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Incentive Thresholds, Performance, and Risk-Taking.

Evidence from Hedge Funds*

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Abstract:

Managerial incentives induce risk-taking as well as effort. Theoretical research has long considered risk-taking a potential side effect of incentives, but empirical investigation is limited. This paper uses exogenous variation in hedge fund manager's incentives to examine both performance and risk-taking. I find, consistent with theory, that being farther below a key incentive threshold increases risk-taking and decreases performance. On average, a manager's risk-taking increases 50% and their performance falls 2.1 percentage points when he is below the incentive threshold. I also show, consistent with the theoretical predictions, risk-taking behavior is non-monotonic; very distant managers take less risk and perform better than less distant managers. Further, I examine the role of organizational features in impacting the responsiveness to explicit incentives and the mechanisms managers use to increase risk. My results highlight the importance of risk-taking in response to incentives designed to induce effort and inform empirical research, contract design, practitioners, and policy makers. The results also show that moral hazard, not just selection, is an important determination of manager performance.

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1. Introduction

Managerial incentives for risk-taking are crucial to understanding how compensation schemes affect the performance and behavior of firms. Understanding managerial risk-taking, and how to manage it, is also more broadly important. As the run up to the deepest recession since the Great Depression demonstrated, risk-taking by managers can have drastic consequences not just for their own firms but also for the global economy. Practically speaking the growth of risk management institutions within firms suggests that risk-taking is a fundamental issue of which firms of all kinds are increasingly aware.

Managerial incentives for risk-taking are widespread. Theoretical work has long noted that performance incentives may induce risk-taking (at least since Jensen and Meckling, 1976). Practically, performance incentives are pervasive. Performance pay is the majority of executive compensation.[1] 9 million workers have stock options as part of their compensation scheme.[2] And millions more have non-stock incentive schemes that can induce risk-taking. However, empirically, the role of incentives in driving risk-taking has been difficult to identify. This paper empirically identifies the role of incentives on risk-taking and shows that risk-taking is an important negative consequence of incentives.

There are four main limitations of the existing empirical research on incentives for risk-taking that I build from. First, because a manager's compensation structure is set based on the specific manager's skills, risk attitudes, characteristics as well as the firm's risk exposure, opportunities and desired risk-taking there can be an issue of endogeneity. Typical cross-sectional comparisons of executives' compensation, such as Wright et al. (2007), do not distinguish between the effects of incentives and the decision to award option based compensation. It might be, for example, that riskier firms give more option compensation. Second, measures of risk-taking incentives are limited. Many studies use measures such as option counts which are difficult to compare across firms, or local measures of incentives such as option delta and vega.[3] Further, more options may not imply more incentive to take risk because they may induce more risk-aversion than the additional risk incentives they provide (e.g. Carpenter 2000) and compensation for extreme outcomes can provide significant risk-taking incentives. Others, such as Chevalier and Ellison (1997), estimate imputed implicit incentives but lack the richness and foundation of examining explicit incentives. Third, measuring risk-taking is difficult in many contexts. Common measures in the literature such as merger and acquisition behavior and financing decisions (e.g. Sanders and Hambrick 2007) are hard to interpret from the framework of an agency problem because they are measures over which the principal (boards) have direct control. Finally, few studies examine both risk-taking and performance. However, without understanding the performance consequences of risk-taking it is difficult to evaluate its importance.

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[1] Anderson and Muslu (2011) estimate that half of executive compensation is from options, and an additional 30% is from bonuses and long term incentive plans.

[2] "Taking Stock: Are Employee Options Good for Business?" http://knowledge.wpcarey.asu.edu/article.cfm?cid=8&aid=26

[3] Option delta and vega are the derivatives of the value of an option with respect to price and volatility respectively. They are a subset of option "Greeks" or sensitivities of option value to marginal changes in parameters.

The two trillion dollar hedge fund industry is a fertile setting in which to empirically investigate impacts of incentive contracts on risk-taking and performance for four major reasons. First, incentive contracts in hedge funds are fixed ex-ante, so a fixed-effects approach can control for endogenous contracts. Second, market movements and industry level asset flows provide exogenous variation in the effective incentives of the fixed contract. Thus, using this exogenous variation in effective incentives and a fixed-effects approach allows examination of risk-taking holding the endogenous contract fixed. Third, risk-taking is a standard metric of hedge fund outcomes. Further, risk-taking measures in this setting are not subject to veto or review by the principals who set incentives, in contrast to many measures used to examine risk-taking of executives. Moreover, unlike in other settings, agents have similar opportunity sets of risk choices.[4] Fourth, performance measures are straightforward and driven by the same contracts that incent risk-taking. In addition to the empirical features of this setting, incentive contracts, performance outcomes, and risk-taking are particularly relevant in this context. In fact, unlike other investment vehicles, risk management is a first-order concern for hedge funds as the particular appeal of hedge funds is often not the prospect of outsized returns, but rather the promise of steady returns.

This paper focuses specifically on threshold incentive schemes. These are compensation schemes in which total compensation varies little, if at all, with performance when below a performance threshold but varies widely with performance above. Figure 1 shows an example of a compensation scheme of a firm manager. In this example, the intercept of the compensation scheme is the manager's base compensation including fringe benefits. The low initial slope represents the impact of equity holdings on total compensation as firm value increases. The steeper region represents the realized value of option holdings where the exact threshold is determined by the exercise price of those options.

Such threshold incentives are pervasive. While we might imagine that only executives' compensation has this structure, in reality, the same incentive scheme characterizes the compensation of any employee holding stock options in their employer. Entrepreneurs also face a similar incentive scheme from limited liability if they have any debt or debt-like terms that are common in venture capital financing terms. Downs and Rocke (1994) argue that political leaders face similar limited liability where the threshold reflects the approval necessary to remain in office. Sales people who face an increasing commission schedule also face threshold incentives, though the relevant horizontal axis would be sales rather than firm value (Larkin 2012). Profit-sharing contracts, such as those used in the movie industry, have a similar shape where the horizontal axis is revenue (Weinstein 1998). Many employment contracts in the asset management industry also have a similar incentive scheme in regards to return; an asset management fee that moves with returns and a performance fee that grows quickly above a threshold.

Hedge fund fee contracts have a threshold – known as a "high-water mark" – in the determination of fees paid to the investment manager. These contracts specify a management fee which is a fixed percentage of all assets. In addition, the contracts specify a performance fee which is a fixed percentage of the investment profits and which is only paid when the returns are above a high-

[4] For example, two managers at different firms contemplating an acquisition of a third firm face different outcomes because of the different synergies with their firms. In contrast, two different funds making the same investment realize the same returns on that investment.

water mark for the investments. The high-water mark is the highest value for which performance fees have previously been paid or the initial value of the investments if none have been paid, and so is adjusted up each time the performance fee is paid. As a simplified example,[5] if a fund starts with $100 million in assets and earns $10 million in the first year, the management fee would be a percentage of $110 million, the performance fee would be a percentage of $10 million, the new high-water mark would be $110 million, and the fund would be at its high-water mark for the following year's calculation. If the fund instead losses $10 million, the management fee would be a percentage of $90 million, the performance fee would be zero, the high-water mark for next year's calculation would remain $100 million, and the fund would be $10 million below its high-water mark. The threshold from which profits are measured – the high-water mark – is adjusted up each time the performance fee is paid. If in the second year the fund earned $15 million the size of the performance fee would depend on the distance to the high-water mark which is different in the two cases above. If the fund was at its high-water mark (i.e. had not lost money its first year), the performance fee would be a percentage of $15 million, but if the fund was $10 million below, the performance fee would be a percentage of $5 million.

The fund's distance to the high-water mark, and thus effective incentives, depends on past performance. However, market movements, particularly downturns, provide an exogenous movement of funds away from their threshold and the fixed contracts mean that there is no discretion in resetting incentives. My data set contains hedge funds that self-categorize into one of 34 strategies, which reflect the types of markets the funds intend to participate in. I use the return of each of the funds in each strategy to estimate the exposure of the strategy to a set of market indexes used to explain performance of hedge funds and other financial assets (Fama and French 1993, Carhart 1994, and Fung and Hsieh 2004). This approach provides a measure of how exposed a strategy is to a unique composite of the market indices. Since downturns in the indexes affect strategies differently this provides within time period variation in the exogenous distance to the threshold. Further, I use the panel nature of my data set to control for cross-sectional differences between managers, contracts, incentives, performance, and risk-taking with fixed effects. Thus I use within fund variation in distance to the threshold caused by exposure to the strategy specific market to examine the effect of these incentive contracts within funds on outcomes, both in terms of performance and risk-taking.

My results provide causal evidence that managers respond to being farther below their incentive thresholds by increasing risk and reducing performance. The results show sizable effects: the average treatment effect, equivalent to moving a fund just 15% below its threshold, reduces returns over the next year by 2.1 percentage points and increases the riskiness of the fund by about 50%.

To further explore this initial result, I develop a simple model of a manager's decision making when facing a threshold incentive. In the model the manager chooses both how much costly effort to exert, where effort improves outcomes on average, and a risk level, where higher risk spreads the distribution of outcomes but also may have a performance cost. In addition to the prediction that risk-taking increases and performance falls when managers are farther below their thresholds, this model yields predictions about what happens when managers are very far from the threshold and how different management and performance fee rates would affect responsiveness to distance from the threshold.

[5] See Section 4 for more details.

With respect to the former, the model predicts that when managers are very far below their threshold they stop taking additional risks, but their incentives for effort continue to decrease monotonically. The intuition behind this prediction is that a manager very far from the threshold has little to gain from taking more risk but faces the same costs of risk-taking as a manager closer to the threshold. Empirically, the results are consistent with this prediction, as I find that managers that are very far below their thresholds take less risk and perform better than managers who are moderate distances below their thresholds. The results further suggest that the performance costs of risk-taking are large. Given my baseline assumption on the functional forms, the data suggest that 83% of the performance drop observed by managers that are not very far below their thresholds is due to the performance costs of risk-taking and 17% of the performance declines are due to effort reduction.

The next set of results is that managers with higher performance fees or lower management fees should respond more to being below their thresholds. We would not expect a manager with a small or nonexistent performance fee to respond to the threshold as much as a manager with a higher performance fee. Similarly, if the manager has a small or nonexistent management fee, exceeding the threshold is even more important. Again I find evidence consistent with these predictions. These add additional causal evidence that the performance and risk-taking effects I estimate are being driven by the contracts themselves rather than implicit incentives from aspirations, reference point behavior, loss aversion, or relative performance contests.

Applying these findings to executives, the results suggest that guaranteeing compensation for members of the top management teams, which reduces the importance of performance pay, and granting them equity compensation and holdings in firms, which act like the management fee for fund managers in that managers compensation varies with both failure and success, would temper risk-taking when managers' option holdings are out of the money.

The organizational economics literature suggests additional reasons for heterogeneous responses. Reputational value is often an important implicit incentive for managers. Direct incentives provided by increasing a manager's ownership stake are also an often suggested solution to agency problems in firms. In the model, both of these incentives should have the same types of heterogeneous responses as the management fee. This is because these incentives do not vary depending on the manager's threshold. This leads to the predictions that reputation and ownership stakes should decrease risk-taking and mitigate performance declines when managers are below their thresholds. Multi-tasking arguments (Kerr 1975, Holmstrom and Milgrom 1991) suggest that managers with more incented choices of where to expend effort will reduce effort and thus performance more when incentives are reduced on the focal task. Put simply if a manager paid for both A and B has incentives for A reduced they will reduce effort on A more than if they were paid only for A. Using proxies for each of these predictions, I find variation in responses consistent with each of these theoretical predictions.

These results suggest that thresholds are a critical feature of incentive contracts and have important effects on a manager's behavior. I show that when these incentives are misaligned they can lead to meaningful and undesirable increases in risk-taking behavior. When thresholds are more distance managers perform worse. By exploiting a non-monotonic prediction, I also find evidence that suggests that risk-taking, not effort, may be the source of the majority of the performance effects I find. Finally, organizational features also contribute to the impact of contractual incentives. Reputational value and direct incentives moderate the risk-taking induced, while the decision to allocate effort among different tasks can magnify performance declines.

This paper makes several contributions to different streams of work. First, this paper provides strong casual empirical evidence that managers do take meaningfully more risk when they have incentives to do so. Second, the combination of findings on both risk and performance reinforces the importance of contracting research to examine multidimensional tasks and contracts. Third, I show that incentives for effort are important in complex jobs and that these incentives serve to induce managers to improve performance. Fourth, these findings plausibly extend to other contexts with similar contracts such as corporate executives. Fifth, these findings have significant policy implications towards risk-taking. Finally, the effects I estimate are economically large and suggest the importance of improving contracts in this context.

As discussed above, existing empirical research into risk taking faces many limitations. This paper addresses them in providing strong causal evidence that incentives do change behavior and lead to more risk-taking. The fixed-effect approach with fixed contracts and the exogenous movement of the effective incentives for risk-taking together provide a causal foundation for the findings. Explicit incentives allow examination of not only non-monotonic incentives, but also evidence that these responses are being driven by the terms of the contracts. I use direct and clear measures of risk-taking which are under the control of the manager. Finally, I present evidence that this extra risk is associated with worse performance.

This work also informs research on contract design. The high powered incentives I study were designed to induce effort and reward success. However, I show that while they do impact effort they also induce undesirable risk-taking. Indeed, my results suggest that the standard incentive answer to how to induce more productivity: increase incentives, has undesirable consequences because not only can managers work harder they can also take risk. The magnitudes of my findings suggest that ignoring such multidimensional response is a significant loss. These multidimensional agency problems deserve more attention by both empirical and theoretical approaches.

Practitioners have already begun experimenting with the contract design. Following the financial crisis in 2008 many hedge funds began experimenting with alternative contracts that allowed investors and managers to agree to move the fund closer to its threshold in exchange for a lower performance fees. Other funds instituted longer and rolling high-water marks so that managers would effectively remain closer to their thresholds. In other contexts, publically traded firms regularly reprice employee stock options following stock market declines by replacing an option for which the employee was far below the threshold to one in which the employee is at the threshold. For example, Google spent $460 million in 2009 resetting employee stock options.[6]

The performance effects I measure are also significant on their own. Murphy (1999) and Bloom and Van Reenen (2011) in surveys of the empirical incentive literature ask whether the strong causal evidence that incentives matter in simple jobs translate to more complicated jobs such as managers. They note that the literature has not answered this question with causal evidence. This paper provides that causal evidence. Even fund managers with complex jobs perform better when they have higher

[6] http://www.nytimes.com/2009/03/27/business/27options.html; http://www.cbsnews.com/2100-500395_162-4750463.html

incentives. Oyer and Shafer (2011) question the relative importance of incentives to lead managers to improve their output, or just to find the right managers. The scale of the performance effect I find addresses this question: explicit contractual incentives matter.[7]

The empirical context of this research is hedge fund management, but the implications are broader. Compensation for hedge fund managers and executives share a similar structure. I estimate that hedge funds realize 46% percent of their fees from option-like performance fees. By comparison, CEOs of public firms earn 51% percent of their total compensation from option pay. Indeed, CEO's compensation schemes may even be more "convex", because an additional 30% of total pay is in other incentive pay such as bonuses, long term incentive plans and equity (Anderson and Muslu, 2011). While executive compensation contracts may reflect executives power in setting their own compensation and "incentive" pay may not actually reward managers for shareholder performance, the incentives under the compensation schemes are quite similar. This similarity in the share of CEO option pay suggests that the thresholds provided by options are significant features of executive compensation schemes. More broadly, 80 percent of employee stock options are issues to non-executives and 9 million workers have stock options as part of their compensation scheme.[8] While the magnitudes may differ, all of these employees face the same incentives. Further, the job of a hedge fund manager though focused on financial transactions, involves many of the same tasks of a CEO. They review information, make decisions under uncertainty, and organize, motivate, manage and develop people and organizations. Though the discretion to directly take risk and the ability to influence performance may vary among managers, all managers have the ability to use both avenues in response to their incentive schemes.

