency costs arise primarily from managers' exposure to idiosyncratic risk. Overall, these results are consistent with firms designing managerial compensation contracts to mitigate risk-related agency costs. Additional findings highlight that the incentives from equity-based compensation depend on the risk-return tradeoffs that managers face, providing one explanation for the conflicting results in prior literature regarding the incentives from managerial stock price exposure.

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1. Introduction

The moral hazard literature argues that managerial risk aversion introduces agency conflicts between managers and shareholders and, as a result, shareholders may provide risk-taking incentives to reduce the costs of these conflicts (e.g., Jensen and Meckling, 1976; Smith and Stulz, 1985). Throughout this literature, the underlying assumption is that managers may avoid certain investment-related risks and thereby reduce shareholder value (i.e., increasing the value of investment projects requires increasing risk and thus managerial risk aversion may diminish shareholder value). However, there is limited empirical evidence supporting this assumption or, more importantly, examining how this relation between risk and shareholder value influences incentive compensation design. In particular, there is little evidence regarding whether firms appear to provide risk-taking incentives to help manage agency costs of managerial risk aversion, or if managerial incentive compensation may instead motivate "excessive" (i.e., value-destroying) risk-taking to the potential detriment of shareholders, as several studies suggest (e.g., Lambert, 1986; Dong, Wang, and Xie, 2010; Athanasakou, Ferreira, and Goh, 2013).[1] In this paper, I address these issues through two primary analyses. First, I estimate the relation between risk-taking and firm value by evaluating whether greater investment risk is associated with greater increases in firm value from these investments. Second, I examine how this risk-return relation[2] influences managers' compensation contracts. Specifically, I test whether firms provide more risk-taking incentives when potential agency costs stemming from managerial risk aversion are greater.

Managers' risk aversion may impose agency costs on shareholders for a number of reasons.[3] First, managers might forgo value-increasing projects (from outside shareholders'

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[1] This concern about excessive risk-taking is also widespread among the popular press and regulators. See, for example, "U.S. Regulators Revive Work on Incentive Pay Rules; Compensation That Rewards Excessive Risk Taking Is a Concern," Wall Street Journal, February 16, 2015.

[2] Throughout the paper, I use the terms "risk-return tradeoffs" and "risk-return relations" interchangeably to refer to the relation between risk and firm value (i.e., whether firm value increases with risk). This is distinct from the relation between risk and required return (i.e., whether discount rates increase with risk). These two ideas are not necessarily inconsistent because if expected cash flows increase with risk, firm value may also increase despite an increase in discount rates.

[3] In particular, risk aversion may create agency costs if managers are more risk averse than shareholders (e.g., if managers are averse to idiosyncratic risk while shareholders are indifferent). I discuss managerial risk aversion in more detail in Section 2.

perspective) that they deem too risky, even if shareholders view the risk as acceptable. For example, managers are often poorly diversified and therefore unable to eliminate their exposure to the firm's idiosyncratic risk (e.g., Jensen and Meckling, 1976; Amihud and Lev, 1981; Smith and Stulz, 1985). As a result, they may impose higher discount rates than well-diversified shareholders when evaluating investment opportunities, potentially causing them to reject value-increasing projects that carry significant amounts of idiosyncratic risk. Second, for a given level of investment, managers may reallocate investment away from riskier projects, even if these riskier projects generate greater returns. For example, Coles, Daniel, and Naveen (2006) argue that managers with fewer risk-taking incentives shift investment toward lower-risk projects. If these less risky investments tend to generate smaller returns, this shift may be detrimental to shareholders. Third, managers may choose to enter the firm into costly hedging contracts (Smith and Stulz, 1985) or engage in diversifying acquisitions (Amihud and Lev, 1981), which prior literature argues reduce both firm risk and value (e.g., Lang and Stulz, 1994; Berger and Ofek, 1995). In summary, risk-related agency costs[4] stem from managers avoiding certain projects that increase both shareholder value and risk (or, similarly, from managers investing in projects that decrease both shareholder value and risk). That is, the basic assumption in this literature is that there exists a positive relation between risk and shareholder value and, given this assumption, potential agency costs arise because risk-averse managers have incentives to choose a level of risk (and therefore value) that is "too low" from shareholders' perspective.

In response to these potential risk-related agency costs, shareholders may choose to provide managers with risk-taking incentives. Much of the prior literature focuses on convex compensation contracts (e.g., stock options) as a mechanism to reduce managerial risk aversion (e.g., Jensen and Meckling, 1976; Haugen and Senbet, 1981; Smith and Stulz, 1985).[5] These

[4] More precisely, agency costs that arise from managers being more risk-averse than shareholders. I use the term "risk-related agency costs" in this paper to refer to these costs of managerial risk aversion (and not, for example, any potential costs from managers being overly risk-tolerant from shareholders' perspective).
[5] If shareholder value and risk are positively related, linear contracts on stock price (e.g., restricted stock) may also provide risk-taking incentives. However, these linear contracts are likely to be less effective than convex contracts at motivating risk-taking because they also increase managers' sensitivity to negative outcomes and

contracts reward managers more for increases in firm value of a given magnitude than they penalize managers for decreases in firm value of the same magnitude. As a result, managers' expected payoffs from these contracts increase as risk increases, potentially increasing their appetite for risk. Consistent with this reasoning, empirical studies examining equity-based compensation and risk-taking generally find that managers respond to convex compensation contracts by taking greater risk and therefore conclude that these types of contracts help reduce managerial risk aversion (e.g., Rajgopal and Shevlin, 2002; Coles, Daniel, and Naveen, 2006; Low, 2009).

The objective of this paper is to examine the risk-return tradeoffs that managers face when making investment decisions and how these tradeoffs influence firms' incentive compensation choices. In particular, I argue that the potential costs of managerial risk aversion are larger when the relation between risk and shareholder value is more positive. As a result, I expect that firms should provide more managerial risk-taking incentives as this relation becomes stronger. For example, if the riskiest investments earn twice the returns of the least risky investments at one firm while at another firm the difference in returns is insignificant, I expect the first firm to provide more risk-taking incentives.

I conduct my analysis in two stages. First, I estimate the investment risk-return tradeoffs that firms face by examining contemporaneous changes in equity value and stock volatility for firms with large amounts of new investment. I find that, on average, the value of investment projects increases with risk, both in total and per dollar of investment. That is, firms that make riskier investments experience greater increases in value than those who make lower-risk investments. This is consistent with managerial risk aversion potentially imposing agency costs on shareholders and inconsistent with widespread excessive risk-taking.

Second, I test how the strength of this risk-return relation influences firms' incentive compensation decisions. Consistent with firms considering these "returns on risk" when designing

are more costly to implement (see, e.g., Lambert, Larcker, and Verrecchia, 1991; Lambert and Larcker, 2004). I discuss this issue in more detail in Sections 2 and 5.

their incentive compensation, I find that firms provide their managers with more convex compensation contracts as the relation between risk and equity value becomes more positive. Furthermore, this association between compensation convexity and risk-return tradeoffs is concentrated at firms where payoffs to investment increase in idiosyncratic (rather than systematic) risk, consistent with predictions from agency theory that risk-related agency costs primarily stem from managerial aversion to idiosyncratic risks (e.g., Amihud and Lev, 1981; Smith and Stulz, 1985). I also find that firms tend to use less convex incentive compensation (i.e., compensation that is more linear in firm value) when the returns to lower-risk investment are higher. Overall, these results are consistent with firms providing risk-taking incentives to help mitigate potential risk-related agency costs.

I also consider how risk-return tradeoffs may directly influence managers' risk-taking incentives, independent of any effect on firms' incentive compensation decisions. In particular, managers may benefit from increasing their firm's cash flows for reasons unrelated to compensation or ownership stake in the firm. For example, greater cash flows may allow managers to more easily increase the size of the firm or invest in pet projects (e.g., Jensen, 1986). Thus, managers may have greater incentives to take on risk when the payoffs to riskier investment are larger, independent of the incentives provided by their compensation contract. Additionally, risk-return relations may also influence how managers respond to a given compensation contract. In particular, if increased risk-taking increases the value of the firm, equity-based compensation potentially provides managers with two incentives for greater risk-taking: a "direct" effect, from greater risk increasing the value of the manager's option portfolio independent of any effect of this greater risk on firm value, and an "indirect" effect, from greater risk increasing firm value, which in turn increases the value of the manager's stock and option holdings.[6] The option portfolio vega

[6] The total change in a manager's wealth from increasing risk (i.e., "risk-taking incentives") can be expressed as the sum of the partial derivative of wealth with respect to risk and the derivative of firm value with respect to risk times the partial derivative of wealth with respect to firm value:

$$\frac{dW}{d\sigma} = \frac{\partial W}{\partial \sigma} + \frac{\partial W}{\partial V}\frac{dV}{d\sigma}$$

measure commonly used in the prior literature (i.e., the sensitivity of the manager's wealth to a one percentage point increase in stock volatility) captures this "direct" effect but omits any "indirect" effect. The "indirect" effect is related to the manager's portfolio delta (i.e., the sensitivity of the manager's wealth to a one percent increase in stock price) and is increasing in the strength of the relation between risk and return, suggesting that delta may provide more risk-taking incentives for managers when risk-return relations are stronger (i.e., more positive). Consistent with both these hypotheses, I find that stronger risk-return tradeoffs appear to increase both managers' appetite for risk-taking, independent of incentives from their compensation contracts, and the risk-taking incentives provided by managers' delta.

I make several contributions to the literature. I find that, on average, there is a positive relation between the risk of and return on firms' investments. I also find evidence that riskier projects (per dollar of investment) tend to generate greater returns, suggesting that risk-related agency costs may result not only from firms investing in "too few" projects (i.e., underinvesting) but also investing in projects that are "too safe". These results highlight that risk-taking is an integral component of making investments that increase shareholder value, consistent with assumptions in the prior moral hazard literature (e.g., Jensen and Meckling, 1976; Smith and Stulz, 1985) and in contrast to more recent notions of excessive risk-taking and concerns regarding increased risk-taking largely harming shareholders.

Next, I show that firms behave as if they consider risk-return tradeoffs when designing their incentive compensation structures. In particular, I find that firms provide managers with more risk-taking incentives when the potential costs of managerial risk aversion are greater. While the existing literature provides extensive evidence regarding the effectiveness of convex compensation contracts in promoting managerial risk-taking, there is limited evidence as to whether firms seem to provide such contracts with the intent of motivating risk-taking, or if this is perhaps an unintended

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where W is the manager's wealth, σ is the firm's risk, and V is the firm's value. The first term on the right-hand side is the "direct" effect and the second term is the "indirect" effect.

consequence of these compensation contracts.[7] I provide evidence that firms do appear to manage potential risk-related agency costs through their choice of incentive compensation contracts.

My findings highlight that understanding the incentive consequences of managerial equity-based compensation requires considering not only the magnitude and shape of the payoff structure (i.e., delta and vega) but also the relation between risk and shareholder value for the firm's potential investments. Two managers with identical compensation contracts but facing different risk-return tradeoffs may respond very differently to equity incentives. For example, increasing the amount of equity-based compensation (i.e., delta) at a firm with a highly positive relation between risk and shareholder value might motivate a manager to increase risk but have the opposite effect at a firm with a negative or zero relation between the two. In contrast, prior literature largely assumes that managers have relatively homogeneous responses to a particular incentive contract, independent of the risk-return tradeoffs or other firm characteristics they may face.

Lastly, my results suggest a potential method to address the conflicting results in the prior literature regarding how stock price exposure (i.e., delta) influences managerial risk-taking incentives. For example, Coles et al. (2006) report that delta reduces risky investment but increases stock volatility. Brockman, Martin, and Unlu (2010), Chava and Purnanandam (2010), and Panousi and Papanikolaou (2012) also suggest delta reduces risk-taking incentives, while Feng et al. (2011) find a positive relationship between delta and financial misreporting and Armstrong and Vashishtha (2012) find that delta increases stock volatility. This literature generally explains these mixed results by arguing that delta provides two opposing risk-taking incentives and therefore the overall effect is ambiguous. First, risk-taking may increase stock price and therefore incentivize risk-taking, assuming that there is a positive relation between risk and return. Second, risk-taking may increase stock price volatility, which managers are presumably averse to, and therefore disincentivize risk-taking. Because the firm's risk-return tradeoff is a key element determining the balance between

[7] For example, boards may provide convex compensation contracts because they are a less costly form of equity-based compensation and not because of any specific risk-taking objectives. I discuss this in more detail in Section 5.

these two effects, estimating this tradeoff may allow for clearer inferences regarding these opposing incentives stemming from managers' portfolio delta.

The remainder of this paper proceeds as follows. Section 2 reviews related literature on risk-related agency conflicts between managers and shareholders and the consequences of managerial risk-taking incentives. Section 3 describes the research design and data I use in my primary analyses and Section 4 discusses the results. Section 5 separates risk into systematic and idiosyncratic components and evaluates whether risk-return tradeoffs and their relation with incentive compensation depend on the type of risk involved. Section 6 explores the role of managerial risk aversion in firms' compensation design and Section 7 examines whether risk-return tradeoffs provide risk-taking incentives incremental to their effect on managers' equity-based compensation. Section 8 presents robustness tests and Section 9 concludes.

2. Background and Hypotheses

2.1. Managerial risk aversion and agency conflicts

Prior literature argues that managerial risk aversion creates a number of potential agency conflicts between managers and shareholders (see, e.g., Jensen and Meckling, 1976; Amihud and Lev, 1981; Smith and Stulz, 1985). Broadly speaking, these conflicts stem from managers' inability to fully diversify their exposure to firm-specific risks. Shareholders, in contrast, are generally viewed as well-diversified with respect to these risks (i.e., risk-neutral) and therefore tend to desire greater levels of risk-taking than managers. For example, both analytical and empirical studies typically assume that managers hold relatively large proportions of their total wealth in their firm's equity (e.g., Jensen and Meckling, 1976; Dittman and Maug, 2007; Conyon, Core, and Guay, 2011).[8] As a result, managers have undiversified exposure to idiosyncratic risk in the firm's stock price and therefore may avoid investing in value-increasing projects that increase idiosyncratic risk.

[8] Empirical studies typically rely on assumptions regarding the proportion of managerial wealth held in firm equity because wealth data is unobservable. One exception is Becker (2006), who examines a sample of Swedish CEOs and finds that these CEOs tend to hold significant portions of their total wealth in the firm's equity.

Alternatively, managers may choose to invest in projects that reduce idiosyncratic risk, such as diversifying acquisitions, which prior studies suggest reduces firm value (e.g., Lang and Stulz, 1994; Berger and Ofek, 1995). Forced turnover or other career concerns provide another potential reason for managers to avoid investing in value-increasing risky projects, even in the absence of large undiversified equity positions (Amihud and Lev, 1981). For example, heightened risk increases managers' likelihood of termination (Bushman, Dai, and Wang, 2010; Peters and Wagner, 2014) and therefore career concerns may provide additional incentives for managers to pass up risky projects that would increase firm value.

One commonly suggested solution to these risk-related agency costs is to provide managers with incentive compensation that rewards risk-taking. In particular, many studies argue that compensation contracts that are convex in firm value (e.g., stock options) increase managers' incentives to take risk and therefore potentially reduce agency costs resulting from managerial risk aversion (see, e.g., Jensen and Meckling, 1976; Haugen and Senbet, 1981; Smith and Stulz, 1985; Guay, 1999). These contracts reward managers for taking additional risk by increasing expected payoffs as risk rises and, consequently, may incentivize managers to take on greater amounts of risk.[9]

Several studies note that, from a theoretical perspective, providing risk-averse managers with convex compensation contracts does not necessarily induce them to increase risk (see, e.g., Lambert, Larcker, and Verrecchia, 1991; Carpenter, 2000; Ross, 2004; Lewellen, 2006). This occurs because in addition to increasing expected payoffs from risk-taking, these contracts also increase the sensitivity of managers' compensation to the firm's value and therefore the uncertainty surrounding the amount of their compensation. That is, while these contracts provide risk-taking incentives through their convexity, they also make managers' overall wealth more dependent on the firm's value. Because risk-averse managers have incentives to minimize uncertainty regarding their wealth, this latter effect may motivate them to instead attempt to reduce the firm's risk in order

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[9] For example, payoffs to an at-the-money stock option increase if the stock price increases but do not fall if the stock price falls. Thus, investing in some project that either increases or decreases the firm's stock price by a given amount with equal probability (i.e., increases risk) increases expected payoffs from the option.

to reduce this uncertainty. However, empirical studies examining this issue generally find that convex payoffs, typically measured by option portfolio vega, motivate greater risk-taking (e.g., Rajgopal and Shevlin, 2002; Coles, Daniel, and Naveen, 2006; Low, 2009; Chava and Purnanandam, 2010; Armstrong and Vashishtha, 2012). Thus, despite the theoretical ambiguity noted above, empirical evidence largely concludes that convex compensation contracts are effective at increasing managers' appetite for risk.[10]

2.2. Hypotheses

The relation between investment risk and shareholder value depends on firms' investment opportunity sets and may vary across firms. Standard mean-variance efficient asset pricing models (e.g., Sharpe, 1964) suggest a positive relation between risk and required returns on potential investment projects.[11] Alternatively, shareholder value may increase with investment risk simply due to limited liability, which shifts the consequences of negative project outcomes to other parties, particularly for more levered firms (e.g., Jensen and Meckling, 1976). However, there are also reasons that shareholder value may decline as investment risk rises. For example, competitive advantages or other similar factors may give some limited subset of firms access to relatively high return, low risk projects, while a wider set of firms may have access only to lower return, higher risk projects. In this situation, there might be a negative relation between investment risk and shareholder value. This idea is analogous to capital market models involving incomplete information (e.g., Merton, 1987), where firms with relatively small potential investor bases (i.e., firm-specific investment opportunities) may have higher returns and lower risk than firms with broader investor exposure.[12] Thus, because the shape of firms' investment opportunity sets is not clear, I do not make any directional prediction regarding the relation between investment value and risk:

[10] Specifically, the studies noted above document risk-taking incentives from vega after controlling for delta (i.e., the overall amount of equity-based compensation). In other words, convex compensation contracts seem to promote risk-taking relative to linear contracts that provide managers with the same exposure to stock price.

[11] More generally, risk-averse managers may simply demand greater returns to invest in riskier projects, leading to a positive relation between observed investment value and risk.

[12] Many studies in the organizational theory literature, starting with Bowman (1980), also find a negative relation between risk and return within the firm.

H1: Investment value is related to investment risk.

Next, I consider how risk-return relations influence incentive compensation choices. Moral hazard theory suggests that firms should provide more risk-taking incentives in situations where potential risk-related agency costs are greater (e.g., Haugen and Senbet, 1981; Smith and Stulz, 1985). The magnitude of these agency costs depends on the relation between risk and shareholder value and the overall returns on the firm's potential risky investments. For example, firms should have little reason to provide risk-taking incentives if riskier potential investments, or the firm's potential investments in general, generate very little return (e.g., Smith and Watts, 1992; Guay, 1999). In other words, risk itself is not valuable to shareholders; rather, it is the potential increase in value associated with this risk (e.g., Jensen and Meckling, 1976; John and John, 1993) that may motivate shareholders to provide risk-taking incentives to managers. Furthermore, because increased risk-taking also potentially imposes additional costs, firms should have less reason to provide managers with risk-taking incentives if relatively low-risk investments generate large returns. For example, Froot, Scharfstein, and Stein (1993) argue that riskier firms are more likely to suffer cash flow shortfalls that prevent them from internally funding future investments. In the presence of imperfect capital markets, this may prevent the firm from investing in value-increasing projects in the future, to the detriment of shareholders. This discussion suggests my second set of hypotheses, that firms provide more risk-taking incentives when the relation between investment value and risk is more positive, and less when returns on low-risk investments are greater:

H2a: Firms provide more risk-taking incentives when risk-return relations are stronger (more positive).

H2b: Firms provide fewer risk-taking incentives when returns on lower-risk investments are larger.

3. Research Design and Data

3.1. Risk-return relations

I examine the relation between investment risk and shareholder value using contemporaneous changes in the firm's stock price and volatility. The basic idea behind this analysis is that I view the firm as a collection of investment projects, and the firm's value and risk reflect this project portfolio. In any given year, the firm may choose to make new investments that add to this collection of projects, potentially changing both the firm's value and risk. I attempt to capture the incremental effect of these new investments by examining contemporaneous relations between equity value and volatility after controlling for factors other than new investment that may also affect these quantities. Specifically, I first estimate the value of new investment projects using the firm's abnormal stock return after adjusting for the effect of unexpected earnings, as an extensive stream of literature dating back to Ball and Brown (1968) finds that unexpected earnings may influence stock prices.[13] However, these earnings are unlikely to materially reflect cash inflows generated by the current year's investment projects, as both capital expenditures and R&D are defined as costs whose associated cash inflows are expected to occur in future periods, rather than the current period. Next, I estimate the risk associated with these investments using the change in the firm's stock volatility, after adjusting for changes in its size and leverage. I adjust for these changes to attempt to isolate changes in the firm's underlying risk, as stock price volatility is a function of not only the firm's underlying risk but also factors such as its size and capital structure (see, e.g., Christie, 1982). That is, I estimate the value of new investment with residual abnormal stock returns (controlling for unexpected earnings) and the risk of this investment with residual change in stock volatility (controlling for size and leverage). However, these residual changes in stock price and volatility also capture the effect of other factors besides new investments. To address this issue, I estimate these measures using observations with large amounts of unexpected investment to attempt to focus on situations where investment is most likely to be a

[13] See Kothari (2001) for a review of the literature on earnings and stock prices.

primary factor driving changes in the firm's stock price and stock volatility. The following sections describe this analysis in more detail.

3.1.1. Investment value

As described above, I estimate the value of a firm's new investments in a given year as the portion of annual abnormal stock return not explained by that year's unexpected earnings, which may influence stock price but are unlikely to include significant cash inflows stemming from the current year's investments. Specifically, I estimate the following regression:

$$AR_t = \alpha_0 + \alpha_1 UX_t + u_t \qquad [1]$$

where AR is the firm's market-adjusted return and UX is unexpected earnings, defined as the change in earnings from the prior year.[14] I estimate this model separately for each industry-year (i.e., I assume the mapping between earnings and returns is relatively constant across firms within an industry-year). I define the value of the firm's new investments during the year as the residual u from this model.

3.1.2. Investment risk

Similarly, I estimate the risk of investment in a given year using the change in the firm's stock volatility not explained by changes in its size and leverage, as changes in either of these quantities may influence the firm's stock volatility without any change in the firm's underlying risk. Specifically, I estimate the following regression:

$$\Delta Vol_t = \gamma_0 + \gamma_1 \Delta Size_t + \gamma_2 \Delta Lev_t + w_t \qquad [2]$$

where ΔVol is the change in the standard deviation of firm's stock return, $\Delta Size_t$ is the change in the firm's market capitalization, and ΔLev is the change in firm's leverage. I again estimate the

[14] I add back depreciation and R&D expense to reported earnings when computing this measure to attempt to eliminate the effect of investment costs on earnings. My inferences are unchanged if I instead use reported earnings, unadjusted for depreciation and R&D expense during the period.

model separately for each industry-year. I define risk of the firm's investments during the year as the residual w from equation 2.[15]

3.1.3. Investment value and risk

I examine the relation between the value and risk of the firm's new investments by comparing the investment value estimated in Section 3.1.1 (i.e., u in equation 1) with the investment risk estimated in Section 3.1.2 (i.e., w in equation 2). If investment value is positively (negatively) associated with investment risk, there should be a positive (negative) relation between the two measures. I first test whether there exists a linear relation between the two measures by estimating the following model:

$$Return_t = \delta_0 + \delta_1 Risk_t \qquad [3]$$

where $Return$ is the residual u from equation 1 and $Risk$ is the residual w from equation 2. As mentioned above, I estimate this model using observations with relatively large amounts of unexpected investment in order to focus on firms where I can best identify investment value and risk, and therefore the relation between the two.[16] Specifically, I estimate equation 3 using firms with top-quartile unexpected investment.[17] I compute the firm's unexpected investment during the year by first estimating expected investment levels as follows (see, e.g., Hubbard, 1998):

$$I_t = \beta_0 + \beta_1 CF_t + \beta_2 SG_{t-1} + \beta_3 I_{t-1} + v_t \qquad [4]$$

where I is new investment, scaled by lagged market capitalization, CF is operating cash flow plus R&D expense, scaled by lagged market capitalization, and SG is percentage sales growth. I follow Richardson (2006) and define new investment as the sum of capital expenditures, R&D expense, and acquisitions in the current year less sales of PP&E and depreciation. As in equations 1 and 2,

[15] To be more precise, this residual-based measure captures unexpectedly large or small changes in volatility, given the amount of investment in the period (i.e., investment with above- or below-average risk). This is because changes in the firm's size are likely to partially reflect increased investment during the period, and thus I effectively control for the average effect of investment on stock volatility.
[16] For example, estimating investment value and risk is not practical when investment is very close to zero.
[17] This corresponds to firms with unexpected investment in excess of approximately 3 percent of market capitalization.