These findings are important not only for the individual firms involved, but also inform policy. The recent financial crisis makes clear that risk-taking by firms is not only a private concern; it can have significant externalities on the economy as a whole. Compensation contracts have been the object of much regulatory attention, and this research reinforces its potential significance. Indeed, the structure of these incentive schemes has the potential to transform a transient negative shock into a persistent increase in risk-taking. Once the shock moves managers below their thresholds, they then take more risk and perform worse, which can perpetuate the process. Reshaping contracts has the potential not only to reduce total incentives for risk, but also arrest the propagation of negative shocks.

Finally, the cost of these imperfect incentives is high. To get a sense of the magnitude of the impacts I perform the following partial equilibrium hypothetical calculation. Suppose that the contracts were redesigned so that the threshold would reset following a loss so that the manager began each period always at their threshold, but in a way that did not impact incentives for managers who did not have a loss and thus were already at their thresholds, these results imply that performance would be higher by an average 1 percentage point per year. This is an annual cost of $20 billion to hedge funds' investors. If I assume that investors have a coefficient of risk aversion equal to one, the cost of the extra

[7] One way to compare the scale of these two effects is to compare the performance effect of incentives that I measure with the variation in performance. Fama and French (2010) provide a measure of the distribution of abilities for mutual fund managers. While these measures are in slightly different industries, the magnitudes of their results that moving a manager from 15% below their threshold to their threshold is equivalent to replacing an average manager with one in the 95th percentile of managers.

[8] "Taking Stock: Are Employee Options Good for Business?" http://knowledge.wpcarey.asu.edu/article.cfm?cid=8&aid=26

risk is $11 billion a year. These results also only evaluate the cost to the investors in the funds, not to society as a whole. To do that, I would need to know more about the nature of the transactions that have changed and their trading partners. Of course, simply resetting the threshold would presumably affect both how the managers behave in other periods and the selection of managers into these roles so this calculation should be thought of as only suggestive. However, this calculation suggests that if contracts could be designed to minimize the general equilibrium effects there is plenty of potential value for improved incentives.

The next section describes the conceptual framework and predictions. Section 3 describes the data and institutional context. Section 4 describes the empirical approach used to estimate the risk and average return consequences of being below the incentive threshold. Section 5 provides the primary results. Section 6 examines managers very far from their thresholds. Section 7 shows the differential effects of fees. Section 8 tests predictions from the organizational economics literature. Section 9 discusses mechanisms of risk-taking. Section 10 discusses robustness concerns and considers several additional pathways for these results. The last section concludes.

2. Conceptual Framework

The general conclusion that convex incentive schemes influence managerial risk-taking is not new. Classic incentive theory has linked options as an effective way to align managers and principals (e.g. Haugen and Senbet 1981) but at the cost of inefficient risk allocation (Jensen and Meckling 1976). More recently Vereshchagina and Hopenhayn (2009) argue that entrepreneurs facing a similarly shaped incentive scheme will choose higher risk projects. Hall and Murphy (2000 and 2002) directly consider the question of at what price options should be granted, but do not consider risk-taking as a consequence. Other research has looked at risk-taking incentives but does not consider the placement of the incentive threshold. Carpenter (2000) finds that additional options may reduce risk-taking, because risk aversion may dominate the additional convex incentives. Panageas and Westerfield (2009) focus on the dynamic ratcheting of thresholds in hedge funds and show that the value of future periods reduces risk-taking. In this section I develop some predictions on the consequence of the distance to the threshold in threshold incentives. I focus specifically on how distance to the threshold changes the manager’s risk-taking and performance.

To do this, I first formalize a stylized model of the decision a manager makes between projects with threshold incentives. This formal model is helpful to fix ideas as well as formally develop empirical predictions. The manager simultaneously chooses an effort level where higher effort increases the mean of the distribution of outcomes at a private cost and a binary risk level. The higher risk project differs from the low risk project in two ways. First, extreme outcomes are more likely. Second, for any given level of effort the high risk project produces lower expected performance than the low risk project.[9]

[9] Though this stylization is not in line with the usual assumption that higher risk yields higher return, it is consistent with the decisions a manager has available, and might exercise, given convex incentives (Palomino and Prat, 2003). See the appendix for some additional discussion.

To formalize this stylization, the agent chooses effort level $e \in [0, \infty)$ at cost $c(e) = e^2/2$. The agent also chooses either low or high risk , $r \in \{l, h\}$. A decision is a pair (e, r), and yields the following outcome x.

$$\text{If } r = l \text{ then, } x = \begin{Bmatrix} e + \epsilon, with\ probabiltiy\ \frac{1}{2}, \\ e - \epsilon, otherwise \end{Bmatrix}$$

$$\text{If } r = h \text{ then } \ x = \begin{Bmatrix} e - q + k\epsilon, with\ probabiltiy\ \alpha, \\ e - q + \epsilon, with\ probabiltiy\ \frac{1}{2} - \alpha, \\ e - q - \epsilon, with\ probabiltiy \frac{1}{2} - \alpha\ , \\ e - q - k\epsilon\ otherwise \end{Bmatrix}$$

Where $\epsilon > 0$ is spread of the low risk project. The high risk project spreads α of probability from each of the low risk outcomes to outcomes $k > 1$ times more extreme, and reduces the value of all outcomes by $q \geq 0$. In other words, q, is the expected performance cost of risk-taking. q can be thought of as the manager's type, or ability to efficiently take risk.

The manager in my model is opportunistic and risk-neutral, and the manager's compensation scheme is an exogenous, convex, two part linear contract. The contract pays the manager a share of the performance of the project (base rate) and a share of the performance of the project above a threshold (performance rate). For an executive the base rate would reflect his equity holdings and the performance rate would reflect options.[10] For a fund manager these reflect the base or management fee and the performance or incentive fee respectively. Formally, the compensation of the manager for realized outcome x is:

$$\pi(x) = bx + \max\{0, p(x - (a + d))\}$$

Where $b > 0$ is the base rate, $p > 0$ is the performance rate, and d is the manager's distance below the threshold.

Assumptions:

1a) $d \geq 0$

1b) $\epsilon > b + p$

1c) $k > \frac{b + \frac{1}{2}p}{2\epsilon} + 1$

Assumption 1a restricts attention to cases where the manager begins at, or below, the threshold, which is the empirical context of this work. Assumption 1b ensures that the low risk project entails enough uncertainty that the manager is not so good an improving outcomes that they would never put in enough effort to ensure that even the "failure" outcome of the low risk project exceeds the threshold. Assumption 1c ensures that the high risk project is enough riskier than the low risk project.

[10] In a one period game the level of fixed compensation provides no incentives so I ignore it. The base rate can equally be thought of as expected (linear) increases in future compensation conditional on this period's performance.

Characterization of the manager's decision requires solving the manager's effort decision under different risk levels and comparing the expected compensation less costs from that process. This results in four potential choices.

Lemma 1: Under assumptions 1a and 1b[11] *the manager chooses between one of four projects:*

1) *The "Low Risk Low Effort" choice of* $(e, r) = (b, l)$ *and expected payoff:*

$$\Pi_{LowRiskLowEffort} = b(b) - \frac{b^2}{2}$$

2) *The "Low Risk High Effort" choice of* $(b + p/2, l)$*, and expected payoff:*

$$\Pi_{LowRiskHighEffort} = b\left(b + \frac{p}{2}\right) + \frac{p}{2}\left(b + \frac{1}{2}p + \epsilon - d\right) - \frac{\left(b + \frac{1}{2}p\right)^2}{2}$$

3) *The "High Risk Moderate Effort" choice of* $(b + \alpha p, h)$ *and expected payoff:*

$$\Pi_{HighRiskModerateEffort} = b(b + \alpha p - q) + \alpha p(b + \alpha p - q + k\epsilon - d) - \frac{(b + \alpha p)^2}{2}$$

4) *And the "High Risk High Effort" choice of* $(b + p/2, h)$*, and expected payoff:*

$$\Pi_{HighRiskHighEffort} = b\left(b + \frac{p}{2} - q\right) + \frac{p}{2}\left(b + \frac{p}{2} - q + \epsilon - d\right) + \alpha p(k-1)\epsilon - \frac{\left(b + \frac{p}{2}\right)^2}{2}$$

Proof: See Appendix.

The logic of this is straight forward. The effort level chosen depends on the probability of reaching past the threshold. This leaves only a finite set of effort levels to consider. The condition on ϵ ensures that the manager does not want to exert enough effort to ensure that even bad outcomes exceed the threshold.

Result 1: Under assumptions 1a, 1b, and 1c,

1) *The manager prefers the "Low Risk High Effort" choice if and only if:*
   a. It is preferred over Low Risk Low Effort: $b + \frac{1}{4}p + \epsilon > d$,
   b. It is preferred over High Risk High Effort: $\frac{\alpha p(k-1)\epsilon}{b + \frac{1}{2}p} < q$, and
   c. It is preferred over High Risk Moderate Effort: $\frac{q\left(\frac{b}{p} + \alpha\right)}{\left(\frac{1}{2} - \alpha\right)} + (b + \epsilon) + \left(\frac{1}{2}p\right)\left(\frac{1}{2} + \alpha\right) - \frac{\alpha}{\left(\frac{1}{2} - \alpha\right)}(k-1)\epsilon > d$
2) *The manager prefers the "High Risk High Effort" choice if and only if:*
   a. It is preferred over Low Risk High Effort: $\frac{\alpha p(k-1)\epsilon}{b + \frac{1}{2}p} > q$
   b. It is preferred over High Risk Moderate Effort: $\frac{1}{2}p\left(\frac{1}{2} + \alpha\right) + (b - q) + \epsilon > d$
3) The manager prefers the "High Risk Moderate Effort" choice if and only if:

[11] These are sufficient assumptions, stricter than the necessary ones.

   a. It is preferred over Low Risk High Effort: $\frac{q\left(\frac{b}{p}+\alpha\right)}{\left(\frac{1}{2}-\alpha\right)}+(b+\epsilon)+\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)-\frac{\alpha}{\left(\frac{1}{2}-\alpha\right)}(k-1)\epsilon<d$
   b. It is preferred over High Risk High Effort: $\frac{1}{2}p\left(\frac{1}{2}+\alpha\right)+(b-q)+\epsilon<d$
   c. It is preferred over Low Risk Low Effort: $-q\left(1+\frac{b}{\alpha p}\right)+\left(b+\frac{\alpha p}{2}+k\epsilon\right)>d$

4) The manager prefers the "Low Risk Low Effort" choice otherwise, that is, if and only if:
   a. It is preferred over High Risk Moderate Effort: $-q\left(1+\frac{b}{\alpha p}\right)+\left(b+\frac{\alpha p}{2}+k\epsilon\right)<d$
   b. It is preferred over Low Risk High Effort: $b+\frac{1}{4}p+\epsilon<d$

Proof: This follows directly from comparing expected compensation. See appendix for details of these and other results and corollaries below.

Taken together these conditions completely characterize the decision a manager makes. Figure 2 illustrates this. The horizontal axis represents the manager's ability to take risk where a manager with a higher q faces a bigger performance cost of risk taking. The vertical axis is distance below the threshold so that the top of the figure represents managers near their threshold and those at the bottom are far away. A manager in the top left corner faces a small performance cost of risk and strong effort incentives so choose high effort and the high risk project. The managers in the top right of the figure face similar effort incentives, but with a higher performance cost of risk, so choose the low risk level. The managers in the bottom right region are far from the threshold and face high enough performance costs of risk taking to prefer the low risk project and low effort. The managers in the middle left choose a lower effort level than those above them, but since this risk level gives them some chance of reaching past the threshold they choose a moderate level of effort.

The long-dashed blue line (from 1b and 2a in Result 1) between High Risk High Effort and Low Risk High Effort is the dividing line between managers who are both putting in high effort and deciding between the low risk and high risk project. The solid red line (1a, 4b) between Low Risk High Effort and Low Risk Low Effort is the effort decision of a manager whose performance cost of risk is high enough that the manager only considers the low risk project. The short-dashed green line (2b, 3b) divides High Risk High Effort and High Risk Moderate Effort. Since these two choices have the same risk level, this reflects an effort decision. As the manager moves away from the threshold the incentives for effort are reduced. The green line slopes with the performance cost of risk because a manager with a higher performance cost of risk is effectively farther away from the threshold. The triple dashed purple line (3c, 4a) divides High Risk Moderate Effort from Low Risk Low Effort. As the manager moves farther from the threshold their incentives for effort reduce further and move towards low effort. However, at this distance from the threshold high risk low effort does not reach the threshold and the manager chooses the low risk project to avoid the performance cost of risk. The purple line slopes with the performance cost of risk not only because high performance cost of risk means that managers are effectively farther from the threshold, but also because high performance cost of risk makes the low risk choice more appealing. The double-dashed orange line (1c, 3a) divides High Risk Moderate effort from Low Risk High

Effort. As a manager in the low risk high effort area moves away from the threshold risk becomes more appealing, especially for those with relatively smaller performance costs of risk. However, these managers, once they choose to take risk and are relatively farther away from the high incentive region choose to undertake a lower level of effort.

However, the focus of this research is how distance to the threshold influences the risk-taking and performance of managers. To answer this requires understanding how risk taking and performance move with d, the distance to the threshold.

Result 2: As distance below the threshold increases, if the threshold is not too distant ($b + \frac{1}{4}p + \epsilon > d$):

1) *Risk-taking increases.*
2) *Effort falls*

Corollary 2.1: As distance below the threshold increases, if the threshold is not too distant, performance falls.

The line $b + \frac{1}{4}p + \epsilon$ is the solid red line in Figure 2 that divides the Low Risk High Effort Region from the Low Risk Low Effort region. The condition to be above this line ensures that the threshold is attainable even with the low risk project. Result 2 follows from reading the graph. Managers with low performance cost of risk (q) are already taking risk and do not change, but those with relatively higher performance costs of risk choose to move from High Risk High Effort to High Risk Moderate Effort because they benefit less from the extra effort. Managers with intermediate performance cost of risk shift from Low Risk High Effort to High Risk Moderate Effort, increasing risk-taking and reducing effort. Managers with high performance cost of risk do not change their behavior. Performance falls both because of increased risk-taking and reduced effort.

The empirical implications are also straight forward, because of the asymmetry between wins and losses, increasing the distance to the threshold increases risk-taking and decreases expected effort. Put differently, the farther a manager is below their threshold the marginal return to risk-taking increases and so risk-taking would increase. Similarly, the marginal return to mean-improving effort decreases so we would expect the average performance to fall. Further, with the stylized assumption that increased risk-taking lowers average performance, even if effort were unchanged, we would expect average performance to fall. Since effort is also decreasing, we expect average performance to fall.

Result 3: As distance below the threshold increases, if the threshold is distant ($b + \frac{1}{4}p + \epsilon < d$):

1) *Risk-taking falls.*
2) *Effort falls*

Corollary 3.1: As distance below the threshold increases, if the threshold is distant, the net performance effect depends on the performance cost of risk-taking. If that cost is large, performance improves.