I estimate this model separately for each industry-year. I define unexpected investment as the residual v from equation 4.

I also consider the possibility that the relation between investment value and risk may be non-linear. For example, risk-averse managers may require greater returns for increases in risk as risk becomes larger (i.e., managers face increasing marginal costs of risk), potentially resulting in a convex relation between observed investment value and risk. Alternatively, there may be diminishing returns to increasing investment risk, which could instead result in a concave relation. To examine these possibilities, I extend equation 3 by adding a quadratic risk term as follows:

$$Return_t = \theta_0 + \theta_1 Risk_t + \theta_2 Risk_t^2 \qquad [5]$$

where, as in equation 3, $Return$ is the residual u from equation 1 and $Risk$ is the residual w from equation 2. A positive (negative) coefficient θ_2 would be consistent with a convex (concave) relation between investment value and risk. I estimate both equations 3 and 5 with industry-year fixed effects to account for the possibility that investment value or risk may naturally vary across different industries and over time.

Equations 3 and 5 estimate the relation between investment value and risk without controlling for the amount of unexpected investment (i.e., they do not control for the scale of the firm's investments). As a further analysis, I also estimate risk-return relations with equations 3 and 5 after scaling investment value and risk by the amount of unexpected investment in the period. Specifically, I divide the value and risk measures defined in equations 1 and 2 by unexpected investment as defined in equation 4. This essentially converts these measures into "per dollar" quantities, as opposed to aggregated or firm-level quantities, and allows me to evaluate whether investments that carry more risk *per dollar of investment* generate larger returns. This distinction between aggregate and per-dollar investment is important if firms primarily change their investment risk by reallocating their investment dollars between relatively riskier or less risky projects, rather than adjusting their total amount of investment (i.e., they adjust the mix of investments rather than the scale). For example, Coles, Daniel, and Naveen (2006) argue that managers with differing risk preferences alter the mix of riskier and less risky projects in their overall investment pool, rather than (or possibly in addition to) adjusting total investment levels (i.e., the scale of investment). Appendix B discusses the distinction between aggregate and per-dollar investment in more detail.

In my subsequent tests examining incentive compensation, I primarily focus on these per-dollar (scaled) investment value and risk measures to focus on the variation in risk-taking most likely to reflect managerial discretion.[18] For example, managers at firms facing capital constraints may have limited ability to increase the scale of their investments. However, I expect that they should have more discretion over the mix of projects that they select. That is, while factors outside managers' control may constrain the amount of total investment they may undertake (i.e., their investment budget), they should have more flexibility in how to allocate this budget among various potential projects.

3.2. Incentive compensation and risk-return tradeoffs

Next, I consider how the relation between investment value and risk (i.e., the risk-return tradeoff) influences firms' incentive compensation policies. To estimate firms' risk-return tradeoffs, I re-estimate equation 3 separately for each industry-year.[19] Thus, unlike in Section 3.1, where I assume that all firms face the same investment risk-return tradeoffs (i.e., in equation 3, δ_1 is the same for all firms), I now assume only that all firms within the same industry-year face the same risk-return tradeoffs. I use the observed relations between investment value and risk within each industry-year to estimate these risk-return tradeoffs. My estimate of the strength of the relation between value and risk for each firm in that industry-year is the coefficient δ_1 from equation 3. That is, I assume firms within the same industry-year have similar investment opportunity sets and therefore use my industry-year-level estimated risk-return tradeoff to proxy for the tradeoff that each

[18] I obtain similar inferences if I instead estimate risk-return relations using my unscaled investment value and risk measures.

[19] I exclude industry-years for which I have 10 or fewer observations when estimating these models. My inferences are similar using alternative minimum observation thresholds (e.g., 5 or 15 observations). As discussed in Section 3.1.3, I estimate these models using scaled investment risk and return measures (i.e., risk and return per dollar of investment).

firm within that industry-year.[20] For firms in industry-years where δ_1 is larger, the benefits to increasing investment risk are greater. Similarly, I estimate the expected return on lower-risk investments within an industry-year with the coefficient δ_0 from equation 3. For firms in industry-years where δ_0 is larger, the returns on lower-risk investment are greater.

Using these risk-return tradeoff and lower-risk investment return measures, I test my second hypothesis by estimating regressions of the following form:

$$Incentive_t = \kappa_0 + \kappa_1 Return/Risk_t + \kappa_2 LowerRiskReturn_t + Controls \qquad [6]$$

where $Return/Risk$ and $LowerRiskReturn$ are δ_1 and δ_0, respectively, estimated from equation 3 as described above and $Incentive$ is an incentive-compensation measure. Consistent with prior literature examining equity-based compensation, my primary measure of risk-taking incentives is the manager's portfolio vega, defined as the sensitivity of the manager's wealth to a one percentage point change in the firm's stock volatility. H2 implies that $\kappa_1 > 0$ and $\kappa_2 < 0$ in equation 6. I also examine how risk-return tradeoffs influence managers' overall levels of equity-based compensation by estimating equation 6 using the manager's portfolio delta as an incentive measure, where delta is defined as the sensitivity of the manager's wealth to a one percent change in the firm's stock price. One possibility is that delta is more effective at aligning managers' and shareholders' interests when the relation between risk and value is stronger, suggesting a positive relation between delta and risk-return tradeoffs. Alternatively, if greater delta primarily increases managerial risk aversion, as some prior studies suggest (e.g., Brockman, Martin, and Unlu, 2010; Chava and Purnanandam, 2010), shareholders may want to reduce delta when risk-return tradeoffs are stronger.

3.3. Data

I estimate the risk-return relations described in Sections 3.1 and 3.2 using financial data from Compustat and stock return data from CRSP. Consistent with prior literature, I omit financial

[20] As I discuss in more detail in Section 8, I use these industry-year (rather than firm-specific) measures to help alleviate endogeneity concerns regarding how managers' incentive compensation contracts may influence their firm's risk-return tradeoffs.

firms and utilities. My initial sample consists of 115,641 firm-year observations for which I have stock returns and sufficient data to compute new investment and spans the years 1987 through 2012. Because my tests require year-to-year changes for certain measures, the sample for which I am able to compute my investment value and risk measures consists of 83,211 firm-year observations. As described previously, I estimate risk-return relations using firm-years with top-quartile unexpected investment in order to focus on firms where I can best identify investment value and risk. This reduces the final sample that I use to estimate equations 3 and 5 to 20,956 firm-year observations, which consists of 6,903 distinct firms. I winsorize all variables used in these models at the 1st and 99th percentiles.

For my tests involving incentive compensation, I supplement the sample described above with managerial incentives based on data from Execucomp and Equilar. Specifically, I compute CEO delta and vega using the method described in Core and Guay (2002). The sample of firms for which I have managerial incentive data consists of 40,064 firm-year observations between the years 1992 and 2012. I have sufficient data to compute my risk-return relation measures for 33,139 of these observations and estimate equation 6 using this reduced sample, which consists of 4,194 distinct firms.[21]

3.4. Descriptive statistics

Table 1, Panel A reports descriptive statistics for the sample used in my tests on the relation between investment value and risk. The median market-adjusted return is negative (about negative 8 percent), while median new investment is approximately 4 percent of the firm's market capitalization. The median firm in my sample has a market capitalization of approximately $150 million, a book-to-market ratio of 0.88, and annualized stock volatility of 55 percent. In general, these measures are consistent with prior studies examining the sample of Compustat-CRSP firms.

[21] Note that this incentive compensation sample is larger than the 20,956-observation sample that I use to estimate industry-year risk-return relations. This is because I estimate these relations using only firms with top-quartile unexpected investment, then apply the estimated relation to all firms within that industry-year (i.e., including those without top-quartile unexpected investment).

Table 1, Panel B provides descriptive statistics for the sample for my tests on incentive compensation. Compared with the sample in Panel A, median market-adjusted returns are higher (about negative 2 percent), while investment is similar between the two samples. The median firm in my incentive compensation sample is somewhat larger than the median firm from my sample in Panel A, with a median market capitalization of approximately $600 million. Median book-to-market ratio and annualized stock volatility are lower than in Panel A, at 0.77 and 46 percent, respectively. The median manager in my sample has delta of approximately $150,000 and vega of approximately $25,000. These amounts are somewhat smaller than the figures reported in prior literature, reflecting the fact that the Equilar incentive data included in my sample includes smaller firms than those included in Execucomp.[22]

3.5. Investment value and risk characteristics

Before testing my hypotheses, I examine whether the characteristics of the investment value and risk measures described in Section 3.1 seem consistent with the underlying constructs they are intended to capture. I first consider my investment risk measure. R&D investment is generally viewed as more risky than capital expenditures (e.g., Bhagat and Welch, 1995; Coles, Daniel, and Naveen, 2006). This suggests that investment risk should be larger when the firm spends more on R&D compared to capital spending. To test this prediction, I regress my investment risk measures (both scaled and unscaled) on R&D and capital expenditures. I include industry-year fixed effects when estimating these models and also control for a standard set of lagged firm-level characteristics (e.g., size, book-to-market, and leverage). Table 2 presents the results. Columns 1 and 2 present results for unscaled, or "total" investment risk, while columns 3 and 4 present results for scaled, or "per-dollar" investment risk. Columns 1 and 3 report results from a model with only R&D, capital expenditures, and industry-year fixed effects, while columns 2 and 4 also include other firm-level controls. Consistent with the reasoning above, I find that investment risk is positively

[22] Descriptive statistics for delta and vega based on Execucomp data are comparable to prior studies (about $200,000 and $40,000 at the median, respectively).

related with R&D, and more positively related with R&D than capital expenditures, under all specifications ($p < 0.01$ in each specification).

Next, I evaluate my investment value measure. Cohen, Diether, and Malloy (2013) measure returns on investment by examining the relation between investment and future sales growth. Specifically, they regress sales growth on prior investment and argue that larger investment coefficients represent more profitable investments. I employ a similar approach and regress my investment value measures (both scaled and unscaled) on future sales growth. If these measures capture investment value, the coefficients on future sales growth should be positive. As in my investment risk tests, I include industry-year fixed effects and include standard firm-level controls. Table 3 presents the results. Similar to Table 2, columns 1 and 2 present results for unscaled "total" investment value, while columns 3 and 4 present results for scaled "per-dollar" investment value. Columns 1 and 3 provide results from a model with only future sales growth and industry-year fixed effects, while columns 2 and 4 also include other firm-level controls. Under all specifications, I find that investment value is positively associated with future sales growth, consistent with this measure capturing returns on investment.

4. Results

4.1. Risk-return relations

Table 4 reports the results from estimating equations 3 and 5, which examine the relation between investment value and risk. Columns 1 and 2 report results based on unscaled investment value and risk measures. I find that the estimated coefficient on investment risk is positive and significant in both specifications (0.40 and 0.39 in columns 1 and 2, respectively, $p < 0.01$ for both). These coefficients imply that an investment which increases the firm's stock volatility by one percentage point corresponds to an approximately 40 basis point increase in firm value.[23] Column

[23] To put this into some context, I compute an average "cost of risk" over my sample period based on the Sharpe ratio for the market portfolio. The average annual excess return in my sample period is 7.1% with a standard deviation of 16.8%, or approximately 42 basis points of return per percentage point of risk. This is roughly consistent with the cost of risk implied by the risk-return tradeoffs that I estimate.

2 in Table 4 suggests that the relation between investment value and risk is slightly convex, as the estimated coefficient on squared investment risk is positive. However, this result is not statistically significant at conventional levels ($p = 0.12$). Overall, the results in Table 4 are consistent with the assumption throughout much of the agency theory literature that firms face risk-return tradeoffs when making investment decisions. Figure 1 plots the estimated relation between investment value and risk based on the results in columns 1 and 2 of Table 4.

Columns 3 and 4 report results from estimating equations 3 and 5 after scaling investment value and risk by unexpected investment (i.e., per-dollar value and risk). I find that this scaled investment value also increases as risk increases, suggesting riskier investments (per dollar) generate greater expected returns (coefficient of 0.35 in both columns, $p < 0.01$). The coefficient on unscaled investment risk in column 1 is somewhat larger than the coefficient on scaled investment risk in column 3 ($p = 0.04$), which is consistent with the positive relation between investment value and risk in columns 1 and 2 being driven by both larger amounts of risky investment and a greater proportion of riskier, more profitable investments. This suggests that risk-related agency costs arise both from risk-averse managers investing in fewer risky projects, and in projects that are less risky, than shareholders would prefer.

In contrast to the results in column 2, the positive relation between scaled investment value and risk seems to be concave, as the coefficient on squared investment risk is significantly negative in column 4 (-0.011, $p < 0.01$).[24] Thus, while riskier investments (per dollar) seem to generate greater returns, there appear to be diminishing returns as risk continues to increase. Figure 2 plots the estimated relation between per-dollar investment value and risk based on the results in columns 3 and 4 and Table 5 ranks industries in my sample by their time-series average risk-return tradeoff. The industries with the most favorable risk-return tradeoffs (i.e., largest benefits to risk-taking) are apparel, construction, and personal services. The industries with the least favorable tradeoffs are printing and publishing, fabricated products, and consumer goods.

[24] This difference in convexity between unscaled and scaled investment is consistent with firms receiving diversification benefits as they increase the amount of total investment.

Next, I examine industry characteristics that I expect to be associated with these risk-return tradeoffs. First, more competitive industries are likely to have more positive risk-return tradeoffs, as firms "compete away" the payoffs to lower risk projects and therefore must take on riskier projects to increase value. That is, I expect firms in more competitive industries to have less access to relatively high return, low risk projects. Second, industries with fewer growth opportunities may also have more positive risk-return tradeoffs. This lack of growth opportunities should lead to greater competition among available projects and again drive down the payoffs to less risky projects. I test these hypotheses by regressing my estimated risk-return tradeoffs on industry competition and growth opportunities.[25] I also include year fixed effects to attempt to control for other economy-wide factors that may change over time and influence risk-return tradeoffs. I measure industry competition with the Herfindahl index, computed as the sum of squared market shares within an industry-year, and I measure growth opportunities with the average book-to-market ratio within an industry-year. Smaller values for these measures indicate increased competition and greater growth opportunities, respectively; thus, the discussion above suggests a negative (positive) relation between risk-return tradeoffs and Herfindahl index (book-to-market). Table 6 presents the results from this analysis. Column 1 reports results for only industry competition, column 2 reports results for only growth opportunities, and column 3 reports results for both measures. I find a significantly negative relation between risk-return tradeoffs and Herfindahl index, consistent with risk-taking providing greater benefits in more competitive industries. I also find a positive relation between risk-return tradeoffs and book-to-market, consistent with greater benefits from risk-taking when firms have fewer growth opportunities.

[25] Recall that I estimate risk-return tradeoffs by industry-year, and thus for this analysis my sample consists of one observation per industry-year. There are 583 total industry-years in my sample for which I have sufficient data to estimate risk-return tradeoffs.

4.2. Incentive compensation and risk-return tradeoffs

Table 7 presents the results from examining the relation between risk-return tradeoffs and incentive compensation based on equation 6.[26] Column 1 reports results with vega as the dependent variable and column 2 reports results with delta. The estimated coefficient on the risk-return tradeoff is significantly positive in column 1 (0.025, $p < 0.01$), indicating that firms provide more convex incentive compensation contracts (i.e., higher vega) when the relation between investment risk and value is stronger. In other words, firms provide more incentives to take risk when the potential benefits from such risk-taking (or, alternatively, the costs from managerial risk aversion) are greater. In terms of economic magnitude, this coefficient implies that firms with the largest risk-return tradeoffs (i.e., greatest incremental returns to risk-taking) provide their managers with approximately 30 percent higher vega compared to firms with the smallest risk-return tradeoffs.

I also find that firms provide more equity-based compensation, but not more convex compensation, when the return on lower-risk investment is greater. Specifically, I find a significantly positive relation between delta and lower-risk return in column 2 (coefficient of 0.013, $p < 0.01$) but a significantly negative relation between vega and lower-risk return in column 1 (coefficient of -0.015, $p < 0.01$). These coefficients imply that firms with the largest lower-risk returns (i.e., greatest incremental returns to projects that do not increase risk) provide their managers with approximately 15 percent higher delta and 20 percent lower vega compared to firms with the smallest lower-risk returns. These results are consistent with firms offering convex compensation contracts when they seek to motivate risky investment, rather than investment in general. For example, when lower-risk investment is relatively profitable, firms may have weaker incentives to motivate managers to invest specifically in higher-risk projects. Overall, the results in Table 7 support the idea that firms design their managers' risk-taking incentives to mitigate risk-related agency costs.

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[26] As discussed in Section 3.1.3, I estimate these risk-return tradeoffs using scaled (per-dollar) investment risk and return measures. My inferences are unchanged if I instead estimate these relations with unscaled measures.

5. Systematic vs. Idiosyncratic Risk-Return Tradeoffs

In this section, I examine whether the relations between incentive compensation structures and risk-return tradeoffs in Section 4 depend on the type of risk involved (i.e., systematic or idiosyncratic). The analysis in the previous section does not distinguish between these different types of risk, and the distinction is potentially important because risk-related agency conflicts between managers and shareholders primarily stem from managers' aversion to idiosyncratic risk, rather than risk in general (e.g., Amihud and Lev, 1981; Smith and Stulz, 1985; Lewellen, Loderer, and Martin, 1987). If shareholder value and risk are positively correlated but this relation is due purely to effects from systematic risk, there may be no significant risk-related agency conflict between managers and shareholders. However, if this relation results from firms earning greater returns on projects with greater idiosyncratic risk, managers' and shareholders' incentives may be more misaligned. Specifically, risk-related agency conflicts arise from differential preferences for risk between managers and shareholders. Because both of these parties are averse to systematic risk (i.e., because shareholders cannot diversify this type of risk), differences in tolerance for systematic risk between managers and shareholders are likely to be relatively minor compared to differences with regard to idiosyncratic risk, which is much more difficult for managers to diversify.

Given that risk-related agency costs largely result from managers' exposure to undiversifiable idiosyncratic risks, firms seeking to mitigate these costs should primarily be interested in providing managers with risk-taking incentives when firm value is related to idiosyncratic risk, rather than systematic risk. That is, potential risk-related agency costs are largest when the firm has access to high-NPV investments that managers might avoid due to their aversion to idiosyncratic risk. In contrast, managers should require fewer incentives to invest in positive-NPV projects that increase systematic risk, since managers and shareholders are both averse to such risk and consequently their incentives are better aligned. In fact, some studies indicate that managers may be less averse to systematic risk than the typical shareholder (e.g., Dittman and Maug, 2007; Graham, Harvey, and Puri, 2013). As a result, shareholders might actually want to disincentivize investment in projects with systematic risk.

Examining differential effects between systematic and idiosyncratic risk also allows me to evaluate an alternative explanation for the use of convex equity-based compensation contracts; namely, that firms provide convex compensation contracts to their managers not to help manage risk-related agency conflicts, but rather because these contracts are more “powerful” than linear contracts (i.e., compared to linear contracts, convex contracts tend to magnify managers’ sensitivity to stock *price*; see, e.g., Lambert, Larcker, and Verrecchia, 1991; Lambert and Larcker, 2004; Ross, 2004). Lambert and Larcker (2004) discuss how convex compensation contracts may be optimal even in the absence of risk-related agency conflicts between managers and shareholders. Specifically, they demonstrate that the optimal compensation contract between a risk-neutral manager and risk-neutral shareholders may be convex in firm value if managerial wealth constraints prevent shareholders from addressing potential agency conflicts by simply selling the firm to the risk-neutral manager (e.g., Harris and Raviv, 1979; Holmstrom, 1979). This occurs because convex contracts offer a relatively low-cost way for firms to provide their managers with exposure to the firm’s stock price (i.e., delta). That is, firms may design compensation contracts to provide an optimal level of delta, while any risk-related incentive effects may be “unintended consequences” of these convex contracts rather than their primary objective.

One potential explanation for the results in Section 4 is that shareholders are more receptive to these potential risk-related “side effects” and consequently employ more convex compensation contracts when risk-return tradeoffs are more favorable. Under this explanation, the relation between compensation convexity and risk-return tradeoffs need not be tied to the particular type of risk involved. That is, if any benefits (or costs) from risk-taking are simply a side effect of achieving a targeted level of delta with a relatively low-cost compensation contract, whether these benefits result from systematic or idiosyncratic risk should be irrelevant to the contract’s design. If anything, firms in this situation may be more inclined to give equity-based risk-taking incentives when systematic risk-return tradeoffs are stronger, given that Armstrong and Vashishtha (2012) find that such incentives are more effective at promoting systematic, rather than idiosyncratic, risk-taking.

To examine whether the relation between firms' incentive compensation contracts and their risk-return tradeoffs varies between systematic and idiosyncratic risk, I decompose total stock volatility into systematic and idiosyncratic components based on a market model.[27] I then re-estimate investment risk based on equation 2 using changes in each of these components, rather than total stock volatility. Specifically, I define systematic (idiosyncratic) investment risk as the residual from estimating equation 2 with the change in systematic (idiosyncratic) volatility as the dependent variable. I then re-estimate systematic (idiosyncratic) risk-return tradeoffs with equation 3 using this systematic (idiosyncratic) investment risk, rather than overall investment risk. Finally, I re-estimate equation 6 using these two investment risk measures, both individually and simultaneously.

Table 8 reports the results from this analysis. I find that the positive relation shown in Table 7 between vega and risk-return tradeoffs is driven by idiosyncratic risk-return tradeoffs (estimated coefficients of 0.021 in both columns 2 and 3, $p < 0.01$). In contrast, I find no significant relation between vega and systematic risk-return tradeoffs, and the estimated coefficients are negative in both columns 1 and 3. That is, firms seem to provide more convex compensation contracts only when idiosyncratic risk, rather than systematic risk, is more strongly associated with investment value. These results are consistent with risk-related agency costs arising largely from managerial aversion to idiosyncratic risks, rather than risk in general, and shareholders designing incentive compensation packages accordingly. Furthermore, the lack of any significant association between compensation convexity and systematic risk-return tradeoffs suggests that any use of stock options as "high-powered" sources of delta when risk-taking in general is more favorable does not appear to be a primary factor behind the results discussed in the previous section.

[27] I obtain similar results to those described in this section if I instead estimate systematic and idiosyncratic risk with three-factor Fama-French (1993) or four-factor Carhart (1997) models.

6. Managerial Risk Aversion

Next, I examine whether managerial risk aversion influences the relation between risk-taking incentives and risk-return tradeoffs described in Sections 4 and 5. If firms provide managers with more convex compensation contracts to help mitigate risk-related agency conflicts between managers and shareholders, it is plausible that this effect should be stronger for firms with more risk-averse managers (to the extent that the board can observe or discern managers' risk aversion). The severity of these agency conflicts depends on managerial risk aversion; in the extreme, if managers and shareholders are both risk-neutral, there should be no risk-related agency conflicts between the two parties. To examine whether the relation between managers' compensation convexity and firms' risk-return tradeoffs varies depending on risk aversion, I estimate this relation separately for CEOs with relatively high and relatively low risk aversion. The discussion above suggests that the relation between these two measures should be stronger (more positive) for CEOs with relatively high risk aversion.

I measure CEO risk aversion based on Malmendier and Nagel (2011), who tie households' lifetime stock market returns ("experienced returns") to risk aversion.[28] Specifically, they find that households with lower experienced returns have greater risk aversion, generalizing the "Depression babies" effect discussed in other studies (e.g., Malmendier, Tate, and Yan, 2011), where individuals growing up during the Great Depression exhibit greater risk aversion. In each year, I define CEOs with bottom-tercile experienced returns as "high risk-aversion" managers and CEOs with top-tercile experienced returns as "low risk-aversion" managers. I then re-estimate the relation between convexity in managers' compensation contracts and risk-return tradeoffs separately for these two categories of CEOs.[29]

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[28] I choose this measure of risk aversion for several reasons. First, it is available for all CEOs in my sample because the only data requirement is the CEO's age. Second, it exhibits a reasonable amount of cross-sectional variation. Third, it is not derived from the CEO's equity-based compensation, which limits reverse causality concerns.

[29] Following Malmendier and Nagel (2011), I compute experienced returns as the weighted average of inflation-adjusted equity returns over each CEO's lifetime, where the weights decline linearly from the previous year to zero in the CEO's year of birth. For example, suppose a CEO is born in year 0. In year 3, the respective weights for years 1 and 2 would be 1/3 and 2/3. Likewise, in year 4, the respective weights for years 1, 2, and 3 would be 1/6, 2/6, and 3/6.

Table 9 presents results from estimating these models. Column 1 provides results for low risk-aversion managers and column 2 provides results for high risk-aversion managers. I find that the positive relation between compensation convexity and risk-return tradeoffs appears to be concentrated among relatively risk-averse CEOs, as the risk-return tradeoff coefficient is larger and statistically significant only in column 2. However, the difference between the coefficients in the low and high risk-aversion samples is not statistically significant at conventional levels ($p = 0.23$). Overall, these results provide some evidence that the relation between risk-return tradeoffs and incentive convexity is largest among relatively risk-averse CEOs, consistent with firms designing their compensation contracts to help alleviate agency conflicts stemming from managerial risk aversion.