This result again follows from Figure 2. Managers with very small performance cost of risk-taking at distances near the red line shift between High Risk High Effort to High Risk Moderate Effort. Those same types of managers very distant from the threshold shift from High Risk Moderate Effort to Low Risk Low Effort. Thus these managers reduce effort, and if very far from the threshold reduce risk-taking. Managers with low or moderate performance costs of risk-taking shift from High Risk Moderate Effort to Low Risk Low Effort, thus reducing effort and risk-taking. Managers with high performance cost of risk-taking shift from Low Risk High Effort to Low Risk Low Effort leaving risk unchanged.

The net performance effect of being very far from the threshold depends on the importance of the performance cost of risk-taking compared to the impact of effort on performance. The reduced risk-taking should improve performance, but the reduced effort should reduce performance. Empirically, if the performance cost of risk-taking is small, then there should not be a big difference in the impact of distance on performance between moderately far and being very far distances. However, if the performance cost of risk-taking is large there should be a sizable difference; the effect of distance on performance when very far from the threshold should be much smaller, or even positive, if risk-taking has a large performance cost.

The magnitude of the manager's changes in risk-taking and performance to distance below the threshold may also depend on the parameters of the compensation contract. This leads to the next set of results, which ask how the changes in effort and risk taking change with the compensation contract. However, one more assumption is necessary. All the previous results hold for any arbitrary type q. That is the results hold weakly for all types. However, the effects of the contract terms will vary depending on the manager's ability to take risk, or their type, q. In order to produce empirical predictions about aggregate behavior, the distribution of types must be specified. Assumption 2 moves the model to one which considers the aggregate behavior of managers. For simplicity, it assumes that managers are uniformly distributed in their ability to take risk.

Assumption 2: q is distributed according to $F(q)$ and is independent of all other model parameters. Further, $F(q)$ is uniform on $(0, \overline{q})$.

Result 4: Under assumptions 1(a-c) and 2, and the threshold is not too distant:

1) *The rate of increase in risk-taking with distance increases with the performance rate.*
2) *The rate of decrease in effort with distance increases with the performance rate.*

Corollary 4.1: Under assumptions 1(a-c) and 2, and the threshold is not too distant the rate of decrease in observed performance with distance increases with the performance rate.

Increasing the performance rate makes changes in the distance to the threshold more important. Managers with a low performance rate should not respond meaningfully to the threshold because there is little difference in compensation structure above and below the threshold. Following this logic, managers with higher performance rates should be more responsive. Empirically, the effects from Result 2 should be magnified with higher performance fees.

Result 5: Under assumptions 1(a-c) and 2, and the threshold is not too distant:

1) The rate of increase in risk-taking with distance decreases with the base rate.
2) The rate of decrease in effort with distance decreases with the base rate.

Corollary 5.1: Under assumptions 1(a-c) and 2, and the threshold is not too distant the rate of decrease in observed performance with distance decreases with the base rate.

The logic of this is a bit more subtle. Higher base rate managers are less likely to take risk when moved from the threshold because they face more of the performance cost. There is not a direct interaction between the higher base rate and the effort decision, since the base rate provides the same incentive for effort regardless of distance. However, because these managers are less likely to shift to the High Risk Moderate Effort choice from the Low Risk High Effort choice they are more likely to maintain high effort levels. Empirically, this suggests that the magnitudes of the risk-taking and performance predictions of Result 2 would be moderated by the base rate.

Organizational Moderators

The organizational economics literature provides several additional factors that influence the responsiveness of managers. Here I explore predictions of how direct ownership, reputations, and task-design each affect the responsiveness of managers to their thresholds. The organizational economics literature often considers these factors separately from explicit incentives, but in this context I explore how the organizational features interact with the explicit incentives. The results suggest that some forms of organizations might be more resilient to the misalignment of incentive thresholds, as well as some cautionary factors that may magnify responsiveness.

The first factor I consider is direct ownership. The principal-agent literature has long acknowledged that, absent risk aversion, direct ownership by the agent is a first-best solution to the agency problem. Indeed, the literature has developed to explain contexts where direct ownership is infeasible or subject to some other negative consequence. Managers, however, often own significant shares in the firms they manage. Entrepreneurs and founders generally retain large shares in their ventures. Other managers may amass large holdings through equity compensation. In the hedge fund context, hedge fund managers are often large investors into the hedge funds they manage, either from initial investment much like firm founders or from subsequent investment of earnings. Different investment levels would lead to differing responses. From the conceptual framework these investments function like the base rate and the predictions of Result 5. The manager receives directly all the gains and losses to the investments, without regard to the threshold. To the extent that their own investment returns drive their behavior rather than the potential fees, we should see funds with larger manager's capital respond less to being below their thresholds. That is, risk increases and average performance drops should be smaller.

Reputation is well developed as an important incentive mechanism in organizations. Conceptually, we would expect managers and firms with more valuable reputations to protect these intangible assets and not to increase risk as much when below their incentive threshold as those with less valuable reputations, while the differential effect on effort would be small. This logic follows from the same argument regarding the base rate in Result 5. A valuable reputation makes riskier, even negative expected valued, choices less attractive because of the harm to reputation. However the value of marginal effort on increasing the average performance is not as clearly affected. Indeed, following the argument above about the base rate, the interactive effects on performance are driven by the direct effect on performance of risk-taking.

Task allocation is also an important organizational consideration. One result of the classic multitasking literature (Holmstrom and Milgrom 1991) is that when incentives are reduced for one task then an agent with a second incentivized task will reduce effort more on the first task than and agent without a second incentivized task. In this context, the implication on average performance is straight forward: managers with more incentivized tasks will have bigger drops in performance when their incentives are reduced. On the other hand, implications for risk-taking are less clear. To the extent that changing the level of risk is a decision, rather than something that takes effort, we should expect task allocation to have little direct impact on risk-taking**.** Indirectly, lower average performance effectively means a greater distance to the threshold so the second order effect would be more risk-taking. Table 1 provides a summary of the empirical predictions.

3. Industry and Context

The setting for this study is the hedge-fund industry. In this industry hedge fund managers are paid fees to make investments with investor's assets. Each hedge fund is a standalone private investment vehicle with hedge fund management firms as general partners and high net worth individuals and institutional investors as limited partners. Hedge funds face minimal regulatory constraints and managers are free, unlike other asset managers such as those who manage mutual funds, to make almost any investments, including derivatives, short sales, leveraging and private transactions. Hedge funds identify an investment strategy that broadly identifies the sort of assets the fund will invest in, the sort of profit opportunities that the manager will pursue, and the risk exposure that the fund will accept. In this research I view these categorizations as much like industry classifications; they identify that within strategy firms face similar exogenous factors that influence performance.

Hedge fund management firms earn revenue from fees paid from the assets of investors. These fees are composed of a management fee and a performance fee. The management fee pays the manager a percentage of fund assets each year. Management fees are usually between 1 and 2%. On average, the performance fee pays the manager a substantially larger share of the profits the fund makes than the management fee. The most common performance fee rate is 20%. Because the performance fee is calculated on profits, sometimes above a benchmark rate, it provides the threshold in the incentive structure. The details of this performance fee are central to my analysis and I discuss it in detail in the context of my empirical approach. While the internal organization of the management firms vary, all are known for high powered incentives that tie compensation of the individuals in the firm quite closely to fees and performance. Each hedge fund generally has a single individual within the management firm known as the portfolio manager responsible for ultimate investment decisions. These fund managers are usually owners or partners in the management firm.[12]

Much of the existing research on hedge fund risk-taking and performance is descriptive and cross-sectional in nature. Ackermann, McEnally, and Ravenscraft (1999) describe hedge fund risk, return and fee profiles. Agarwal and Naik (2004) focus on identifying market factors that are relevant to explaining hedge fund performance and risk exposures. Agarwal, Daniel, and Naik (2009) correlate a measure of marginal fees with expected outcomes. Kouwenberg and Ziemba (2007) correlate fee rates and various measures of risk-taking. Like Chevalier and Ellison (1997), Brown, Goestzmann, and Park (2001) focus on intra year changes in risk-taking following good absolute and relative performance, but do not consider the contracts explicitly. Similarly, Holland, Kazemi, and Li (2010) correlate performance in the first half of the year and changes in risk-taking. Smith (2011) looks at how investors respond to idiosyncratic risk-taking by managers.

I use a dataset of month assets and returns of about 9,000 hedge funds from 1994 through 2006. This dataset was compiled by merging data on hedge funds from Lipper-TASS and Hedge Fund Research. Each of these datasets retain data on funds even once they stop reporting. While exact measures do not exist, these datasets are together estimated to include about a quarter of the entire hedge fund industry. In addition to the monthly assets and returns in these datasets, I use data about the fee structures of the funds and self-classification of the funds into 34 categories that reflect their investment strategies and exposure. One limitation of these sources of data is that the data are self-reported, presumably for self-interest. This leads to several potential selection concerns. These results, however, are robust to these concerns and are more fully discussed in Section 9.

4. Empirical approach

My empirical approach focuses on the performance fee and the role of the high-water mark. The high-water mark is the threshold in the calculation of the performance fee. Managers share only in the returns of a fund above the high-water mark. It is calculated so that the manager is not paid a performance fee for recouping previous loses. At the end of each year managers are paid any performance fees they have earned and the high-water mark is adjusted for this payment. Figure 3 illustrates this. The red line identifies the cumulative return of a hypothetical hedge fund. At the end of 1994 this fund is 8% below its high-water mark and not paid a performance fee. In this event, the fund is considered to have a *Distance* of 8%. At the end of 1995, however, this fund is paid a performance fee because returns exceed the previous high-water mark and its high-water mark ratchets up. High-water marks are tracked individually for each investment into the fund, so each vintage of assets may have a different high-water mark. In the example of Figure 3 investments made at the end of 1994 are at their high-water mark when they are made, but older vintages are not. Because managers cannot make separate investment decisions for separate vintages, I use an asset weighted average of the distance to the threshold. So in the example of Figure 3, if the fund at the end of 1994 was composed equally of two

[12] Because the data I use does not include information about the decisions of the manager separate from the ultimate actions of the management firm I cannot distinguish between actions of the individual or of the firm. However, the strong internal incentives suggest that in this context the two are closely aligned. These results can be fairly interpreted as either about the individuals' decisions or the firms' response.

vintages, one from the end of 1993 and one from the end of 1994, I would average the distance and treat this fund as if it is 4% below its high-water mark.

The implementation of this calculation depends on the returns the fund experiences as well as the flow of assets in and out of the funds. Returns are directly reported in the data, but funds do not report asset flows. Instead, I use reported assets to impute net flows of assets. I treat net inflows as new vintages and allocate net outflows proportionally across previous vintages. I discuss potential concerns of this source of measurement error in Section 7.

The formal calculation of how far a fund is from its threshold follows. Let r_{it} represent the return of fund i in period t. Note represent the initial period of fund i as t_{0i} Let $CR_{it} = \Pi_{j=t_{0i}}^{t}(1+r_{ij})$ be the cumulative return to period t. The high-water mark of investments of vintage v is $HWM_{ivt} = \max(CR_{iv}, CR_{iv+1} \ldots CR_{it})$. To aggregate each vintage's high-water mark, I measure how far from the threshold as $Distance_{ivt} = \frac{HWM_{ivt}-CR_{it}}{CR_{it}}$ or what percentage growth is needed to bring that vintage to its high-water mark. To aggregate vintages, I weight each vintage by its share of assets. Let In_{iv} be the dollar inflows in period v. Let Out_{iv} be the outflows in period v as a percent of assets. So the assets remaining in vintage v at time t is $A_{ivt} = In_{iv}\left(\frac{CR_{it}}{CR_{iv}}\right)\left(\Pi_{j=v+1}^{t}(1-Out_{ij})\right)$. Note that by construction the assets of fund i at time t is $A_{it} = \sum_{v=t_{0i}}^{t} A_{ivt}$. Then, weighting vintages by assets: $Distance_{it} = \sum_{v=t_{01}}^{t}\left(Distance_{ivt} * \frac{A_{ivt}}{A_{it}}\right)$. How this depends on the underlying data is clearer with some expansion:

$$Distance_{it} = \sum_{v=t_{0i}}^{t}\left(\frac{\max(CR_{iv}, CR_{iv+1} \ldots CR_{it}) - CR_{it}}{CR_{it}} * \frac{In_{iv}CR_{it}\left(\Pi_{j=v}^{t}(1-Out_{ij})\right)}{CR_{iv}\,A_{it}}\right) \tag{1}$$

Risk-taking of the funds is measured as the realized variance of the fund's monthly returns and return is the net return of the fund, both over the following year.[13] A year is the natural length of time over which to measure response because that is the period until the next payment of performance fees, but the results are robust to shorter and longer measurement periods of 6 months and 24 months.

Using this calculated $Distance$ suggests the basic, fixed effect regressions of the form:

$$Risk_{it+1} = \beta_1 Distance_{it} + \lambda X_{it} + \delta_i + \gamma_t + \epsilon_{it+1} \tag{2}$$

Where X_{it} are linear and curvature terms for assets and age, δ_i are fund fixed effects, γ_t are time fixed effects, and each period is a year. Empirically, the fund fixed effects are important. They make the analysis within a fund so that the effects are not driven in differences between funds or managers. Time varying age and asset controls are included to capture any systematic differences in risk or return that are due to fund age and size. In order to capture the non-linearities in these described in the literature, I include both linear and curvature terms for assets and age. Similarly, to examine the return consequences, I use:

[13] This measure of risk-taking measures realized risk and not intended risk directly. See Section 9 for some discussion.

$$Return_{it+1} = \beta_2 Distance_{it} + \lambda X_{it} + \delta_i + \gamma_t + \epsilon_{it+1} \tag{3}$$

However, there are several endogeneity concerns in both the return history of a fund and the fund flows that together go into calculating how far a fund is from the threshold. Consider the return history of a fund chooses a higher return, higher volatility risk profile in period 2. This increases the probability that it is below its high-water mark at the end of period 2 and increases the distance below the high-water mark that it is. This also increases the realized volatility and performance in period 3. Because the fund pursued a different risk profile in period 1 these differences are not absorbed by the fund fixed effect.

To address this concerns, I use an instrumental variable approach in which I instrument for $Distance_{it}$ with how far from the threshold a hedge fund in the same strategy would be expected to be based on exogenous variation, $\overline{Distance}_{it}$. $\overline{Distance}_{it}$ is based on a synthetic high-water mark that does not depend on the time varying choices of the manager or the fund specific funding decisions of investors. As is shown in equation (1) above $Distance_{it}$ is a function of the return history of a fund and the flows it experiences. I calculate $\overline{Distance}_{it}$ using the same formula, but with exogenous return histories and flows.

Instead of the endogenous return history of a fund, I use the performance of 15 market "factors". These factors represent the returns to indexes of various market baskets. The factors reflect both the performance of equity markets (Fama and French 1993) as well as additional factors found to be important in explaining the returns of mutual funds (Carhart 1997) and hedge funds (Fung and Hsieh 2004). For each fund strategy I regress the monthly return of the funds in that strategy on the monthly performance of the market factors. That is, I estimate:

$$Return_{it} = \alpha_s + \beta_{sj} Factor_{jt} + \epsilon_{it} \tag{4}$$

Then, using the estimates $\widehat{\alpha_s}$ and $\widehat{\beta_{sj}}$ I calculate the predicted return of strategy s in time , r_{st}:

$$r_{st} \equiv \widehat{\alpha_s} + \widehat{\beta_{sj}} Factor_{jt} \tag{5}$$

The predicted values from this regression capture the return of a hypothetical "passive" hedge fund in each strategy that does not make time varying investment decisions.

From r_{st} I calculate the return and variance of a passive hedge fund would experience in each outcome period. I use these to control for changes in the opportunity set of investments available, including, for example cyclicality in strategy returns. Additionally, I use this to estimate the risk increases that a passive fund would experience. If there is persistence or cyclicality in the performance and risk characteristics of underlying assets beyond that absorbed by time fixed effects, as for example Carhart (1997) demonstrated, then using the variation driven by these factors makes controlling for the risk and return that is driven by market factors particularly more important.

The fund flows that a fund experiences are another source of endogeneity. When investors decide to invest additional assets in a fund it experiences in-flows. When investors withdraw assets, a fund experiences redemptions, or out flows. Collectively, these additional investments and redemptions are called fund "flows." Suppose that the flows a particular fund experiences reflect investors' beliefs about the future performance of the fund. Also, suppose that investors believe that a fund with recent poor performance will experience low risk returns in the next period. If investors add funds to this fund at the end of this period then it will be less underwater than it would have been and, if those beliefs were correct, realized risk would be lower. Thus, the correct beliefs would produce a correlation between distance to the threshold and realized risk.

To replace flows, I use the flows of funds that identify themselves as "Fund of Funds", which I exclude from the analysis otherwise. These funds aggregate and allocate investments into other hedge funds. The flows they experience proxy for the general availability of funds to the industry that are not a consequence of the beliefs of investors about the future performance of particular funds or of their strategies. Indeed, these flows directly induce flows of specific strategy funds but are likely also to be correlated with general capital availability. Thus, these flows are correlated with flows into individual funds but are not correlated with flows that reflect beliefs about individual funds or strategies. For each of these funds I calculate the average percentage inflows In_{FoFt} and outflows Out_{FoFt}. Combining the two exogenous sources of variation, I calculate the synthetic $\overline{Distance}_{it}$ by replacing the actual return r_{it} with r_{st} (and CR_{it} with the analogue CR_{st}) and in and out flows with In_{FoFt} and Out_{FoFt}. That yields:

$$\overline{Distance}_{it} = \sum_{v=t_{0i}}^{t} \left(\frac{\max(CR_{sv}, CR_{sv+1} \dots CR_{st}) - CR_{st}}{CR_{st}} * \frac{In_{FoFv} CR_{st} \left(\Pi_{j=v+1}^{t} \left(1 - Out_{FoFj}\right)\right)}{CR_{sv} \ \sum_{k=t_0(i)}^{v} \left(\frac{In_{FoFk} CR_{st}}{CR_{sk}} \left(\Pi_{j=v}^{t} \left(1 - Out_{FoFj}\right)\right)\right)} \right) \tag{6}$$

Despite the apparent complexity of this formula it has a simple interpretation. It is the $Distance$ of a fund that had the same initial period as the fund, experienced the average flows of funds of funds, and had the returns that reflected the average exposure of its strategy to market factors.

With the calculated $\overline{Distance}_{it}$, I estimate the first stage regression[14]:

$$Distance_{it} = \beta \overline{Distance}_{it} + \lambda X_{it} + \delta_i + \gamma_t + \epsilon_{it} \tag{7}$$

Which yields $\widehat{Distance}_{it}$ as its predicted value that I then use to estimate the second stage regressions:

$$Risk_{it+1} = \beta_1 \widehat{Distance}_{it} \ + \lambda X_{it} + \delta_i + \gamma_t + \epsilon_{it+1} \tag{8}$$

$$Return_{it+1} = \beta_1 \widehat{Distance}_{it} \ + \lambda X_{it} + \delta_i + \gamma_t + \epsilon_{it+1} \tag{9}$$

Indeed, it is illustrative to consider a few of the market factors that lead the instrument to be below from the threshold. The Managed Futures and Global Macro strategies were below their

[14] Note that because $Distance$ is a non-linear calculation based on the endogenous primitives (return history and flows) the exogenous primitives should not be used directly in an instrumental variables approach. Instead, I calculate $\overline{Distance}$ from plausibly exogenous instruments and use it in a linear first stage in the instrumental variables approach (see, e.g. Angrist & Pischke, 2008, Chapter 4).

thresholds in 1994, presumably, because of the spike in interest rates.[15] Similarly, in 1998 emerging market funds were below their thresholds because of the crash in emerging market returns. However, some regional emerging market strategies were much more affected than others. The technology crash in 2000 and the market wide downturn in 2002 are also significant downward shocks that cause strategies to be below their thresholds. Again, despite affecting a wide range of strategies, the different exposures provide variation in how far different strategies are from their thresholds. Each of the listed market factors cause some strategies to be below their thresholds. By using these downturns as instruments I treat all funds in exposed strategies as being below their thresholds. One advantage of the instrumental variable approach is that it does not conflate the difference in the performance of funds that may have planned for the downturns and those that did not.

Beyond the average treatment effect the model also includes predictions of heterogeneous treatment responses. The empirical approach to examine these is to add interaction terms to the specifications in equations (2) and (3) interaction terms. In each of the following I interact some characteristic of the fund $Characteristic$ with $Distance$. So to equations (2) and (3) I add $\beta_2 Characteristic_i * Distance_{it}$. Because of the same endogeneity concerns in both $Distance_{it}$ and $Characteristic_i * Distance_{it}$, I also use an instrumental variable approach in these regressions with $\overline{Distance}_{it}$ and $Characteristic_i * \overline{Distance}_{it}$ as excluded instruments and refine (8) and (9) appropriately. If the heterogeneous characteristic is time varying, I use $Characteristic_{it}$ instead of $Characteristic_i$ and include the direct effect $Characteristic_{it}$ in the regressions.[16]

5. Primary Results

The first prediction is that the farther managers are from their threshold, the more risk they will take. Figure 4 shows the smoothed relationship between the risk-taking of a manager with the distance they are below their high-water mark, restricted to managers that are not extraordinarily far from their thresholds. The horizontal axis is the distance below the high-water mark the manager is as described above. The vertical axis is the variance of fund returns in the following year. The plotted points are non-parametric fitted values after including fund and year fixed effects and controls for age, age-squared, assets under management, and log assets under management. From this we see the fundamental result – the farther the manager is from the threshold the more they increase risk.

Table 2 takes this same approach on the effect of the distance a fund manager is below their high-water mark where we can put standard errors and control for endogeneity. The first four columns of Table 2 examine the question of increased risk taking. Columns (1) and (2) are OLS regressions, with the fund and time fixed effects and controls for age, age-squared, assets under management, and log assets under management. Column (2) includes controls for the return and variance of the passive comparison. With the fixed effects the interpretation of columns (1) and (2) is that a fund with assets equal to half of its high-water mark, and thus a distance of 100% has a variance of 0.0040 more (an amount equal to the average variance) than that fund has when it is at its high-water market. However,

[15] http://money.cnn.com/magazines/fortune/fortune_archive/1994/10/17/79850/index.htm

[16] If $Characteristic_{it}$ is not time varying the main effect is not included since it is absorbed by the fund fixed effects.

even when below their thresholds, funds are rarely that far from their thresholds. The mean distance for funds that are below their thresholds is 15%, implying that these coefficients suggest an increase in risk-taking of 15%.

As described above there are a number of endogeneity concerns with in this approach. Columns (3) and (4) implement the instrumental variables strategy described in section 4. The two stage least squares (2SLS) columns instrument for a fund's distance from its high-water mark using a calculation based on the history of returns for the same portfolio of market factors, the history of asset flows of Funds of Funds, and the fund's inception date as discussed in the empirical approach section above. In this sense, the instrument captures the distance the fund is expected to be below its high-water mark because of the performance of its strategy – not any time varying decisions of its own, or of its investors. The fund fixed effects absorb any time invariant effect of fund inception.

Column (3) shows that when instrumenting for high-water the estimated risk increase is 0.013, or more than three times the average variance. By a similar calculation, the estimated effect on the average underwater fund is an increase in risk of 50% of the average variance. Controlling for the variance of the strategy in that period in column (4) finds a significant, but smaller effect suggesting that market risk increases in periods when managers are below their thresholds. This difference is further discussed in section 8. Both specifications show sizable increases in risk.[17] The coefficient estimates from the 2SLS specifications are larger than the OLS estimates. One explanation for this difference is that the endogeneity of $Distance$ causes some managers to appear to be below their threshold, but they act like they are at it. For example, if a manager borrows capital to arbitrage a mispriced asset they appear to perform poorly until markets adjust. Another potential cause of the larger estimates from the 2SLS specifications is that classical measurement error in the measurement of $Distance$ is corrected for with the IV.

The second prediction is that the farther managers are from their thresholds the worse they will perform. The next four columns look at performance in terms of annual return. The OLS results in Columns (5) and (6) show insignificant increases in performance before addressing endogeneity concerns. This is consistent with mean reversion where funds that have lost money (and thus are below their high-water mark) perform better the following period.[18] Considering the OLS results suggests that being underwater appears to have no correlation with performance or perhaps is even correlated with a very slight increase in performance. Columns (7) and (8) address the endogeneity concerns. In column (7) we see a small, but insignificant decrease in expected returns when below the high-water mark. However, given the potential for cyclical returns to strategies, controlling for the performance of the strategy is an import baseline. The effect of being underwater is larger in column (8). The difference between columns (7) and (8) implies that strategies have higher returns in periods following when the

[17] These specifications include all managers, even those that are very far from their thresholds. If the non-monotonic prediction of Result 3 holds, which I find in the next section, it suggests that these results underestimate the impact for most managers.

[18] This is also consistent with a mechanical effect of fees. A fund that is below its threshold will not asses performance fees until it reaches its high-water mark. Without the fee drag, performance is higher. Similarly volatility is also higher. See robustness check regarding net vs gross fees in Section 10.

strategies are likely underwater.[19] However, unlike the risk-taking analysis there are several reasons to prefer specification (8) over specification (7). First there is cyclicality in the returns of various strategies and this should be controlled for. Second, from a performance evaluation perspective controlling for the passive opportunity set is important to distinguish actions taken by the manager from the market performance.[20] The coefficient in column (8) is large – it implies that annual returns are 14 percentage points lower for that fund with assets equal to half their high-water mark and 2.1 percentage points for the mean fund below its threshold. While these estimated effects are large, they are consistent with other findings in the literature. Agarwal, Daniel, and Naik (2009) find a cross-sectional correlation between hedge fund manager's marginal incentives including those provided by performance fees and future return.

The scale of these effects can also be converted to dollars. If we assume that the contracts were always readjusted so that the manager was always at the threshold, but that this adjustment does not affect performance when the manager is at the threshold, we can convert the coefficients estimates to the cost borne by investors for having misaligned incentives. The cost of the performance effect is straight forward. A fund is on average 7.3% below the threshold, so would perform an average of 1.03 percentage points better per year using column (8). Applied to the 2 trillion dollar hedge fund industry that is $20 billion per year. Valuing the risk requires assuming something about the utility function of investors. Suppose investors have a constant risk aversion coefficient of 1. If returns are normally distributed we can characterize the investors' utility functions as mean-variance utility. Using the coefficient estimate from column (3), the same 7.3% below the threshold, adjusting for the risk aversion coefficient that estimate is 0.0478 percentage points per month, 0.574 percentage points per year, or $11 billion per year across the hedge fund industry.

In sum, Table 2 suggests that funds that are below their high-water mark reduce their expected return and increase their risk – both because of increased underlying risk and additional risk-taking. These results are entirely consistent with the manger being increasingly likely to take the riskier, yet lower expected value project, the farther they are from their threshold. Indeed, this higher risk lower reward combination is consistent with Bowman's (1980) seminal observation that higher risk industries have lower returns. The effects of threshold incentives even provide a potential neoclassical micro foundation for this observation. Suppose all managers in all firms in all industries begin with the same threshold incentive schemes and risk levels. If some industries experience a negative shock, managers in those industries will respond to the threshold incentives by undertaking higher risk lower return projects. This mechanism could produce persistent differences between industries from transient shocks.

A similar logic provides a further cautionary consequence of threshold incentives. Threshold incentives lead managers to increase risk and reduce expected performance following a negative shock. However, if the shock is at the industry or economy wide level, this mechanism suggests that there

[19] This is consistent with mean reversion in strategy returns which is not captured by the time fixed effect: that is a correlation between recent poor performance by a strategy (which makes the instrument predict funds in that strategy are underwater) and positive subsequent performance.

[20] An alternative measurement approach that instead of using return as the dependent variable uses estimated alphas for the manager's performance contribution above asset allocation produces results that are comparable to specification (8).

would be systemic effects. Such a shock would lead to increase risk-taking and reduced performance across the industry or economy in question, essentially multiplying and sustaining the original shock. This magnification effect is important from a public policy perspective as it suggests incentive thresholds may have contributed to both the depth and duration of economic downturns.

6. Distant Managers

The next set of predictions follows from Result 3, which predicts that managers with distant thresholds would behave differently than those closer. The prediction is that those managers would no longer find risk-taking profitable – the fence is so unlikely to be reached it is not worth gambling to reach. However, the incentives for effort continue to decline as distance increases. Performance should continue to decline because of decreased effort, but the performance cost of risk-taking will no longer magnify the decline. Empirically, I estimate this by estimating a separate response to distance for managers far from their thresholds. The measure of "far from their threshold" is somewhat arbitrary. Here I present results using a dividing line of needing a return of 75% to reach the threshold, but the results are robust to other divisions. Approximately 2% of the observations reflect managers beyond this threshold. Figure 5 is a similar plot to Figure 4, but restricted to managers more than 75% from their thresholds.[21] Consistent with the Result 3, it appears that risk-taking does not increase with distance for managers far from their thresholds.

Table 3 presents these results on risk-taking and performance. These are similar specifications to those in Table 2, except the interaction of far from the threshold and distance is included and instrumented for.[22] The interaction term reflects the difference between the main effect – the responsiveness of near managers, and the responsiveness of distant managers. The net effect we see in columns (1) and (2) are that distant managers take much less risk than managers at moderate distances from their thresholds. Indeed, while the point estimate is that distant managers do take more risk than managers at their thresholds, this is not significant. In terms of magnitude, column (2) estimates that a manager 50% from their threshold increases risk-taking by twice the amount that a manager 100% from the threshold does.

Columns (3) and (4) show the same pattern. Managers far from their thresholds perform better than managers at moderate distances from their thresholds. The estimates in Column (4) suggest that a manager 50% from the threshold reduces performance by three times as much as a manger 100% from the threshold. These regressions allow an estimate of how much of the performance drop observed in managers moderate distances from their thresholds are due to reductions in effort, and how much is due to the performance cost of risk-taking. The logic behind this calculation is to assume that the reduction in performance observed by managers far from their thresholds is entirely due to effort reduction[23] and that the difference between this rate and the rate of reduction in performance by

[21] Because of the many fewer points in this range less smoothing is necessary to see the pattern in the data.

[22] Note that this creates potential endogeneity concerns because being far from the threshold is potentially endogenous. However, because the results suggest that risk-taking and performance are better beyond this threshold, the endogeneity concerns seem small.

[23] As the point estimates in columns (1) and (2) suggest that risk-taking is still increasing slowly in managers far from their thresholds this may underestimate the performance cost of risk-taking.

managers closer to the threshold is this reduction of effort combined with the performance cost of risk-taking. This calculation suggests that 83% of the performance drop observed in managers moderately below their thresholds can be attributed to the performance cost of risk-taking and only 17% to the reduced effort.