7. Risk-Taking Choices and Risk-Return Tradeoffs

In this section, I consider how the relation between firm value and risk influences managers' risk-taking choices.[30] Managers at firms where the relation between investment value and risk is more positive should be more inclined to take on risk, as their potential benefits from this risk-taking are greater. Coles, Daniel, and Naveen (2006) argue that R&D expenditures are high-risk investments compared to capital expenditures and therefore firms (or managers) seeking to increase investment risk may allocate investment toward R&D and away from capital expenditures. This suggests that firms with weaker risk-return relations and higher returns on lower-risk investments may be more inclined to make capital investments. In contrast, firms with stronger risk-return relations may be more likely to invest in R&D and less likely to invest in capital spending. I test these hypotheses by estimating the following set of regressions:

$$Investment_t = \lambda_0 + \lambda_1 Return/Risk_t + \lambda_2 LowerRiskReturn_t + Controls \qquad [7]$$

[30] At a firm level, managers' risk-taking choices likely also affect the relation between firm value and risk (i.e., the causality may be reversed). However, because I estimate these relations at an industry-year level, it is unlikely that any particular manager's choices will meaningfully influence the estimated relations between firm value and risk across the industry-year. I discuss this issue in more detail in Section 8.1.

where $Investment$ is either capital expenditures or R&D expense, scaled by lagged total assets, and $Return/Risk$ and $LowerRiskReturn$ are defined as in Section 3.2. The hypotheses above imply $\lambda_1 < 0$ and $\lambda_2 > 0$ for capital expenditures, and $\lambda_1 > 0$ and $\lambda_2 < 0$ for R&D.

Table 10 presents the results from estimating equation 7. Consistent with the preceding discussion, I find significantly positive associations between capital expenditures and the estimated returns on lower-risk investments (coefficient of 0.059, $p < 0.01$) and between R&D expenditures and the estimated relation between investment risk and return (coefficient of 0.083, $p < 0.01$). Likewise, I find significantly negative associations between capital expenditures and the investment risk-return relation (coefficient of -0.055, $p = 0.09$) and between R&D expenditures and the returns on lower-risk investments (coefficient of -0.061, $p = 0.03$). These relations are incremental to incentive effects of delta and vega previously documented in the risk-taking literature, although the economic magnitude of the effects that I estimate are often somewhat smaller than those of delta and vega.[31] Thus, I find some evidence that managers respond directly to risk-return tradeoffs rather than only through their incentive compensation. One possible explanation for this result is that managers benefit when their firm's cash flows increase, even if they do not directly receive these cash flows (e.g., Jensen, 1986; Stulz, 1990), and therefore have greater incentives to take on risk when riskier investment generates greater returns. Another possibility is that the firm's risk-return relation influences how managers respond to their equity incentives. For example, delta is more likely to provide risk-taking incentives when the expected returns to riskier investments are larger (e.g., John and John, 1993).

To evaluate this second possibility further, I examine whether the relation between delta and investment varies depending on risk-return tradeoffs.[32] To do so, I create two subsamples

[31] For example, the difference in expected R&D investment as a percentage of assets between managers with the greatest and least amount of vega is approximately 3 percentage points (about 60 percent of mean R&D investment in the sample), while the difference between managers with the strongest and weakest risk-return tradeoffs is approximately 1 percentage point (about 20 percent).

[32] I focus only on delta in this test because there is no obvious reason why the relation between vega and investment should depend on risk-return tradeoffs. Specifically, vega captures the manager's "direct" incentives to increase risk, independent of any effect of this increased risk on firm value, and therefore these incentives should not vary based on the relation between risk and firm value (i.e., the firm's risk-return

based on firms' estimated risk-return relations. The first subsample consists of firms where I estimate a statistically significant positive relation between investment risk and return (the "high risk-return tradeoff" sample), while the second subsample consists of firms where I find either an insignificant or a significantly negative relation (the "low risk-return tradeoff" sample).[33] I then estimate the following set of regressions across these two subsamples:

$$Investment_t = \pi_0 + \pi_1 Delta_{t-1} + Controls \qquad [8]$$

where $Investment$ is either R&D expense or capital expenditures, as in equation 7. If delta provides more risk-taking incentives when the "returns on risk" are relatively large, I expect to find π_1 for R&D investment is greater for the high risk-return tradeoff sample. If this occurs because managers shift investment away from capital expenditures, I may also find π_1 for capital investment is smaller for this sample.

Table 11 reports results from estimating equation 8. Columns 1 and 2 provide results with capital expenditures as the dependent variable and columns 3 and 4 provide results with R&D expense. Consistent with the hypothesis above, I find that the relation between delta and R&D investment is significantly negative for firms in the low risk-return tradeoff sample but essentially zero for firms in the high risk-return tradeoff sample. The coefficient in the high risk-return tradeoff sample is also significantly larger than the coefficient in the low risk-return tradeoff sample (difference = 0.16, $p < 0.01$). This is consistent with greater delta motivating managers to reduce risky investment when the returns from increasing risk-taking are relatively small, but having no effect when such returns are relatively large. In contrast, I find no significant difference in the relation between delta and capital expenditures across the two subsamples.

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tradeoff). Consistent with this reasoning, I find no significant differences in the relation between vega and investment across the high and low risk-return tradeoff samples in Table 9.

[33] I measure significance at the 10 percent level. Approximately 25 percent of observations fall into the "high risk-return tradeoff" sample. Results are similar if I instead assess significance at the 5 or 15 percent level.

8. Robustness Tests

In this section, I present results from several robustness tests. First, I examine the potential effect of an endogenous relation between the risk-return tradeoffs that I estimate and firms' incentive compensation structures. Second, I include manager fixed effects when estimating the relation between risk-return tradeoffs and managers' incentive compensation contracts to examine the possibility that managers with different risk or compensation preferences may "self-select" into firms with different risk-return profiles. Finally, I estimate risk-return relations based on abnormal returns from Carhart's (1997) four-factor model, rather than market-adjusted returns, to examine whether the results in the preceding sections depend on a specific expected returns model.

8.1. Endogenous relation between risk-return tradeoffs and incentive compensation

One potential concern with the results described in the preceding sections is that there may be an endogenous relation between firms' risk-return tradeoffs and their incentive compensation structures. That is, although I argue that firms appear to design their compensation structures in response to the risk-return tradeoffs that they face, the risk-return tradeoffs that I estimate may also reflect the effect of managers' incentive compensation on their investment choices. Two factors limit the potential effect of this concern in this setting. First, any reverse causality (i.e., observed risk-return tradeoffs reflecting the effect of managers' compensation contracts on their investment choices) is likely to cause a negative relation between compensation convexity and risk-return tradeoffs. Risk-taking incentives diminish the costs that managers face from bearing from additional risk and, consequently, managers with more risk-taking incentives should require smaller incremental returns to invest in riskier projects (i.e., more negative risk-return tradeoffs). In other words, if managers' compensation contracts do influence firms' risk-return tradeoffs, this effect is likely to attenuate the positive relation between compensation contract convexity and risk-return tradeoffs that I hypothesize.

Second, the research design described in Section 3 also helps mitigate these endogeneity concerns. Because I estimate risk-return tradeoffs at an industry-year level, rather than a firm-specific level, it is unlikely that any particular firm's compensation contract design meaningfully influences risk-return tradeoffs for other firms within the same industry-year. That is, while a firm's compensation contract may influence the specific level of risk (and value) that a manager chooses to invest in, it is not likely to influence the relation between risk and firm value across the entire industry-year, and it is this industry-year measure that I use to capture risk-return tradeoffs.

Notwithstanding the discussion above, I conduct two additional analyses to examine the potential effect of an endogenous relation between the risk-return tradeoffs that I estimate and firms' incentive compensation structures. First, I re-estimate the relation between compensation contract convexity and risk-return tradeoffs using lagged risk-return tradeoffs. Even if managers' incentive compensation does influence the risk-return tradeoffs that I estimate for the industry-year, it is not plausible that their compensation contracts influence risk-return tradeoffs in the prior year. Table 12 presents results from this analysis. I continue to find a significantly positive relation between managers' vega and risk-return tradeoffs, with nearly identical magnitudes and statistical significance, suggesting that these results are not driven by the potential effects of incentive compensation contracts on risk-return tradeoffs across an industry-year.

Next, I re-estimate this relation between vega and risk-return tradeoffs excluding firms that I use to estimate risk-return tradeoffs. Recall that I estimate these risk-return tradeoffs using firms with top-quartile abnormal investment to focus on firms where I can best identify the effects of incremental investment choices. I then assume all firms within an industry-year have similar investment opportunity sets and therefore apply the same risk-return tradeoff to all firms in that industry-year. This allows me to examine the relation between managers' compensation convexity and risk-return tradeoffs using these remaining firms (i.e., those in the bottom three investment quartiles), whose compensation contracts are more unlikely to influence the risk-return tradeoffs that I estimate. Table 13 presents results excluding firms that I use to estimate risk-return tradeoffs. I continue to find a significantly positive relation between managers' vega and risk-return tradeoffs, although the coefficient is somewhat smaller and statistical significance is slightly weaker ($p = 0.02$).

This attenuated result seems reasonable given that my risk-return tradeoff measures are likely noisier for this subset of firms that I exclude from my risk-return estimations.

8.2. Manager fixed effects

It is possible that the relation between firms' risk-return tradeoffs and managers' incentive compensation structures reflects managers with different risk or compensation preferences choosing (or "self-selecting") to work at firms with certain types of risk-return tradeoffs. For example, more risk-tolerant managers may prefer to work at firms with greater returns to risk-taking and also be more willing or likely to accept compensation packages with more risk-taking incentives. This could result in a positive relation between firms' risk-return tradeoffs and managers' risk-taking incentives without firms choosing to adjust their compensation policies in response to the risk-return tradeoffs that they face. To examine this possibility, I re-estimate equation 6 including manager fixed effects. To the extent that managers' preferences are time-invariant, this should capture the effect of different types of managers self-selecting into different types of firms.

Table 14 provides the results from this model with manager fixed effects. Consistent with the results in Table 7, I continue to find a significantly positive relation between firms' risk-return tradeoffs and managers' vega (coefficient of 0.014, $p < 0.01$). Thus, time-invariant manager preferences do not appear to explain the relation between risk-return tradeoffs and managers' risk-taking incentives reported in previous sections. In contrast, the relation between lower-risk investment returns and managers' vega and delta is no longer significant, although the signs remain consistent with those in Table 7. Thus, it is possible that the relations between lower-risk investments and managers' incentive compensation structures described in previous sections reflect different types of managers selecting into certain types of firms and compensation structures. Alternatively, the lack of significance for lower-risk investment returns may reflect the loss of statistical power from including manager fixed effects in the specification.

8.3. Four-factor expected returns model

In previous sections, I compute risk and return relations using firms' market-adjusted stock returns to measure their abnormal returns during the year. In this section, I instead estimate these abnormal returns using Carhart's (1997) four-factor model. Specifically, I estimate firms' four-factor alphas based on daily stock returns during the year and recompute my risk and return measures described in Section 3 using these estimated alphas in place of market-adjusted returns. I then re-estimate equation 6 using these alternative risk-return measures.

Table 15 reports the results from this analysis based on four-factor alphas. I continue to find that firms provide managers with more vega when the risk-return relation is more positive and that they provide more delta when lower-risk investments have greater returns. In general, these results are very similar to those in Table 7, both in significance and magnitude. Thus, my results do not appear to depend on any particular specification of expected stock returns.[34]

9. Conclusion

Agency theory posits that managerial risk aversion imposes agency costs on shareholders and that one of the primary purposes of incentive compensation is to help mitigate these agency costs. These risk-related agency costs arise from the assumption that the firm's risk and return are positively correlated, and risk-averse managers may "underinvest" in risk to the detriment of shareholders. This suggests that firms with stronger risk-return relations should provide more risk-taking incentives, as the benefits of providing them (or the costs of not doing so) are larger.

In this paper, I examine how the relation between the risk of and return on a firm's investments influences its managerial incentive compensation choices. I first evaluate whether, or for which firms, riskier investments seem to generate greater expected returns for shareholders. I then examine if firms appear to design managers' compensation contracts accordingly. In particular, I expect firms to provide managers with the most risk-taking incentives when the benefits

[34] I also obtain very similar results if I estimate expected returns using a three-factor Fama-French (1993) model (untabulated).

from increased risk-taking are greatest (i.e., when riskier investments generate the greatest incremental returns).