7. Fee Variation

The above fundamental results show that the average treatment effect of being below the threshold increases risk-taking and reduces performance. Yet, these average treatment effects include significant heterogeneity. In this section I examine the varying response of mangers depends on the details of their fee contracts. In addition to the direct interest in how the variation in fees affects this behavior, this investigation has several useful implications. First, these results provide significant additional confidence in the empirical strategy outlined above. One potential concern about the instrumental variable approach is that most of the variation I use is at the strategy level and I might be measuring something about the pattern of variance and performance of the underlying assets. The first method to address this concern is to directly control for the performance of the underlying assets as I do above. However, these results provide an additional test. Because the fees vary within strategy-year if the effect were driven by the pattern in the underlying assets all funds in a strategy, responses would not vary with fee structure. Because I find that they do, these results suggest that the instrumental variables approach is not finding an uncontrolled for relationship between factor performance and flows and the subsequent environment, except through the pathway of fee contracts. Second, this investigation has the potential to disentangle effects driven by the explicit fee contracts and other non-neoclassical behavior.

The first four columns of Table 4 explore the role of base or management fees. The predictions above are that higher management fees would lead to less risk-taking and smaller performance declines when below the threshold. About 40% of the funds have a management fee of 1%, and about 20% each have management fees of 1.5% and 2%, and the rest distributed at other values between 0 and 3%. Columns (1) and (2) show, consistent with the prediction, that funds with high base fees increased risk less when below the threshold. The magnitude of the interaction suggests that a fund without a base fee increases risk about 50% more than a fund with modal base fee of 1%. Columns (3) and (4) show that there is no effect of the base fee on the average return effect of being underwater. Not only are these results not statistically significant, the coefficient is small. Looking at column (4), the difference between 1% and 2% base fees implies a drop in performance of just 14 basis points. While the point estimate in column (4) is the predicted sign, the magnitude is small. Reconciling the different findings in columns (1) and (2) compared to (3) and (4) has several potential explanations. One is that risk-taking has no meaningful performance cost and that the base fee does not affect responsiveness to distance to the threshold. On the other hand, it maybe that risk-taking is costly, but that managers with higher base fees actually reduce the effort they place on improving performance when they are below their thresholds, perhaps to focus on soliciting investors.

The second fee of interest is the performance fee. This fee pays a manager a share of the profits the manager earns above the threshold. This fee is central to the empirical approach in this paper. Indeed, funds without a performance fee have no threshold in their explicit incentives. The predictions of this fee developed above are straightforward. The higher the performance fee the larger the response we should see – both in increased risk-taking and reduced average return. Indeed if the linear functional form is right, we would expect that the direct measured effect of being below the threshold is zero if an interaction with the performance fee is included. Performance fee is the interaction in columns (5) through (8) of Table 4.[24] Approximately 80% of the funds have performance fees of 20%, with about 5% each having performance fees of 0%, 15%, and 25% and the rest distributed at other fees between 0 and 50%. Because of this distribution this test has somewhat limited power, and particularly limited support for the intercept of distance. Though not strongly significant, the results in columns (5) and (6) are consistent with about half of the increase in total risk-taking being driven by the performance fee. Indeed, column (6) estimates that funds with no performance fee do not have a statistically significant increase in active risk-taking when below the threshold and the coefficient estimate reflects an effect of just a 10% increase in risk for the average fund below its threshold. Despite this, looking at column (8) we see that all of the decrease in expected return is being driven by funds with performance fees. Indeed, this suggests that a fund with a 15% performance fee has a drop in return equal to about 75% of the drop that a fund with a 20% performance fee experiences. This suggests that performance fees provide strong incentives in these funds.

Taken together the heterogeneous response of managers depending on their contractual fee structures provides several interesting results. First, consistent with theory, bigger performance fees lead to more responsiveness to the threshold, and in contrast higher management fees serve to blunt the incentives to take extra risk. In other contexts, higher base and equity compensation can be an important moderator of option and other threshold compensation. Further, these results provide quite a lot of robustness to the empirical findings in section 5. They suggest that the results are not driven by contamination of the instrument by some serial correlation in strategy performance. Furthermore, they give additional confidence that these behaviors are being driven by explicit incentives. Indeed, if these behaviors were the result of, for example, reference points, we would not expect differential responses for different fee structures. Applied more broadly these results suggest that top management teams with many options are more likely to increase risk and decrease effort when they are out of the money. Guaranteed compensation and equity holdings and compensation for firms that are not in bankruptcy risk serve a role similar to the base fee and should reduce the increased risk-taking.

8. Organizational Interactions

In this section I examine the predictions suggested by the organization economics literature. The first prediction is that direct capital investment would reduce responsiveness to the contractual incentives. Unfortunately, direct measures of manager's capital are not available. Agarwal, Daniel, and Naik (2009) use a proxy for additional manager's investments based on past performance fees. They argue that managers are likely to invest performance fees earned into the fund. Because this measure does not capture the manager's initial capital investment it is somewhat limited. It is closer in concept to

[24] Theory would suggest that there might be an inverse relationship between base and performance fees. In this dataset, there is effectively no correlation between these fees and the results are substantially similar in a specification with interactions of both base and performance fees with distance. Empirically, this also means that the results are unchanged if both interactions are included in one specification.

the manager that amasses equity holdings over time, rather than the founder as manager. Nonetheless, I recreate their proxy in the data and interact it with the distance variable.

Columns (1) through (4) of Table 5 show this interaction. “New Manger’s Capital” is this proxy. It is scaled in percent of fund assets. Though this proxy is incomplete - managers often make significant capital investments at fund inception - they provide some evidence of the role of manager’s capital. This specification also has potential endogeneity concerns in that actual investments of additional capital by managers are endogenous decisions. This proxy, however, assumes that a fixed share of performance fees is reinvested. Since actual additional or initial investments are not observed which reflect the endogenous investment decisions of managers, this is resembles an instrumental variable approach. However, because the actual investments are not observed, the “instrument” is used directly. Given these concerns, this specification is merely suggestive. Interpreting columns (1) and (2), the scale suggests that once a manager’s ownership of the fund reaches 10% there is no effect of being below their threshold on risk-taking. While the interactions are not significant for the return effects, the coefficient estimate suggests about 20% ownership is sufficient. These estimates are consistent with the theory – managers with more of an ownership stake respond to contractual explicit incentives less.

Reputation is the next organizational characteristic I explore. Connecting to the model, reputation functions similarly to the base rate in that a manager with a more valuable reputation has more to lose and gain, without regard to the threshold. However, because investors may be risk-averse, we might expect the risk-taking to be even more responsive than performance. While there are many facets to reputational value, I use two measures: one which reflects industry perceptions of reputation and a second which captures ability to profit from reputation.

The first measure reflects industry perceptions that age is a good measure of reputation because of the value of having a long track record. Columns (5) through (8) of Table 5 look at age and show that the effect of being below the threshold decreases with age. The estimates are all consistent with the effects of being below the threshold being totally dissipated by the time the fund is 10 years old. While suggestive of reputational effects, there are many possible drivers of the age results. These results are consistent with the predictions of reputation discussed above. But age is also correlated with increases in a manager’s capital. Similarly, older funds may have more experience, other incentives, or different institutional characteristics such as structure inertia (de Figueiredo et al., 2012). Note, however, that this result is not driven by one apparent explanation: It cannot be that older funds reflect the funds’ fixed quality as time invariant firm-specific effects are absorbed by the vector of fund fixed effects. Therefore, it must be that the funds either improve with age or that quality only differentiates performance in the types of environments that persist after poor strategy performance.

The second measure draws on existing literature. De Figueiredo and Rawley (2011) develop a model of diversification which shows how firms profit from a reputation. In their model, manager’s face a privately observed cost of diversification. Those with low diversification costs find it more profitable to diversify if investors believe they are high quality. Managers with high diversification costs are unlikely to diversify, regardless of investors beliefs. As such, high cost managers have less to gain from investor’s beliefs about their quality, that is, their reputation. Following this logic, realized diversification is then correlated with having a low diversification cost, and thus having a high value for one’s reputation. As such, I use the number of funds I observe a fund to ever have as a measure of its ability to diversify and thus value of reputation. We should expect those who eventually have many funds to increase risk less.

Note, because of the potential reverse causality – that eventual number of funds a firm has might be caused by their relative success when underwater, the effect on returns can be a test of this endogeneity. If diversifiers have comparably better average returns when below the threshold this concern would be most plausible.

Columns (9) through (12) examine the eventual scope the firm will achieve as a proxy of their reputational value. This is perhaps a cleaner test of the value of reputation following the logic discussed above. Though the firm's eventual scope may capture many things, one interpretation is to capture the value to the fund of its reputation. Empirically, there are several concerns. First, the proxy used is imperfect because low cost, high quality and/or lucky managers are those that we observed diversify but many of the non-diversifiers may be low cost (and thus high reputation value), but unlucky or low quality managers. If true, the results will be biased towards zero and reduce the power of the measure. Second, the specification has a potential endogeneity concern in that it describes a fund today with a future characteristic, the firm's future scope, which reflects among other things the performance of the fund today. If good performance leads to increase diversification, as de Figueiredo and Rawley (2011) find, we should be particularly concerned if future scope is correlated with better performance when below the threshold. However, in columns (11) and (12) we see a negative coefficient on the interaction term, suggesting that, if anything, diversifiers experience larger return drops. However, columns (9) and (10) do show less risk-taking among those with valuable reputations. Much like those with high management fees, those with valuable reputations appear to take fewer gambles.

This measure also allows some examination of the value of a reputation. Here we observe managers with valuable reputations taking less risk. Thus, they sacrifice short term contractual compensation for unobserved returns from reputation. The value of their reputation, then, must be higher than the compensation we observe them forgo. Using the estimated reduced risk-taking from column (9) we can calculate this lower bound on the value of reputation. To do this I estimate fee realizations assuming returns are normally distributed and using the mean values for returns and variances. With those assumptions this should be considered a lower bound not just because the benefits of reputation are not observed, but also because the use of a proxy biases the measure towards zero. A manager who is the average distance below the threshold with a 20% performance fee and a reputational value one standard deviation higher than average earns fees approximately 0.37% of the assets of the fund, or $410,000 for an average sized fund, less than a fund with an average reputation.[25]

The scope of a fund's management firm has also connects to the multi-tasking prediction. A firm with more funds has more incentivized tasks to which the manager may allocate effort. This leads to the prediction that firms with more funds will have larger decreases in average return. While not quite significant in this specification the coefficients in column (12) suggests that one reason a fund performs less well might have to do with the manager's alternative areas of work. Those managers with more funds, which may not be below their thresholds, are those who show the biggest decreases in expected outcome – these managers are likely shifting effort to where incentives are stronger. Considering the internal organization of the hedge fund – even if the manager of a particular fund is not a formal participant in the investment process of a separate fund the attentions of others in the firm as well as the allocation of investment ideas to funds may shift away from the fund below its threshold.

[25] Including the reduced performance from column (11) results in an estimate of 0.44% of the fund, or $490,000.

The interactions with the firm scope are also informative on the whether these behaviors are responses of the management firm as an organization or of the managers, and other individuals in the firm, responding to their incentives. The performance feedback literature suggests that when organizations direct resources in response to underperformance by entities within that organization. Essentially, it argues that organizations “put fires out”. Being under the incentive threshold is indeed such an underperformance. This suggests that firms would redirect resources to the underperforming entity and those with more available resources would deploy them to the underperforming entity and improve its subsequent performance. The results in columns (11) and (12) have the opposite sign than this prediction. Certainly, this is not a strong test of performance feedback theory, but it suggests that the responses by managers in this context are more concordant with individual behavior or the aggregation of individuals in an organization with closely aligned incentives.

The interactions in Table 5 are suggestive, but subject to some potential bias and measurement issues. However, these results show that age is correlated with smaller decreases in returns and smaller increases in risk. Eventual scope (reputation value) leads to less increase in risk. Scope is also correlated with bigger decreases in return, consistent with managers reallocating effort. Taken more broadly, these results provide some evidence that reputation can restrain managers and multi-tasking concerns can magnify the effort effects. These results have implications to organizational design. Creators of organizations can manage scope and use reputation and ownership incentives to balance contractual incentives.

9. Mechanisms

The previous sections have characterized that managers take more risk and reduce performance when they are farther below their thresholds and that this behavior is driven by explicit contracts and moderated by organization factors. In this section I use the data to explore the nature of this risk-taking. Second, I use the results of the conceptual framework to shed light on the relative importance of effort versus risk-taking on the performance of financial managers.

How are managers taking risk? Realized volatility as a measure of risk-taking does not measure the choices the manager directly makes. Instead it measures the realizations of their decisions. If managers take actions that they believe are riskier but do not result in riskier outcomes, those risk-taking decisions would not be captured. On the other hand if managers believe they are not taking different risks, but the realized environment is riskier that may be captured as risk-taking. Indeed, this distinction allows some understanding of the mechanisms the managers take to increase risk. Indeed, the difference between columns (3) and (4) in Table 2 provide some insight. The difference between the coefficients suggests that about half of the increase in variance is because of increased variance in the underlying markets, and about half is due to explicit increases in risk. To the extent that a hedge fund manager aims to maintain an absolute risk profile – that is, they endeavor to have the same level of risk despite the riskiness of the environment, then column (3) is the appropriate comparison. These managers should reduce their exposure to the market when the market is riskier. However, if hedge fund managers aim to maintain a relative risk profile, that is, have a constant exposure to market risks then column (4) is the right comparison. These managers should have riskiness that increases with the market risk.

The results in Table 4 actually provide suggestive evidence of whether managers account for increases in market-risk in their responses. To the extent that they do, it suggests that managers both have correct expectations about market risk and are concerned about total, not relative risk-taking. Consider column (5) in Table 4. Assuming the functional form is correct, the direct effect of $Distance$ reflects the risk increases by a manager with no performance fee, and thus no reason to vary risk-taking with distance to an arbitrary threshold. The positive and significant coefficient suggests that managers are either surprised by the market risk or intend to maintain some exposure to market risks. Comparing column (5) to column (6) is also informative. If managers were surprised by the market risk, controlling for the market risk should not change the responsiveness of managers to their performance fee, and the coefficient on the performance fee interaction in columns (5) and (6) should be the same. While the difference is not statistically significant, the smaller coefficient in column (6) is consistent with managers expecting and compensating for the market risk.

To further decompose the nature of risk-taking, Table 6 contains several specifications with different dependent variables. These dependent variables are the results of a set of regressions. For each fund-year, I regress the performance of the fund on the performance of the passive market index for that fund's strategy. The first column has as the dependent variable the fund-year beta. This shows that increasing exposure to the market was an important part of the risk-taking. The second column has as its dependent variable the variance of returns not explained by the exposure to market risk. This "alpha risk" shows that not only do managers increase market risk they also increase their idiosyncratic risks. The coefficient suggests that about a quarter of the total increase increased in risk is due to idiosyncratic risks. Figure 6 aggregates the estimates of the mechanisms by which managers increase risk.

Another mechanism worth exploring is the importance of managerial effort and risk-taking to influence performance. The conceptual framework shows that both manager's risk decisions and effort can affect the average performance. Indeed, there is debate about the importance of effort in incentive contracts both because it is not entirely clear how much impact manager's effort can have on performance and because most managers appear to exert so much effort so that only minimal additional effort might be induced. This research provides additional evidence that effort, or at least effort allocation, responds to incentives in meaningful ways. First, the multi-tasking results above suggest that the opportunity to exert effort elsewhere reduces performance when incentives fall. Beyond that the framework allows us to isolate the performance impact of risk-taking separately from the effort choice. This is through the non-linearity result in the framework. As calculated above this leads to an estimate that 80% of the reduction in performance observed may be caused not by reduced effort, but by increased risk-taking. Taken together, both of these results suggest that incentives are important drivers of performance, even among individuals and managers with complex jobs. Second they both suggest that simple, one-dimensional, models of tasks and incentives may miss important responses of agents.

This evidence that additional risk-taking is not associated with higher realized return can also inform a debate about the role of convex incentives to encourage risk-taking by risk-averse agents. Implicit in that debate is that because of risk-aversion, a manager would not undertake risky, but profitable, projects for the firm because their disutility from exposing their compensation to risk. This optimal convexity depends on the interaction of the manager's risk aversion, the responsiveness of the firm to the manager's decisions and the firm's ability to insure. However, with no additional return for additional risk-taking the answer is simpler. Regardless of the degree of risk aversion, when managers are below their thresholds the compensation schemes induce too much risk-taking.

10. Robustness Concerns

The data used in this analysis has many potential limitations. In this section I address several of these and propose robustness tests. The first set of challenges comes from the fact that these data are self-reported and represent only a subset of the hedge fund industry. The funds included in this dataset represent approximately a quarter of the hedge funds during this period and are believed to be broadly representative. However, no comprehensive database of the hedge fund industry exists to evaluate this sort of selection bias. Furthermore, because this study looks at how these managers respond to their incentives, it is unclear that any systematic difference between this set of funds and the remainder would reduce the implications for risk-taking consequences of being below their thresholds.

Beyond the question of coverage, the voluntary reporting nature leads to two additional kinds of selection discussed in the literature. These selection come from the fact the funds decide when to report data. Intermittent reporting of data is not problematic. Few funds appear to report intermittently, and those that do are excluded. However, when a fund first begins to report to the data vendor, it generally reports not only current and future performance, but past performance as well. This "instant history" bias tends to include funds with particularly good initial performance. To account for this bias, the standard approach is to exclude the first two years of a fund's data. Doing this does not have a qualitative change to the results reported. Additionally, for a subset of this data, I have access to information about when a fund first began reporting. This allows robustness checks by limiting only to funds that began reporting immediately or to more precisely exclude the instant history.

The second selection question is that exiting the data set (stopping to report) is also voluntary. One way to test this is to restrict the analysis to a set of funds that as of a particular point are actively reporting, and only including those funds before that time. Again, the results are not qualitatively changed by this restriction. Additionally, for a subset of the funds that have exited the data set I have the reason the fund has left. While prior literature has assumed that exiting these data because of extreme success and failure were both common, this data suggests that the vast majority of fund exits are due to fund liquidation (45%) or firm failure (18%). Less than one percent of exits are closures to new investments (a sign of success). 26% are voluntary decisions to stop reporting for an unspecified reason, and 5% are mergers into other funds. These last three groups would be the potential sources of this reporting bias.

Survivor bias is another concern in this style of research, but is not a limitation of this data. Funds are included in this analysis regardless of whether or not they exit. Indeed, the robustness check described to address voluntary ending of reporting induces selection bias, but does not change the qualitative nature of the results, suggesting that survivor bias, if it existed, would not be a major problem.

There are, additionally, a variety of sources of measurement error in the data and in the calculation of high-water marks. Calculation of the high-water marks and distance depends on accurate reporting of returns and assets under management. While returns are regularly reported there are some funds for which assets are occasionally not reported. Returns before the first reporting of assets are excluded from the calculation of the high-water mark. This produces a bias in that some of these funds may be below their threshold, but they are treated at their threshold. This would, in general, bias the estimates towards zero. Similarly, any funds for which returns are not available from inception would produce the same bias. A robustness check restricting to funds for which assets are available at inception would check for this. Any funds which stop reporting assets but continue to report returns are treated as exits and are addressed in the robustness checks for voluntary reporting. For funds for which assets are not reported for some intermediate period, net flows over that period are distributed evenly over the period. This particular measurement error may in fact be corrected for by the instrumental variable approach.

Another measurement issue comes from the fact that the return of a fund in a particular period may have several definitions and the reporting practices are unclear. Some funds may report gross returns. Other funds may report the after fee returns. However, since different vintages have different fees, some funds may report after the fee of the oldest vintage, while other funds may report an average. Returns net of fees also depend on when fees are accounted for out of assets – returns are monthly, but fees are often accounted for quarterly. In this analysis, I treat all the returns in the data as gross returns, however the results are qualitatively similar treating the raw data as net returns, imputing gross returns, and analyzing those.

An additional complication in the calculation of the high-water mark is the role of hurdles. A hurdle is a base rate of return that a fund must earn before earning a performance fee. Effectively, it moves the high-water mark every year, regardless of performance. Unfortunately, while the data indicates whether a fund has a hurdle, it rarely indicates what this hurdle is. As such, I do not account for hurdle rates in this analysis. Generally, a hurdle will make a fund farther from its threshold than I estimate. The only time this would not be the case is when the hurdle is the rate of return of some asset that has experienced a loss. However, these sorts of hurdle rates are rare.

Another source of measurement error is the self-categorization. This realizes in two ways. First, a category might be too broad, incorporating funds with strategies that differ substantially. Additionally, categorization error might lead for a fund not to be categorized with like funds. Both of these errors will lead to estimates of a passive hedge fund that is a mix of the strategies employed in the category. This would lead to an instrument which is weak because of the low correlation between the “passive” returns and actual performance. This would also lead to less informative predictions about the performance of the passive fund in the year after being underwater. Both of these would lead to biases towards not finding any effect of being below the threshold and not finding a difference when controlling for market performance.

Serial correlation in returns is another potential source of error. There are several sources of serial correlation. First, funds which hold illiquid assets may use valuation measures that induce serial correlation. Second, assets that the funds own may exhibit momentum. The second source is partially addressed by the inclusion of Carhart’s (1997) momentum factor for equity. However a broader robustness check is to estimate for each fund an AR(1) process and use a measure of return which is net of this AR(1) process. This does not change the qualitative results.

Finally, the calculation of high-water marks depends on vintages of investments into funds. However, I do not observe actual flows. Instead, I observe net flows each month. Net flows are a subset of actual flows. That is, there are always weakly more fund inflows and weakly more fund outflows than I observe. Effectively, this leads me to assume that the assets that are in a fund are from older vintages than they actually are. As older funds always have the highest high-water mark, this means that my measure of distance is biased towards the assets that are most distant. Thus, some funds are closer to their threshold than I measure. However, this is only a problem of scale. This is because the vintages do not matter unless a fund is some distance below its threshold. This scaling issue, however, is further complicated by not observing which assets are those that have flowed out of the fund. Instead, I apply the outflows proportionally among all funds. An alternative assumption is to apply exits on a first-in first-out basis that assumes that the funds that leave are the always the oldest vintages. Neither is a perfect representation of actual flows. Similarly, this mis-weighting of vintages introduces bias in the scale of distance. The biggest consequences of this source of error is that one should be careful in comparing the absolute levels of distance with those measures created from more detailed flows.

Beyond the robustness and measurement concerns, the question of what pathways lead to these risk and return changes is worth additional discussion. While, I emphasize the role of effort and risk-taking in response to incentives as the main drivers there are additional pathways worth exploring. One potential driver of changes in fund performance would be flows. For example, if a fund is experiencing significant net outflows it may change the composition of the fund as the fund sells liquid assets. Similarly, as a fund experiences in flows it may acquire liquid assets faster than illiquid assets. If illiquid and liquid assets have different risk and return profiles, flows, which may be correlated with distance, might be potential drivers of the changes I estimate. Further, flows may also change the concentration of a fund’s assets, thus changing its risk. Empirically, because flows are potentially endogenous, this is not a simple robustness check to perform. However, the results in Table 4 suggest that the effects are being driven by the contracting terms. For the results in Table 4 to be spurious there must be a correlation not only between flows and distance, but also differential correlations between those flows as the contracting terms. The first is quite plausible, the second less so.

Further contemplation about the instrument used also suggests that some other pathways are possible. The instrument represents strategy specific performance, particularly, recent strategy specific losses. One concern is that strategy specific losses capture something relevant to the performance of the funds. From discussions with industry participants on of the main internal consequences of not earning a performance fee is employee retention. Hedge fund principals have to decide whether to invest additional capital in the firm to retain talent when performance fees are not earned, or risk losing that talent. If the entire strategy has performed poorly that risk may be lower. However, there are several limits to this possible pathway. First, industry participants were thinking partially of the financial crisis. This analysis does not include the financial crisis and the impacts of earlier macro-economic conditions on employee mobility were much smaller. Second, because the instrument is strategy specific performance that is not captured in the time fixed effect the potential scope of employee mobility would have to be not to some other place in the hedge fund industry, but restricted to strategies that are exposed to similar assets. However, the direction of this bias would seem to be against finding an effect. If the effect is driven by talent leaving funds that are distant, then when mobility is reduced because all the funds in a strategy are below their thresholds we should see smaller changes in risk and return than we would if mobility was unaffected.

Another pathway would be if the strategy specific performance changed the nature of competition, either between hedge funds in some fashion or between hedge funds and their trading partners. The results would be consistent with something leading to more competition for trades when funds are below their thresholds. If hedge funds face more competition the return of any particular trade would be lower, and may cause increases in concentration, leverage, or risk-taking. However, it is not obvious that distance is correlated with increased competition. Indeed, being below their thresholds suggests that these strategies have fewer assets than before so that there should be less “money chasing deals” and thus less competition. Further, the fact that these decreases in return and increases in risk are relative to the passive portfolio make the competition pathway less plausible – a passive portfolio is not subject to these competitive pressures and the funds do not choose to remain passive.

11. Conclusion

The empirical results of this research are clear. Managers in firms below their incentive threshold take on more risk and generate lower expected returns. However, those very far from their thresholds take less risk and perform better than managers closer to their thresholds, which is consistent with the added risks being negative expected value. The interactions of distance to the threshold with the management and performance fees strongly suggest that these results are driven by the contractual fee and incentive structure. An examination of organizational incentives suggests that reputation and direct ownership mitigate misbehavior induced by thresholds. Finally, the multitasking result suggests that much of the return effect observed is not driven by a direct reduction in effort, but instead, these managers reallocate firm resources and attention. Analysis of the mechanisms of risk-taking suggest that increases in risk are driven by a combination of accounted for market risks, increased exposure to market risks, and idiosyncratic risk-taking.

Hedge funds provide an empirical context to measure and observe incentives and risk-taking behavior that sheds light not only on hedge fund managers, but on any decision maker facing similar threshold incentives. While at first blush, the “2 and 20” contract seems to be an extremely powerful threshold incentive, firm managers, on average, earn a larger share of their compensation from threshold incentives than hedge fund managers. This research uses the hedge fund context to measure behavior that should be applicable in other contexts.

The results do not suggest that threshold-based incentive compensation should be avoided – the comparisons above are comparisons within a threshold based compensation scheme. Instead, the results suggest the importance of setting thresholds correctly. Very high thresholds appear to have particularly significant downside potentials. For example, following the recent stock market crash, Google and about 100 other publically traded companies went through option repricings where they exchanged low value, out of the money options, for higher value in the money options, presumably to avoid the distortionary impact of setting thresholds too high. If the risks of high thresholds are indeed significant, then threshold effects imply a concise answer to Hall and Murphy’s (2000, 2002) puzzle about why almost all options are given at the money: the downside of options far out of the money is increased risk-taking.

References

Ackermann, Carl, Randall McEnally, and David Ravenscraft. 1999. “The performance of hedge funds: Risk, return, and incentives.” *The Journal of Finance*. 54:3 pp. 833–74.

Agarwal, V.; N. D. Daniel; and N. Y. Naik. 2009. “Role of Managerial Incentives and Discretion in Hedge Fund Performance.” *Journal of Finance*, October, 64:5, pp. 2221-2256.

Agarwal, V. and N.Y. Naik. 2004. “Risks and Portfolio Decisions Involving Hedge Funds.” *The Review of Financial Studies.* 17:1, pp. 63-98.

Anderson, Mark, and Volkan Muslu. 2011. “Implications of Estimation Error in Option Grants for Evaluating CEO Pay.” Working Paper. http://ssrn.com/abstract=1623467

Angirst, Joshua D. and Jorn-Steffen Pischke. 2009. *Mostly Harmless Econometrics: An Empiricist’s Companion.* Princeton University Press, Princeton.

Bloom, Nicholas and John Van Reenan. “Human Resource Management and Productivity,” in: *Handbook of Labor Economics,* Vol 4b, eds. Orley Ashenfelter and David Card. Great Britain, North Holland, 2011, pp. 1697-1767.

Bowman, Edward H. 1980. “A Risk/Reward Paradox for Strategic Management.” *Sloan Management Review.* Spring, pp. 17-31.

Brown, Stephen J., William N. Goetzmann, and James Park. 2001. “Careers and survival: Competition and risk in the hedge fund and CTA industry.” *The Journal of Finance* 56, pp. 1869-1886.

Carhart, Mark M. 1997. “On Persistence in Mutual Fund Returns.” *Journal of Finance.* March, 52:1, pp. 57-82.

Carpenter, J. N. 2000. “Does Option Compensation Increase Managerial Risk Appetite?” *The Journal of Finance*, October 55:5, pp. 2311–2331.

Chevalier, Judith and Glenn Ellison. 1997. "Risk-taking by Mutual Funds as a Response to Incentives," *Journal of Political Economy*, December, 105:6 pp. 1167-1200.

Fama, Eugene F. and Kenneth R. French. 1993. “Common Risk Factors in the Returns on Stocks and Bonds,” *Journal of Financial Economics*, February, 33:1, pp. 3-56.

Fama, Eugene F. and Kenneth R. French. 2010. “Luck versus Skill in the Cross Section of Mutual Fund α Estimates,” *Journal of Finance,* October, 65:5, pp. 1915-1947.

de Figueiredo, Rui, Evan Rawley and Chris I. Rider. 2012. “Organizational Age and Organizational Change: Evidence from Hedge Fund Product Diversification,” Working Paper.

de Figueiredo, Rui and Evan Rawley. 2011. “Skill, Luck and the Multiproduct Firm: Evidence from Hedge Funds,” *Management Science*, November, 57:11, pp. 1963-1978.

Downs, George W. and David M. Rocke. 1994. “Conflict, Agency, and Gambling for Resurrection: The Principal-Agent Problem Goes to War,” *American Journal of Political Science,* May, 38:2, pp. 362-380.

Fung, W., Hsieh, D., 2004. “Hedge fund benchmarks: A risk based approach.” *Financial Analyst Journal.* 60, 65-80.

Hall, Brian J. and Kevin J. Murphy. 2000. “Optimal Exercise Prices for Executive Stock Options.” *American Economic Review*. May, 90:2, pp. 209–14.

Hall, Brian J. and Kevin J. Murphy. 2002. “Stock Options for Undiversified Executives.” *Journal of Accounting and Economics*. 33:1, pp. 3– 42.

Haugen, Robert A. and Lemma W. Senbet. 1981. “Resolving the Agency Problems of External Capital through Options” *The Journal of Finance* , June 36:3, pp. 629-647.

Holland, A. Steven, Hossein B. Kazemi and Ying Li. 2010. “Compensation Options, Managerial Incentives and risk-taking in hedge funds.” Working Paper.

Holmstrom, Bengt and Paul Milgrom. 1991. “Multitask Principal-Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design.” *Journal of Law, Economics, & Organization.*7:SP, pp. 24-52.