I find that, on average, investment value increases with risk, suggesting that shareholders benefit when managers increase risky investment. I also find that firms provide managers with more risk-taking incentives as the incremental returns to risky investment, and therefore the potential benefits from risk-taking, increase. Likewise, I find that firms tend to provide fewer risk-taking incentives when the returns to lower-risk investment are higher. Overall, my results are consistent with risk-taking incentives primarily mitigating risk-related agency costs, rather than resulting in widespread “excessive” risk-taking.

In addition, I find that managers appear to take on more risk when incremental returns to riskier investment are larger, even after controlling for standard measures of equity incentives. This suggests that understanding managers’ total risk-taking incentives requires considering not only their equity compensation, but also the risk-return relations within their firms. For example, managers at firms where riskier investment generates very large expected returns relative to less risky investment may have significant incentives to increase risk even in the absence of any meaningful equity-based incentive compensation.

My findings provide one potential explanation for the conflicting results in prior literature on the relation between managers’ stock price exposure (i.e., delta) and risk-taking. Managers’ overall risk-taking incentives from delta are a combination of “wealth” effects, from greater risk-taking potentially increasing managers’ expected compensation, and “risk-aversion” effects, from greater risk-taking potentially increasing the variance of managers’ compensation. Because the magnitude of these “wealth” effects depends on the risk-return tradeoffs that managers face, understanding these tradeoffs is an important element in evaluating the overall incentive consequences of managers’ equity-based compensation.

Appendix A – Variable Definitions

Dependent variables	
Delta	Log of 1 plus the sensitivity of manager wealth to a one percent change in the firm's stock price
Vega	Log of 1 plus the sensitivity of manager wealth to a one percentage point change in the firm's stock volatility
Capex	Capital expenditures scaled by lagged total assets
R&D	R&D expense scaled by lagged total assets

Risk-return variables	
Total investment value	Residual from industry-year regression of abnormal return on unexpected earnings, as defined below
Per-dollar investment value	Total investment value scaled by unexpected investment, as defined below
Total investment risk	Residual from industry-year regression of change in stock volatility on stock return and change in leverage
Per-dollar investment risk	Total investment risk scaled by unexpected investment, as defined below
Return-risk tradeoff	Coefficient from industry-year regression of per-dollar investment value on per-dollar investment risk
Lower-risk return	Intercept from industry-year regression of per-dollar investment value on per-dollar investment risk

Other variables	
Abnormal return	Market-adjusted stock return during the year
Investment	Capital expenditures plus R&D expense plus acquisitions less sales of PP&E and depreciation, scaled by lagged market capitalization
Unexpected investment	Residual from industry-year regression of investment on cash flow, lagged sales growth, and lagged investment
Unexpected earnings	Change in income before extraordinary items plus depreciation and R&D expense from the prior year, scaled by lagged market capitalization
Size	Log of market capitalization
Book-to-market	Book value of total assets divided by total debt plus market value of equity
Leverage	Long-term debt divided by long-term debt plus market value of equity
Sales growth	Percentage change in sales from the prior year
Stock volatility	Annualized standard deviation of daily stock return over the prior year
Cash flow	Cash flow from operations plus R&D expense, scaled by lagged market capitalization

Appendix B – Total and Per-Dollar Investment Risk and Return

Suppose the firm consists of a set of projects with uncertain cash flows x_i, $i = 1, \dots, n$. The total cash flows of the firm are the sum of these individual cash flows from each project:

$$CF = \sum_{i=1}^{n} x_i$$

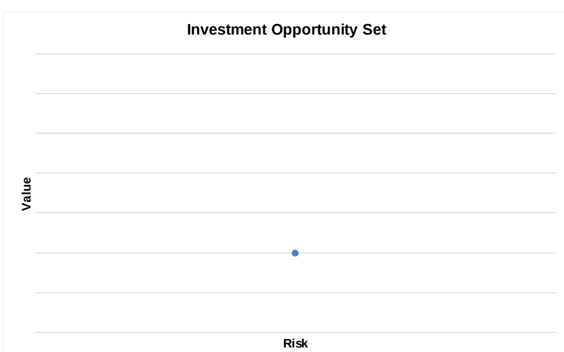
The value of the firm is the expectation of these cash flows and the risk of the firm is the variance of these cash flows:

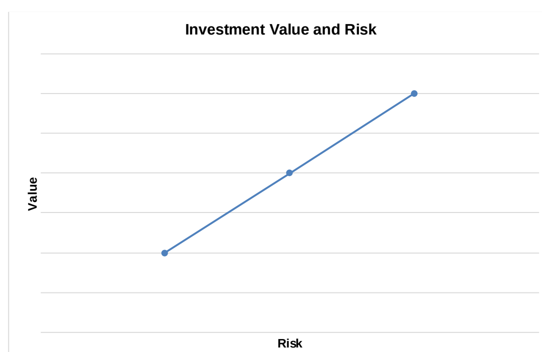
$$Value = E[CF]$$
$$Risk = Var[CF]$$

Thus, project selection potentially influences both the value and the risk of the firm. If projects have positive expected cash flows, the risk-return relation may be positive at the firm level even if it is flat or negative per-dollar. Below, I provide some illustrative examples where the firm's potential investments (i.e., its investment opportunity set) consist of three projects, and the firm can invest in one, two, or all three of these projects (i.e., they are not mutually exclusive). For simplicity, I assume the following:[35]

1) The projects have uncorrelated cash flows, so $Var[CF] = \sum Var[x_i]$.
2) Firms invest in projects in order of increasing risk (i.e., the three project selection permutations that I depict are: a) only the least risky project, b) only the two least risky projects, and c) all three projects).
3) All potential projects require the same amount of investment (i.e., the investment sets depicted are per-dollar).

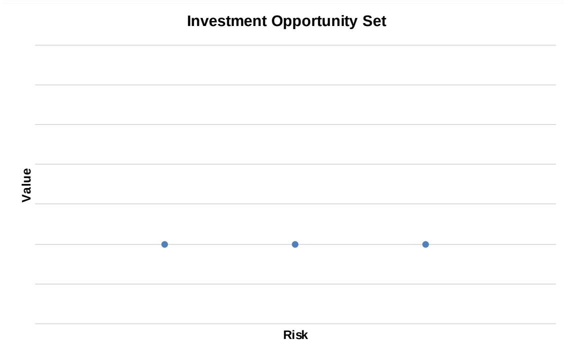
Case 1 (homogeneous projects): Suppose the investment opportunity set consists of three projects, each with risk of 1 unit and expected return (cash flow) of 1 unit. Thus, the opportunity set is a point. This corresponds to potential firm-level (risk, expected cash flow) pairs of (1, 1), (2, 2), and (3, 3), as illustrated below. In this example, there is a positive, linear firm-level (total) risk-return relation but no per-dollar relation. In other words, the firm can increase both risk and return by increasing the scale of investment, but not by investing in riskier projects.

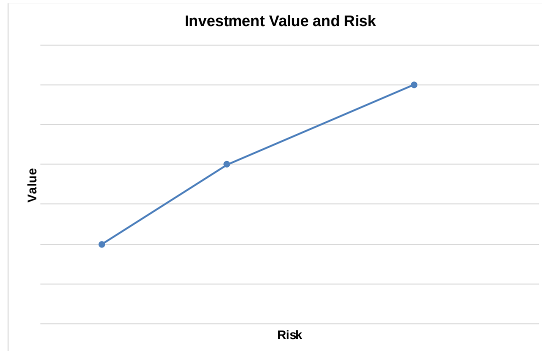




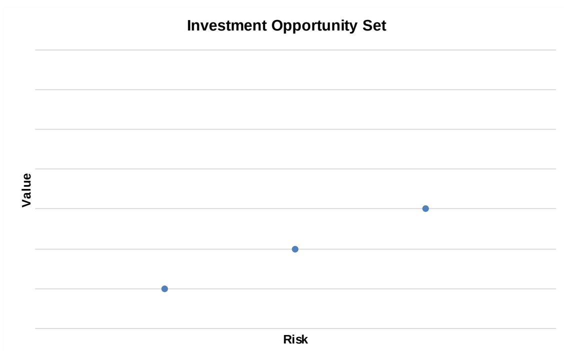
[35] Relaxing assumption 1 to allow for positive (negative) correlations between project cash flows will concavify (convexify) the firm-level relations depicted, and relaxing assumption 2 to allow for alternative permutations may reduce the "smoothness" of the relation between risk and return but will not affect the overall sign.

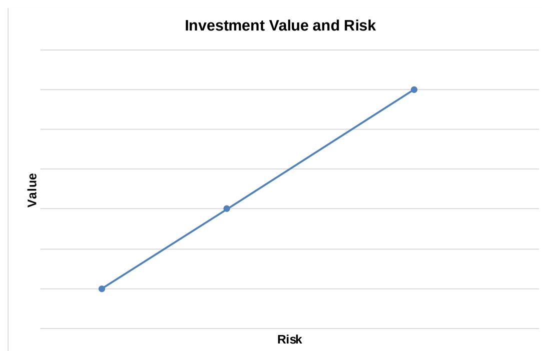
Case 2 (zero per-dollar risk-return relation): Potential risk-return project pairs are (1, 1), (2, 1), and (3, 1). This implies there is no risk-return tradeoff at the per-dollar level. However, there is still a positive relation at the firm level (in this case, it is concave). Again, the firm can increase both risk and return by investing in more projects but not by investing in riskier projects.





Case 3 (positive per-dollar risk-return relation): Potential risk-return project pairs are (1, 1), (2, 2), and (3, 3). In this case, there is a positive and linear risk-return tradeoff at the per-dollar level. This again corresponds to a positive firm-level relation. Here, the firm can increase risk and return either by investing in more projects or by investing in riskier projects. As in case 1, the firm-level relation is positive and linear, which suggests that the firm-level relation is not fully informative about the per-dollar relation.





Case 4 (negative per-dollar risk-return relation): Finally, suppose potential risk-return project pairs are (1, 1), (2, 0.75), and (3, 0.5). This is a negative per-dollar risk-return relation. The corresponding firm-level relation is still positive (and concave). Thus, in this case, increased risk-taking would be beneficial if it stems from the firm increasing the total amount of risky investment, but detrimental if it stems from the firm switching to riskier investments.

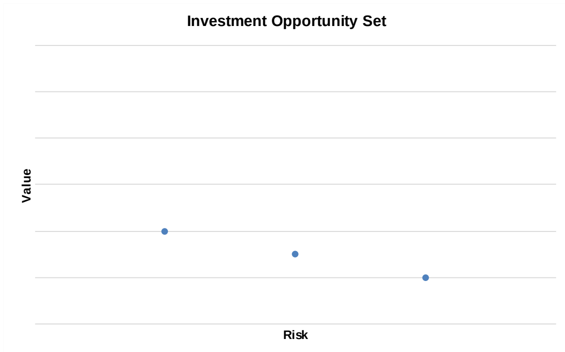


Figure 1. Investment Value and Risk

This figure illustrates the estimated relation between investment value and investment risk based on the method described in Section 3.1. The solid line represents a linear approximation of the relation and the dashed line represents a quadratic approximation.

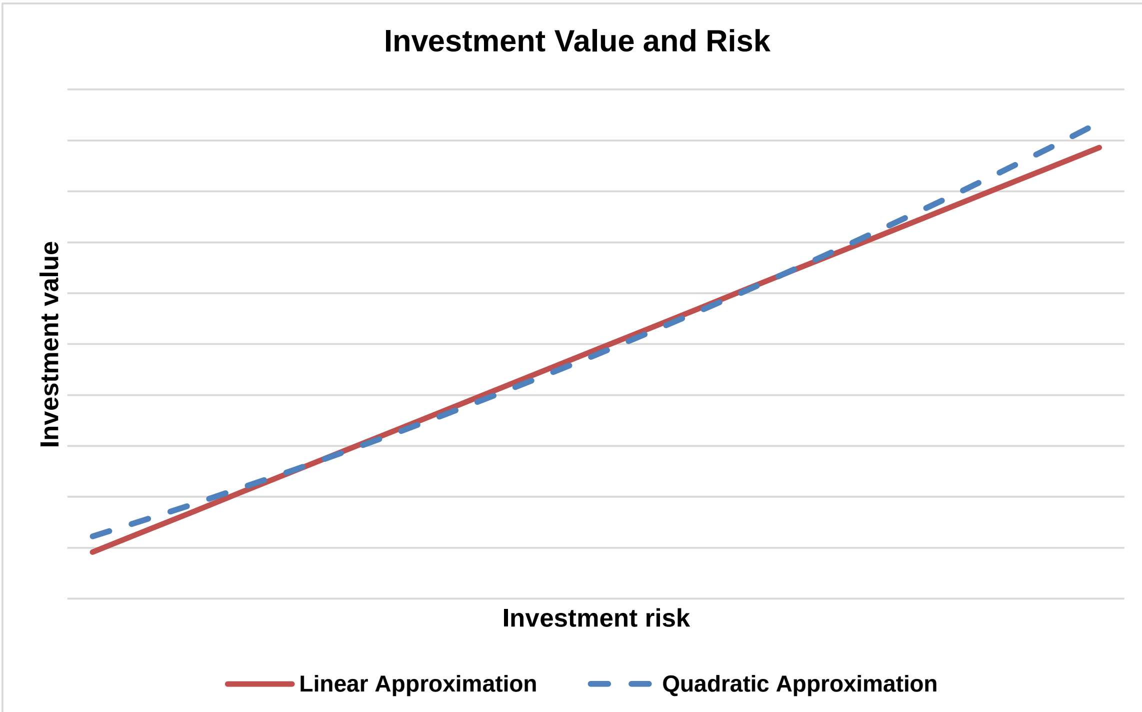


Figure 2. Per-Dollar Investment Value and Risk

This figure illustrates the estimated relation between per-dollar investment value and investment risk based on the method described in Section 3.1. The solid line represents a linear approximation of the relation and the dashed line represents a quadratic approximation.