Jensen, Michael C. and William H. Meckling. 1976. “Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure,” *Journal of Financial Economics*. July, 3:4, pp. 305-360.

Kerr, Steven. 1975. “On the Folly of Rewarding A, While Hoping for B.” *Academy of Management Journal,* 18, 769-783.

Kouwenberg, Roy and Bill Ziemba. 2007. “Incentives and Risk-taking in Hedge Funds.” *Journal of Banking and Finance*. 31, pp. 3291-3310.

Larkin, Ian. 2012. “The Cost of High-Powered Incentives: Employee Gaming in Enterprise Software Sales.” Working Paper.

Murphy, Kevin, 1999. “Executive Compensation”, in *Handbook of Labor Economics*, Vol. III, eds. Orley C. Ashenfelter and David Card. Amsterdam: North Holland

Oyer, Paul and Scott Schafer. “Personnel Economics: Hiring and Incentives,” in: *Handbook of Labor Economics,* Vol 4b, eds. Orley Ashenfelter and David Card. Great Britain, North Holland, 2011, pp. 1769-1823.

Palomino, Frédéric and Andrea Prat. 2003. “Risk Taking and Optimal Contracts for Money Managers.” *The RAND Journal of Economics*, Spring 34:1, pp. 113-137.

Panageas, S. and Westerfield, M. M. 2009. “High-Water Marks: High Risk Appetites? Convex Compensation, Long Horizons, and Portfolio Choice.” *The Journal of Finance*, February 64:1, pp. 1–36.

Sanders, W. G., and D. Hambrick. 2007. “Swinging for the fences: The effects of CEO stock options on company risk-taking and performance.” *Academy of Management Journal*, 50, pp. 1055-1078.

Smith, E.B. 2011. “Identities as Lenses: How Organizational Identity Affects Audiences' Evaluation of Organizational Performance.” *Administrative Science Quarterly*, March 56:1, pp. 61-94.

Vereshchagina, G., and H. A. Hopenhayn. 2009. “Risk Taking by Entrepreneurs.” *American Economic Review*, December 99:5, pp. 1808–30.

Weinstein, Mark. 1998. “Profit-Sharing Contracts in Hollywood: Evolution and Analysis.” *Journal of Legal Studies,* January 27, pp. 67-112.

Wright, P., Kroll, M., Krug, J., and Pettus, M. 2007. “Influences of Top Management Team Incentives on Firm Risk Taking.” *Strategic Management Journal*, 28, pp. 81-89.

Figure 1: Threshold Incentive Schemes.

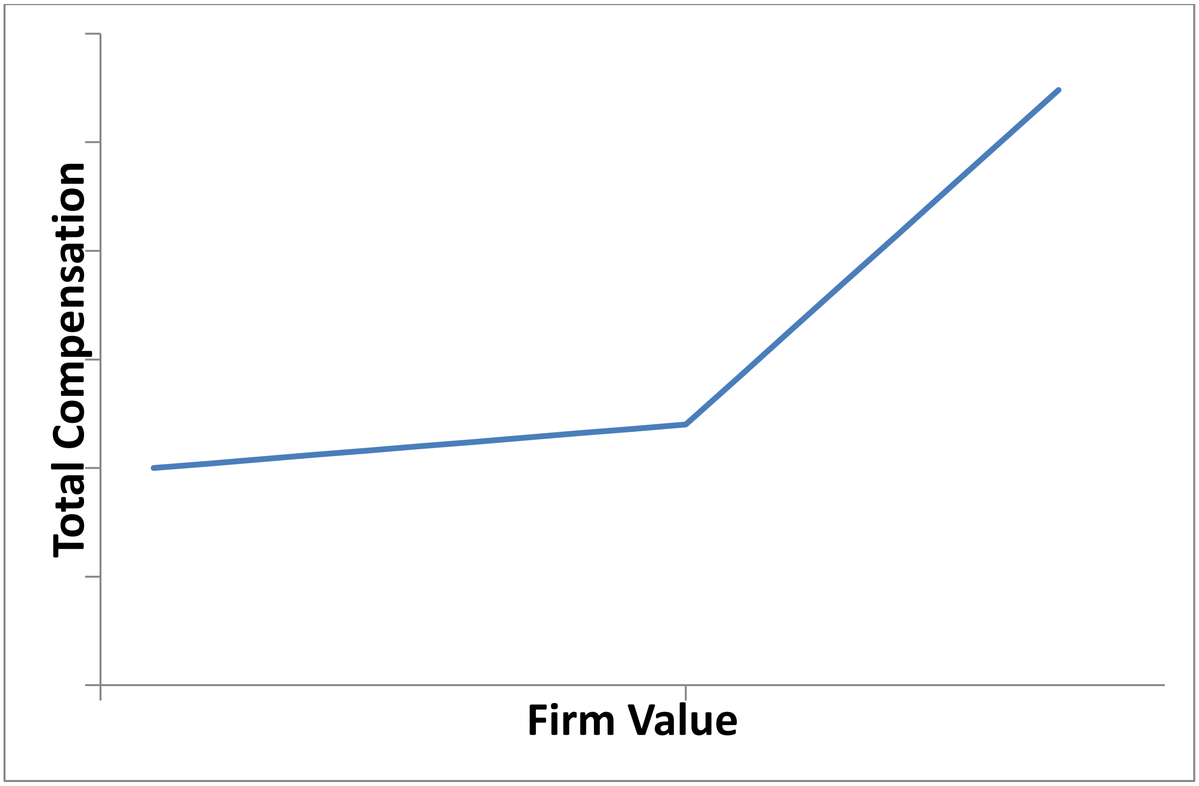
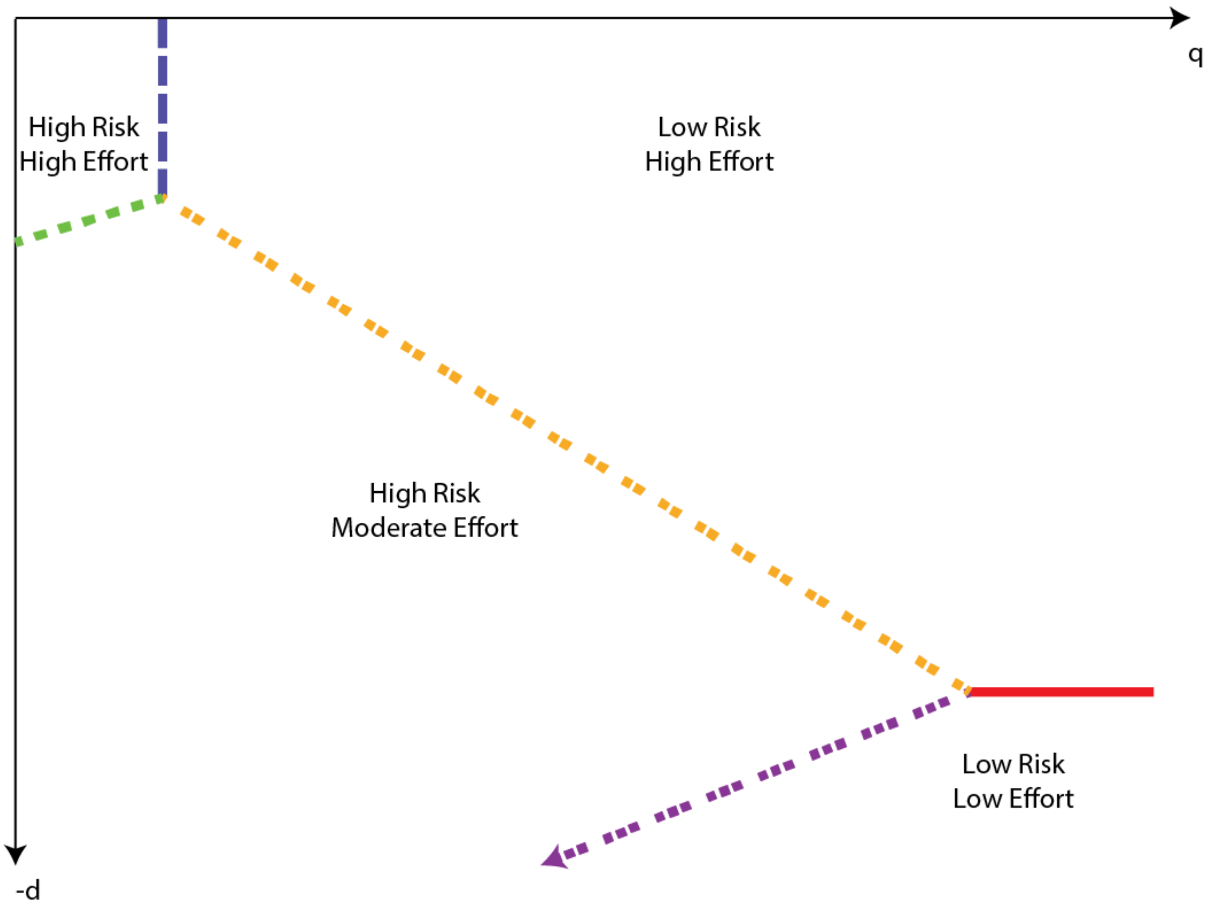
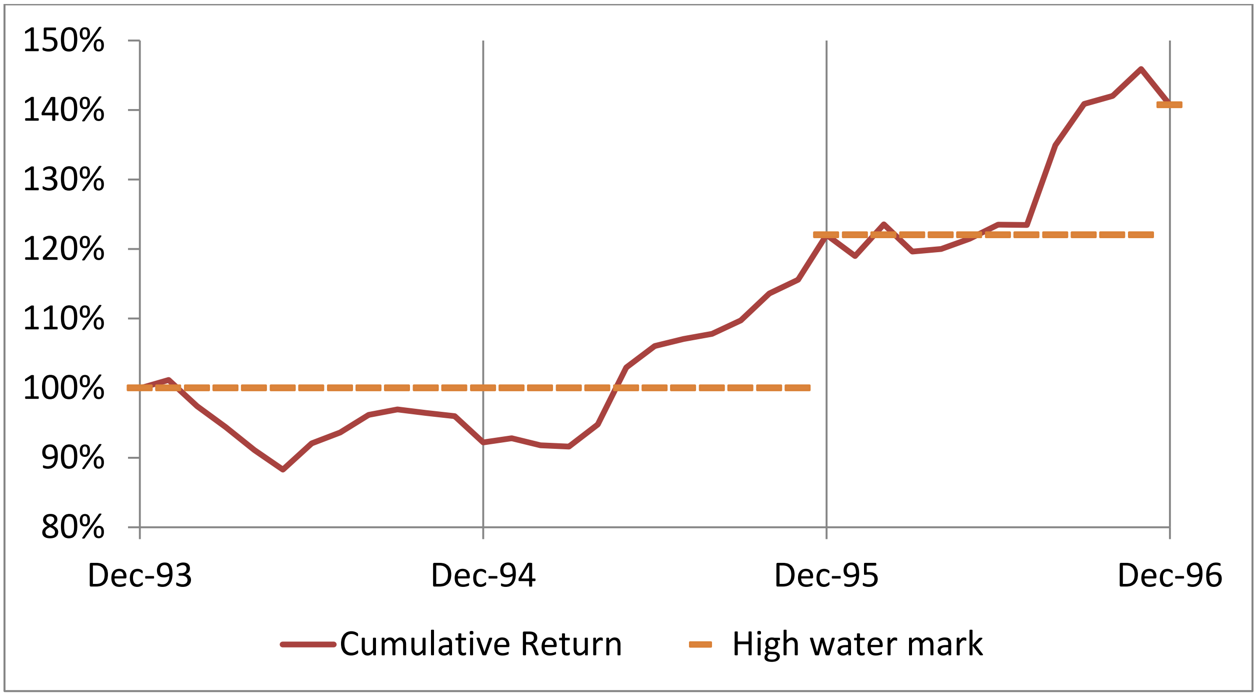


Figure 2: Risk-taking decisions.



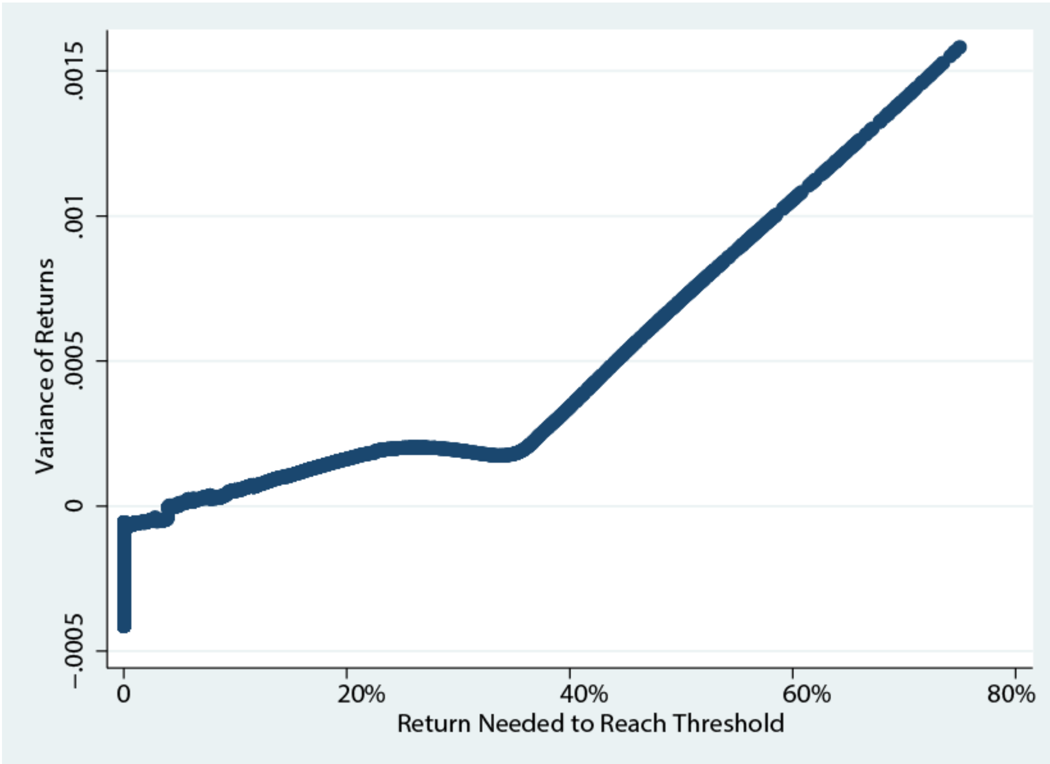
The horizontal axis represents the manager's ability to take risk where a manager with a higher q faces a bigger performance cost of risk taking. The vertical axis is distance below the threshold so that the top of the figure represents managers near their threshold and those at the bottom are far away.

Figure 3: Calculation of High-Water Marks.