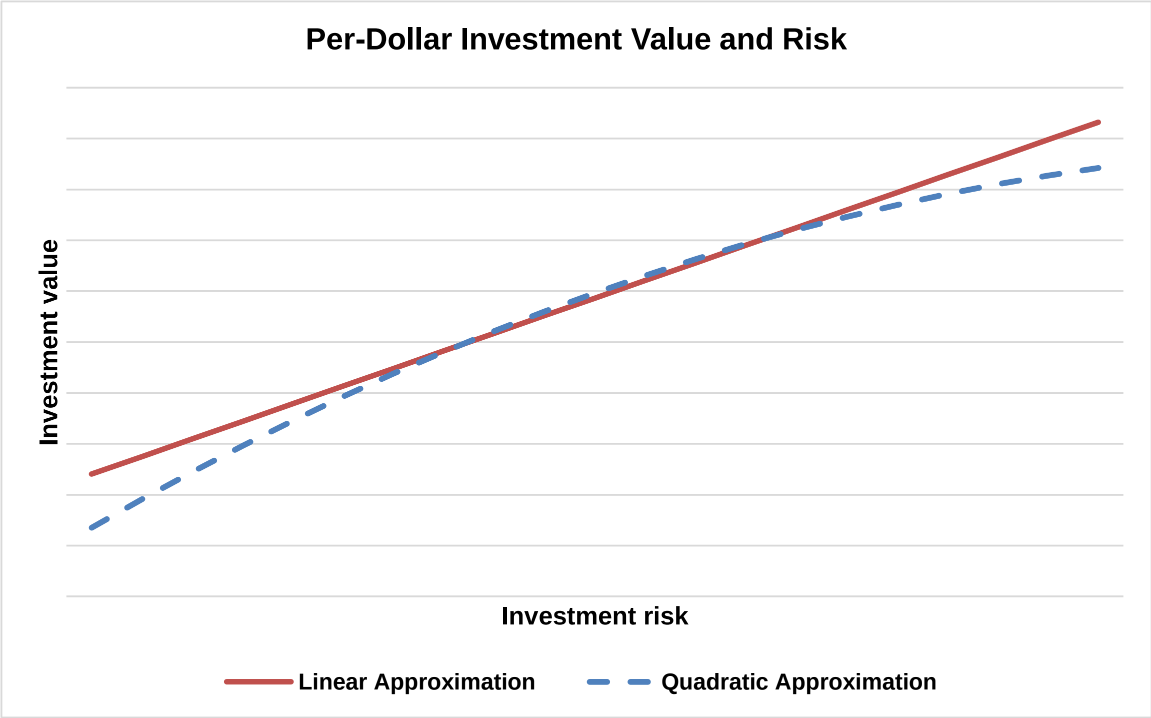


Table 1. Descriptive Statistics

This table reports descriptive statistics for the primary variables used in my tests. Panel A reports statistics for the sample with which I estimate risk-return tradeoffs and Panel B reports statistics for the sample with which I estimate the relation between risk-return tradeoffs and incentive compensation. All variables are defined in Appendix A.

Panel A: Risk-return relation sample

Variable	n	Mean	S.D.	25th	Median	75th
Abnormal return	83,211	0.03	0.66	-0.37	-0.08	0.24
Investment	83,211	0.06	0.12	0.00	0.04	0.10
Unexpected earnings	83,211	0.02	0.27	-0.04	0.01	0.04
Size	83,211	5.11	2.25	3.48	5.03	6.65
Book-to-market	83,211	0.98	0.61	0.54	0.88	1.26
Leverage	83,211	0.19	0.23	0.00	0.10	0.30
Sales growth	83,211	0.13	0.29	-0.03	0.08	0.23
Stock volatility	83,211	0.65	0.43	0.37	0.55	0.80
Cash flow	83,211	0.12	0.16	0.03	0.10	0.19

Panel B: Incentive compensation sample

Variable	n	Mean	S.D.	25th	Median	75th
Abnormal return	38,702	0.09	0.62	-0.27	-0.02	0.27
Investment	38,702	0.06	0.11	0.00	0.04	0.09
Unexpected earnings	38,702	0.02	0.23	-0.02	0.01	0.03
Size	38,702	6.53	1.84	5.33	6.46	7.68
Book-to-market	38,702	0.87	0.54	0.49	0.77	1.12
Leverage	38,702	0.17	0.21	0.00	0.10	0.27
Sales growth	38,702	0.13	0.28	-0.01	0.08	0.22
Stock volatility	38,702	0.53	0.30	0.33	0.46	0.65
Cash flow	38,702	0.12	0.13	0.05	0.10	0.17
Delta	38,702	5.01	1.75	3.97	5.06	6.11
Vega	38,702	3.09	1.77	1.91	3.23	4.35

Table 2. Investment Risk and Types of Investment

This table reports results from regressing investment risk as described in Section 3.1 on R&D and capital expenditures. Control variables are lagged one period from the dependent variable. Industry-year fixed effects are included but not reported. t-statistics, based on standard errors clustered by firm, are in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. All variables are defined in Appendix A.

	(1) Total investment risk	(2) Total investment risk	(3) Per-dollar investment risk	(4) Per-dollar investment risk
R&D	**0.095*** **	**0.242*** **	**0.760*** **	**2.457*** **
	(5.13)	**(10.50)**	**(3.37)**	**(8.49)**
Capex	**-0.009**	**0.045*** **	**-0.057**	**0.535*** **
	(-0.56)	**(2.60)**	**(-0.31)**	**(2.69)**
Size		-0.027***		-0.325***
		(-7.46)		(-7.41)
Book-to-market		0.031***		0.295***
		(6.92)		(5.11)
Leverage		0.045***		0.575***
		(4.41)		(4.56)
Sales growth		-0.247***		-2.909***
		(-6.75)		(-6.80)
Stock volatility		-0.010*		-0.108
		(-1.79)		(-1.32)
Cash flow		-0.146***		-1.610***
		(-9.88)		(-8.49)
Observations	20,956	20,068	20,956	20,068
R-squared	0.036	0.167	0.036	0.131

Table 3. Investment Value and Future Sales Growth

This table reports results from regressing investment value as described in Section 3.1 on future sales growth. Control variables are lagged one period from the dependent variable. Industry-year fixed effects are included but not reported. t-statistics, based on standard errors clustered by firm, are in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. All variables are defined in Appendix A.

	(1) Total investment value	(2) Total investment value	(3) Per-dollar investment value	(4) Per-dollar investment value
Sales growth$_{t+1}$	**0.405*** **	**0.443*** **	**4.460*** **	**4.863*** **
	(16.26)	**(17.23)**	**(13.75)**	**(14.35)**
Sales growth$_{t+2}$	**0.159*** **	**0.163*** **	**2.002*** **	**2.083*** **
	(5.66)	**(5.66)**	**(5.33)**	**(5.36)**
Sales growth$_{t+3}$	**0.079*** **	**0.105*** **	**0.627* **	**0.890** **
	(3.03)	**(3.92)**	**(1.87)**	**(2.55)**
Size		-0.027***		-0.212***
		(-6.65)		(-3.83)
Book-to-market		0.111***		1.078***
		(7.15)		(4.84)
Leverage		-0.022		-0.639
		(-0.61)		(-1.42)
Sales growth		0.104***		0.589*
		(3.59)		(1.79)
Stock volatility		-0.008		0.036
		(-0.34)		(0.12)
Cash flow		0.335***		3.379***
		(7.11)		(5.53)
Observations	14,409	13,689	14,409	13,689
R-squared	0.093	0.123	0.079	0.091

Table 4. Investment Value and Risk

This table reports results from estimating the following model:

$$Return_t = \theta_0 + \theta_1 Risk_t + \theta_2 Risk_t^2$$

where $Return$ is investment value and $Risk$ is investment risk, as described in Section 3.1. Industry-year fixed effects are included but not reported. t-statistics, based on standard errors clustered by firm, are in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

	(1) Total investment value	(2) Total investment value	(3) Per-dollar investment value	(4) Per-dollar investment value
Investment risk	**0.397***** **(13.30)**	**0.387***** **(13.73)**	**0.346***** **(9.44)**	**0.353***** **(9.94)**
Investment risk^2		**0.099** **(1.55)**		**-0.011***** **(-2.96)**
Observations	20,956	20,956	20,956	20,956
R-squared	0.058	0.058	0.053	0.055

Table 5. Risk-Return Tradeoffs by Industry

This table presents the industries with the largest and smallest average risk-return tradeoffs across the sample.

Rank	Industry	
1	Apparel	(most positive)
2	Construction	
3	Personal Services	
4	Machinery	
5	Computers	
6	Steel	
7	Rubber	
8	Wholesale	
9	Entertainment	
10	Business Supplies	
11	Restaurants and Hotels	
12	Chemicals	
13	Transportation	
14	Electronic Equipment	
15	Autos and Trucks	
16	Retail	
17	Healthcare	
18	Toys	
19	Medical Equipment	
20	Electrical Equipment	
21	Business Services	
22	Pharmaceuticals	
23	Food Products	
24	Communication	
25	Construction Materials	
26	Oil	
27	Textiles	
28	Measuring and Control Equipment	
29	Consumer Goods	
30	Fabricated Products	
31	Printing And Publishing	(most negative)

Table 6. Risk-Return Tradeoffs and Industry Characteristics

This table reports results from estimating the following model:

$$Return/Risk_t = \beta_0 + \beta_1 HHI_t + \beta_2 BTM_t + Controls$$

where $Return/Risk$, HHI, and BTM are the industry-year risk-return tradeoff, Herfindahl index, and average book-to-market ratio, respectively. Year fixed effects are included but not reported. t-statistics, based on standard errors clustered by industry, are in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

	(1) Risk-return tradeoff	(2) Risk-return tradeoff	(3) Risk-return tradeoff
Herfindahl index	**-1.550***		**-1.582****
	(-1.93)		**(-2.43)**
Book-to-market		**0.539****	**0.546****
		(2.63)	**(2.69)**
Observations	583	583	583
R-squared	0.054	0.057	0.062

Table 7. Risk-Return Tradeoffs and Incentive Compensation

This table reports results from estimating the following model:

$$Incentive_t = \kappa_0 + \kappa_1 Return/Risk_t + \kappa_2 LowerRiskReturn_t + Controls$$

where $Return/Risk$ and $LowerRiskReturn$ are δ_1 and δ_0 (i.e., the slope and intercept), respectively, from industry-year estimations of equation 3. Industry and year fixed effects are included but not reported. t-statistics, based on standard errors clustered by firm, are in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. All variables are defined in Appendix A.

	(1) Vega	(2) Delta
Return-risk tradeoff	**0.025*** **	**-0.000**
	(4.19)	**(-0.06)**
Lower-risk return	-0.015***	0.013***
	(-3.12)	(2.81)
Size	0.600***	0.550***
	(42.70)	(43.59)
Book-to-market	0.215***	-0.416***
	(6.70)	(-12.41)
Leverage	0.522***	-0.307***
	(6.36)	(-3.63)
Sales growth	-0.203***	0.430***
	(-5.94)	(12.84)
Stock volatility	-0.570***	-0.157***
	(-9.71)	(-3.03)
Cash flow	0.306***	0.314***
	(3.59)	(3.84)
Observations	33,139	33,139
R-squared	0.413	0.437

Table 8. Risk-Return Tradeoffs, Incentive Compensation, and Systematic vs. Idiosyncratic Risk

This table reports results from estimating the following model, after separating risk into systematic and idiosyncratic components as described in Section 5:

$$Incentive_t = \kappa_0 + \kappa_1 Return/Risk_t + \kappa_2 LowerRiskReturn_t + Controls$$

where $Return/Risk$ and $LowerRiskReturn$ are δ_1 and δ_0 (i.e., the slope and intercept), respectively, from industry-year estimations of equation 3. Industry and year fixed effects are included but not reported. t-statistics, based on standard errors clustered by firm, are in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. All variables are defined in Appendix A.

	(1)	(2)	(3)	(4)	(5)	(6)
	Vega	Vega	Vega	Delta	Delta	Delta
Syst. return-risk tradeoff	**-0.002**		**-0.003**	**0.001**		**0.001**
	(-0.86)		**(-1.13)**	**(0.18)**		**(0.16)**
Idio. return-risk tradeoff		**0.021*** **	**0.021*** **		**0.001**	**0.001**
		(3.43)	**(3.50)**		**(0.20)**	**(0.19)**
Lower-risk return	-0.013***	-0.015***	-0.015***	0.013***	0.013***	0.013***
	(-2.75)	(-3.06)	(-2.98)	(2.79)	(2.79)	(2.78)
Size	0.599***	0.600***	0.600***	0.550***	0.550***	0.550***
	(42.67)	(42.69)	(42.68)	(43.59)	(43.60)	(43.58)
Book-to-market	0.215***	0.215***	0.215***	-0.416***	-0.416***	-0.416***
	(6.69)	(6.70)	(6.69)	(-12.41)	(-12.41)	(-12.41)
Leverage	0.525***	0.522***	0.523***	-0.307***	-0.307***	-0.307***
	(6.41)	(6.37)	(6.38)	(-3.64)	(-3.64)	(-3.63)
Sales growth	-0.204***	-0.203***	-0.203***	0.430***	0.430***	0.430***
	(-5.97)	(-5.95)	(-5.96)	(12.84)	(12.84)	(12.84)
Stock volatility	-0.574***	-0.571***	-0.570***	-0.157***	-0.157***	-0.157***
	(-9.78)	(-9.72)	(-9.72)	(-3.03)	(-3.03)	(-3.03)
Cash flow	0.309***	0.307***	0.307***	0.314***	0.314***	0.314***
	(3.63)	(3.60)	(3.60)	(3.84)	(3.83)	(3.84)
Observations	33,139	33,139	33,139	33,139	33,139	33,139
R-squared	0.412	0.413	0.413	0.437	0.437	0.437

Table 9. CEO Risk Aversion

This table reports results from estimating the following model across subsamples of CEOs with relatively low and relatively high risk aversion:

$$Incentive_t = \kappa_0 + \kappa_1 Return/Risk_t + Controls$$

where $Return/Risk$ is the firm's risk-return tradeoff. Low and high risk aversion represent top- and bottom-tercile CEO experienced returns as described by Malmendier and Nagel (2011). Industry and year fixed effects are included but not reported. t-statistics, based on standard errors clustered by firm, are in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

	(1)	(2)
	Vega	Vega
Risk aversion:	Low	High
Return-risk tradeoff	**0.010**	**0.031*** **
	(0.93)	**(2.60)**
Lower-risk return	-0.025***	-0.004
	(-2.68)	(-0.41)
Size	0.612***	0.585***
	(31.08)	(25.30)
Book-to-market	0.348***	0.147***
	(7.36)	(3.49)
Leverage	0.512***	0.586***
	(4.27)	(5.04)
Sales growth	-0.241***	-0.153***
	(-4.11)	(-2.90)
Stock volatility	-0.523***	-0.708***
	(-6.02)	(-7.14)
Cash flow	0.456***	0.252**
	(3.48)	(2.03)
Pr(Low = High)	0.234	
Observations	10,681	10,868
R-squared	0.407	0.419

Table 10. Investment Risk and Risk-Return Tradeoffs

This table reports results from estimating the following model:

$$Investment_t = \lambda_0 + \lambda_1 Return/Risk_t + \lambda_2 LowRiskReturn_t + Controls$$

where $Investment$ is either capital expenditures or R&D expense, scaled by lagged total assets, and $Return/Risk$ and $LowerRiskReturn$ are δ_1 and δ_0 (i.e., the slope and intercept), respectively, from industry-year estimations of equation 3. Industry and year fixed effects are included but not reported. Delta and Vega are lagged one period from the dependent variable and all other controls are measured contemporaneously. t-statistics, based on standard errors clustered by firm, are in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. All variables are defined in Appendix A.

	(1) Capex (x100)	(2) R&D (x100)
Return-risk tradeoff	**-0.055***	**0.083*****
	(-1.71)	**(3.07)**
Lower-risk return	0.059***	-0.061**
	(2.78)	(-2.14)
Delta	0.415***	-0.118**
	(8.09)	(-2.03)
Vega	-0.320***	0.456***
	(-6.01)	(7.12)
Size	-0.073	-0.677***
	(-1.07)	(-8.12)
Book-to-market	-1.553***	-3.519***
	(-11.49)	(-17.04)
Leverage	-1.154***	-5.553***
	(-2.65)	(-13.75)
Sales growth	4.446***	2.524***
	(17.63)	(8.67)
Stock volatility	0.527**	8.426***
	(2.21)	(19.02)
Cash flow	5.082***	6.636***
	(8.70)	(10.18)
Observations	30,798	30,798
R-squared	0.354	0.494

Table 11. Investment Risk, Risk-Return Tradeoffs, and Incentive Compensation

This table reports results from estimating the following model across subsamples with low and high risk-return tradeoffs:

$$Investment_t = \pi_0 + \pi_1 Delta_{t-1} + Controls$$

where $Investment$ is either capital expenditures or R&D expense, scaled by lagged total assets, and $Delta$ is the sensitivity of the manager's wealth to a one percent change in the firm's stock price. The high risk-return tradeoff sample consists of observations where the estimated risk-return tradeoff is significantly positive (at 10%) and the low risk-return tradeoff sample consists of all other observations. Industry and year fixed effects are included but not reported. Delta and Vega are lagged one period from the dependent variable and all other controls are measured contemporaneously. t-statistics, based on standard errors clustered by firm, are in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. All variables are defined in Appendix A.

	(1) Capex (x100)	(2) Capex (x100)	(3) R&D (x100)	(4) R&D (x100)
Return-risk tradeoff:	Low	High	Low	High
Delta	**0.424*** **	**0.392*** **	**-0.167*** **	**-0.007**
	(7.70)	**(6.17)**	**(-2.78)**	**(-0.10)**
Vega	-0.308***	-0.345***	0.462***	0.426***
	(-5.41)	(-5.33)	(7.07)	(5.65)
Size	-0.079	-0.063	-0.619***	-0.800***
	(-1.09)	(-0.79)	(-7.25)	(-7.83)
Book-to-market	-1.551***	-1.615***	-3.527***	-3.457***
	(-10.84)	(-9.20)	(-16.23)	(-13.74)
Leverage	-1.389***	-0.560	-5.650***	-5.273***
	(-2.99)	(-1.01)	(-13.04)	(-10.45)
Sales growth	4.357***	4.484***	2.549***	2.502***
	(15.79)	(12.37)	(7.40)	(5.23)
Stock volatility	0.569**	0.497	8.831***	7.332***
	(2.16)	(1.37)	(18.05)	(10.75)
Cash flow	5.472***	4.102***	6.323***	7.494***
	(8.62)	(5.37)	(9.09)	(8.25)
Pr($Delta_{Low} = Delta_{High}$)	0.577		0.002	
Observations	21,318	9,480	21,318	9,480
R-squared	0.358	0.353	0.489	0.510

Table 12. Lagged Risk-Return Tradeoffs and Incentive Compensation

This table reports results from estimating the following model:

$$Incentive_t = \kappa_0 + \kappa_1 Return/Risk_{t-1} + Controls$$

where $Return/Risk$ is the firm's risk-return tradeoff. Industry and year fixed effects are included but not reported. t-statistics, based on standard errors clustered by firm, are in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

	(1) Vega	(2) Delta
Return-risk tradeoff$_{t-1}$	**0.025*** **	**0.008**
	(4.39)	**(1.28)**
Lower-risk return$_{t-1}$	-0.004	0.006
	(-0.82)	(1.25)
Size	0.604***	0.550***
	(42.90)	(43.99)
Book-to-market	0.218***	-0.413***
	(6.81)	(-12.37)
Leverage	0.522***	-0.309***
	(6.40)	(-3.66)
Sales growth	-0.204***	0.430***
	(-6.01)	(12.90)
Stock volatility	-0.531***	-0.145***
	(-7.76)	(-2.73)
Cash flow	0.331***	0.326***
	(3.88)	(3.98)
Observations	33,495	33,495
R-squared	0.414	0.435

Table 13. Risk-Return Tradeoffs and Incentive Compensation, Excluding Estimation Firms

This table reports results from estimating the following model:

$$Incentive_t = \kappa_0 + \kappa_1 Return/Risk_t + Controls$$

where $Return/Risk$ is the firm's risk-return tradeoff. Firms used to estimate these risk-return tradeoffs are excluded from the sample. Industry and year fixed effects are included but not reported. t-statistics, based on standard errors clustered by firm, are in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

	(1) Vega	(2) Delta
Return-risk tradeoff	**0.017****	**0.003**
	(2.29)	**(0.43)**
Lower-risk return	-0.010*	0.012**
	(-1.69)	(2.28)
Size	0.600***	0.542***
	(38.08)	(39.76)
Book-to-market	0.226***	-0.434***
	(6.36)	(-11.50)
Leverage	0.553***	-0.306***
	(6.28)	(-3.30)
Sales growth	-0.239***	0.449***
	(-5.80)	(11.24)
Stock volatility	-0.587***	-0.145**
	(-8.67)	(-2.45)
Cash flow	0.318***	0.271***
	(3.38)	(2.98)
Observations	25,688	25,688
R-squared	0.415	0.431

Table 14. CEO Fixed Effects

This table reports results from estimating the following model:

$$Incentive_t = \kappa_0 + \kappa_1 Return/Risk_t + \kappa_2 LowerRiskReturn_t + Controls$$

where $Return/Risk$ and $LowerRiskReturn$ are δ_1 and δ_0 (i.e., the slope and intercept), respectively, from industry-year estimations of equation 3. CEO and year fixed effects are included but not reported. t-statistics, based on standard errors clustered by firm, are in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. All variables are defined in Appendix A.

	(1) Vega	(2) Delta
Return-risk tradeoff	**0.014*** **	**0.001**
	(2.71)	**(0.16)**
Lower-risk return	-0.005	0.003
	(-1.23)	(0.95)
Size	0.397***	0.759***
	(13.77)	(36.29)
Book-to-market	0.066*	-0.174***
	(1.92)	(-6.28)
Leverage	0.221**	-0.154*
	(2.29)	(-1.95)
Sales growth	-0.097***	0.081***
	(-3.82)	(3.63)
Stock volatility	-0.603***	-0.098***
	(-11.00)	(-2.75)
Cash flow	0.174***	0.275***
	(2.73)	(4.61)
Observations	33,139	33,139
R-squared	0.868	0.875

Table 15. Four-Factor Expected Returns Model

This table reports results from estimating the following model:

$$Incentive_t = \kappa_0 + \kappa_1 Return/Risk_t + \kappa_2 LowerRiskReturn_t + Controls$$

where $Return/Risk$ and $LowerRiskReturn$ are δ_1 and δ_0 (i.e., the slope and intercept), respectively, from industry-year estimations of equation 3. These measures are computed using estimated alphas from Carhart's (1997) four-factor model, rather than the market-adjusted returns described in Section 3. Industry and year fixed effects are included but not reported. t-statistics, based on standard errors clustered by firm, are in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. All variables are defined in Appendix A.

	(1) Vega	(2) Delta
Return-risk tradeoff	**0.018*** **	**0.003**
	(3.01)	**(0.53)**
Lower-risk return	-0.016***	0.011**
	(-3.12)	(2.30)
Size	0.600***	0.549***
	(42.76)	(43.58)
Book-to-market	0.214***	-0.417***
	(6.67)	(-12.44)
Leverage	0.523***	-0.310***
	(6.37)	(-3.67)
Sales growth	-0.204***	0.431***
	(-5.98)	(12.86)
Stock volatility	-0.572***	-0.159***
	(-9.74)	(-3.06)
Cash flow	0.309***	0.314***
	(3.62)	(3.83)
Observations	33,211	33,211
R-squared	0.413	0.437

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