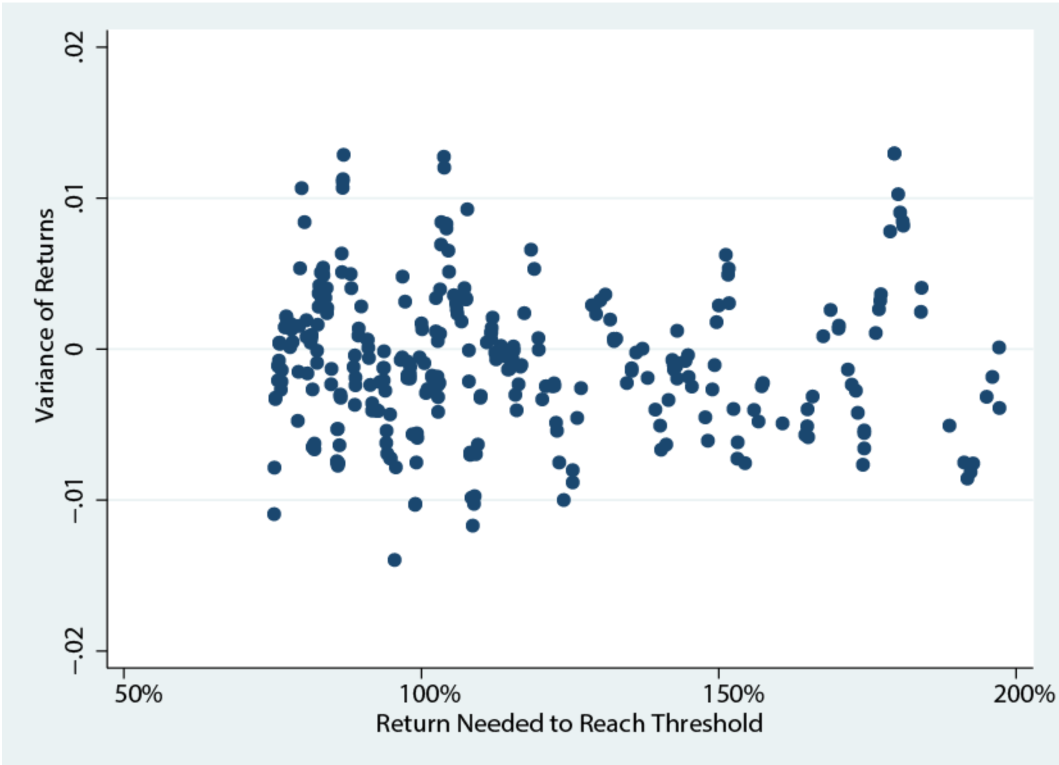
The red line identifies the cumulative return of a hypothetical hedge fund. At the end of 1994 this fund is 8% below its high-water mark. Or in other terms the fund is 8% *Distant.* At the end of 1995, this fund is paid a performance fee and its high-water mark ratchets up.

Figure 4 Increases in Risk-Taking with distance to threshold



The horizontal axis is the distance below the high-water mark the manager is as calculated above. The vertical axis is the variance of fund returns in the following year. The plotted points are non-parametric fitted values after including fund and year fixed effects and controls from age, age-squared, assets under management, and log assets under management.

Figure 5 Increases in Risk-Taking with distance to threshold, Distant Managers



The horizontal axis is the distance below the high-water mark the manager is as calculated above. The vertical axis is the variance of fund returns in the following year. The plotted points are non-parametric fitted values after including fund and year fixed effects and controls from age, age-squared, assets under management, and log assets under management.

Table 1 Summary of Predictions

	Risk-Taking	Performance
Distance to Threshold	+	-
Distance to Threshold X Far	-	+
Explicit interactions		
Performance Fee	+	-
Base Fee	-	+
Organizational Interactions		
Direct Ownership	-	+
Reputation	-	
Multiple Tasks		-

Table 2 – Basic Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Variance				Annual Return			
	OLS		2SLS		OLS		2SLS	
Distance	0.0040***	0.0043***	0.0131***	0.0071**	0.0200	0.0078	-0.0637*	-0.1414***
	[0.001]	[0.001]	[0.003]	[0.003]	[0.015]	[0.015]	[0.037]	[0.036]
Strategy Return		-0.0069		-0.0078		0.6522***		0.7020***
		[0.005]		[0.005]		[0.036]		[0.039]
Strategy Variance		0.2874***		0.2911***		0.1224		-0.0716
		[0.039]		[0.038]		[0.465]		[0.456]
Observations	20,254	20,254	20,254	20,254	20,254	20,254	20,254	20,254
R-squared	0.20	0.20			0.47	0.49		
Number of funds			3,945	3,945			3,945	3,945
Kleibergen-Paap Wald rk F statistic on Excluded Variables			52.45	52.45			52.45	52.45

Robust standard errors clustered by fund in brackets

*** p<0.01, ** p<0.05, * p<0.10

All Specifications include Age, Age Squared, Assets Under Management, Log Assets Under Management, Time Fixed Effects, and Fund Fixed Effects.

“Distance” measures distant below the threshold. “Strategy Return” and “Strategy Variance” are the performance of a passive fund. 2SLS specifications include “Distance” that reflects strategy performance.

Table 3 – Distant Managers

	(1)	(2)	(3)	(4)
	Variance		Annual Return	
	2SLS		2SLS	
Distance	0.0336***	0.0158**	-0.3045***	-0.3694***
	[0.0085]	[0.0074]	[0.1143]	[0.0960]
Distance X More than 75%	-0.0270***	-0.0115*	0.3165***	0.3048***
	[0.0077]	[0.0066]	[0.1044]	[0.0896]
Strategy Return		-0.0071		0.6816***
		[0.0051]		[0.0391]
Strategy Variance		0.2937***		-0.1407
		[0.0386]		[0.4621]
Observations	20,254	20,254	20,254	20,254
Number of funds	3,945	3,945	3,945	3,945
Kleibergen-Paap Wald rk F statistic on Excluded Variables	66.61	66.60	66.61	66.60

Robust standard errors clustered by fund in brackets
*** p<0.01, ** p<0.05, * p<0.10
All Specifications include Age, Age Squared, Assets Under Management, Log Assets Under Management, Time Fixed Effects, and Fund Fixed Effects.

See Notes to Table 2. “More than 75%” indicates if the fund is more than 75% from the threshold.

Table 4 – Explicit Incentives

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Variance		Annual Return		Variance		Annual Return	
	2SLS		2SLS		2SLS		2SLS	
Distance	0.0318***	0.0213**	-0.0412	-0.1623**	0.0068***	0.0030	0.1460	-0.0035
	[0.010]	[0.009]	[0.084]	[0.080]	[0.002]	[0.004]	[0.092]	[0.066]
Distance X Base Fee	-0.0124**	-0.0095*	-0.0149	0.0140				
	[0.005]	[0.005]	[0.044]	[0.045]				
Distance X Performance Fee					0.0004*	0.0003	-0.0138***	-0.0089**
					[0.000]	[0.000]	[0.005]	[0.004]
Strategy Return		-0.0074		0.7014***		-0.0077		0.6992***
		[0.005]		[0.039]		[0.005]		[0.039]
Strategy Variance		0.2983***		-0.0821		0.2941***		-0.1686
		[0.038]		[0.455]		[0.039]		[0.454]
Observations	20,254	20,254	20,254	20,254	20,254	20,254	20,254	20,254
Number of Funds	3,945	3,945	3,945	3,945	3,945	3,945	3,945	3,945
Kleibergen-Paap Wald rk F statistic on Excluded Variables	32.28	32.27	32.28	32.27	26.08	26.07	26.08	26.07

Robust standard errors clustered by fund in brackets

*** p<0.01, ** p<0.05, * p<0.10

All Specifications include Age, Age Squared, Assets Under Management, Log Assets Under Management, Time Fixed Effects, and Fund Fixed Effects.

Table 5 – Implicit Incentives

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Variance		Annual Return		Variance		Annual Return		Variance		Annual Return	
	2SLS		2SLS		2SLS		2SLS		2SLS		2SLS	
Distance	0.0190***	0.0123**	-0.0521	-0.1798***	0.0265***	0.0147***	-0.2678***	-0.2946***	0.0168***	0.0096***	-0.0282	-0.1205**
	[0.005]	[0.005]	[0.055]	[0.057]	[0.007]	[0.005]	[0.056]	[0.057]	[0.004]	[0.004]	[0.050]	[0.047]
Distance X New Manager's Capital	-0.1816**	-0.1523*	-1.2617	0.0984								
	[0.085]	[0.079]	[1.085]	[1.054]								
Distance X Age					-0.0030***	-0.0016***	0.0454***	0.0331***				
					[0.001]	[0.000]	[0.011]	[0.010]				
Distance X Max Funds									-0.0005***	-0.0003**	-0.0043	-0.0025
									[0.000]	[0.000]	[0.003]	[0.003]
Strategy Return		-0.0088*		0.6962***		-0.0081		0.7076***		-0.0079		0.7011***
		[0.005]		[0.040]		[0.005]		[0.038]		[0.005]		[0.039]
Strategy Variance		0.2820***		0.2252		0.2835***		0.0815		0.2912***		-0.0712
		[0.038]		[0.471]		[0.037]		[0.455]		[0.038]		[0.457]
Observations	20,254	20,254	20,254	20,254	20,254	20,254	20,254	20,254	20,254	20,254	20,254	20,254
Number of Funds	3,945	3,945	3,945	3,945	3,945	3,945	3,945	3,945	3,945	3,945	3,945	3,945
Kleibergen-Paap Wald rk F statistic on Excluded Variables	6.807	6.806	6.807	6.806	19.62	19.61	19.62	19.61	17.54	17.53	17.54	17.53

Robust standard errors clustered by fund in brackets

*** p<0.01, ** p<0.05, * p<0.10

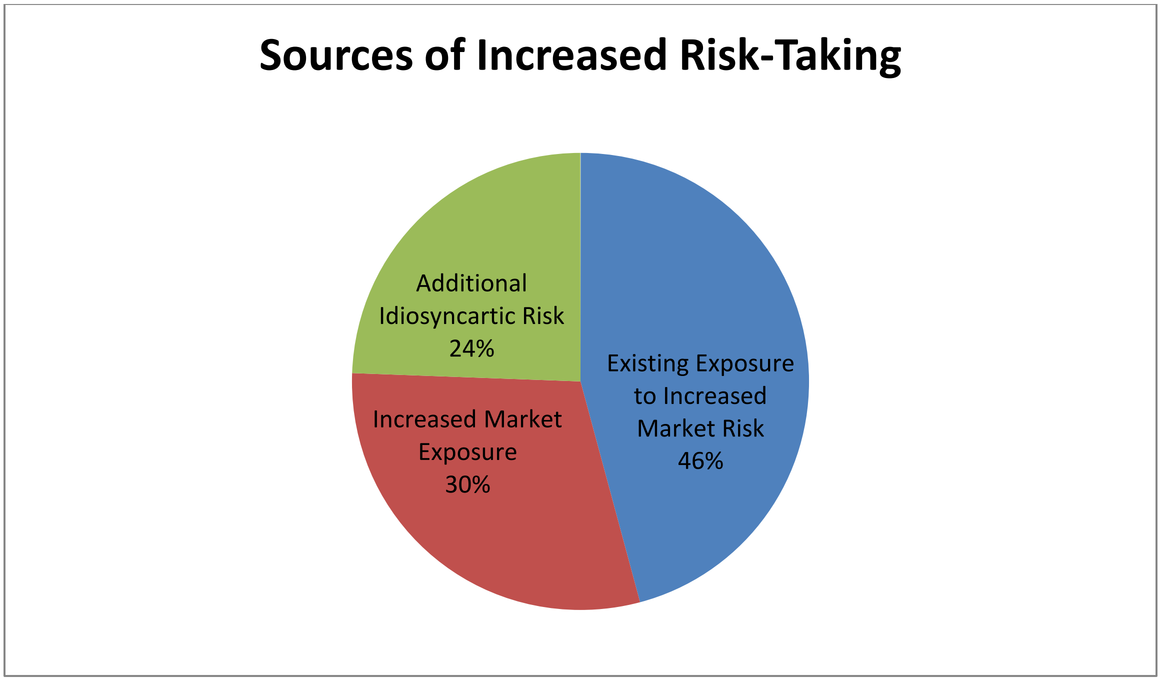
All Specifications include Age, Age Squared, Assets Under Management, Log Assets Under Management, Time Fixed Effects, and Fund Fixed Effects.

Table 6 – Mechanisms of Risk-Taking

	(1) Beta	(2) Alpha Risk
	2SLS	
Distance	0.4205***	0.0032*
	[0.129]	[0.002]
Observations	20,254	20,254
Number of Funds	3,945	3,945
Kleibergen-Paap Wald rk F statistic on Excluded Variables	52.45	52.45

Robust standard errors clustered by fund in brackets
*** p<0.01, ** p<0.05, * p<0.10
All Specifications include Age, Age Squared, Assets Under Management, Log Assets Under Management, Time Fixed Effects, and Fund Fixed Effects.

Figure 6 – Sources of Increased Risk-Taking



Appendix

Lemma 1:

Holding risk choice fixed, the expected payoff from the low risk level is:

$$\Pi_s(e) = b(e) + \frac{1}{2}\max\big(0, p(e-\epsilon-d)\big) + \frac{1}{2}\max\big(0, p(e+\epsilon-d)\big) - \frac{e^2}{2}$$

And the high risk choice is:

$$\Pi_s(e) = b(e-q) + (\alpha)\max\big(0, p(e-q-k\epsilon-d)\big) + \left(\frac{1}{2}-\alpha\right)\max\big(0, p(e-q-\epsilon-d)\big)$$
$$+ \left(\frac{1}{2}-\alpha\right)\max\big(0, p(e-q+\epsilon-d)\big) + (\alpha)\max\big(0, p(e-q+k\epsilon-d)\big) - \frac{e^2}{2}$$

This gives the following FOCs:

For low risk:

$$e = b + \frac{1}{2}p(I[e > \epsilon + d]) + \frac{1}{2}p(I[e > -\epsilon + d])$$

And High risk

$$e = b + \alpha p(I[e > k\epsilon + d + q]) + \left(\frac{1}{2}-\alpha\right)p(I[e > \epsilon + d + q]) + \alpha p(I[e > -k\epsilon + d + q])$$
$$+ \left(\frac{1}{2}-\alpha\right)p(I[e > -\epsilon + d + q])$$

Where $I[\cdot]$ is the indicator function.

The cost function satisfies the INADA conditions, so the possible solutions are interior. Note that the maximum effort might be is $e = b + p$.

Assumptions 1a, 1b, and that $k > 1$ (implied by 1c) ensure that $I[e > k\epsilon + d + q] = 0$, $I[e > \epsilon + d + q] = 0$, and $I[e > \epsilon + d] = 0$, so we simplify the FOCs.

For low risk:

$$e = b + \frac{1}{2}p(I[e > -\epsilon + d])$$

And High risk

$$e = b + \alpha p(I[e > -k\epsilon + d + q]) + \left(\frac{1}{2}-\alpha\right)p(I[e > -\epsilon + d + q])$$

Which yields 5 possible projects. All that remains to show is that $e = b, r = risky$ is dominated. For $e = b, r = risky$ to be a solution to the high risk FOCs implied that $b < -\epsilon + d + q$ so that $b < -\epsilon + d$ so that Low Risk Low Effort $e = b, r = safe$ is a potential alternative. The expected profit of $e = b, r = risky$ is $b(a + b - q) - \frac{b^2}{2}$ which is less than Π_{Lazy}. ■

Result 1 follows from directly comparing the expected profits in Lemma 1. All that remains is

1) To show that the Low Risk Low Effort to High Risk High Effort comparison is not binding

The missing condition for High Risk High Effort to be preferred to Low Risk Low Effort is:

$$-q\left(1 + \frac{2b}{p}\right) + \left(b + \frac{1}{4}p + \epsilon\right) + 2\alpha(k-1)\epsilon > d$$

It is not binding if:

$$-q\left(1+\frac{2b}{p}\right)+\left(b+\frac{1}{4}p+\epsilon\right)+2\alpha(k-1)\epsilon>\frac{1}{2}p\left(\frac{1}{2}+\alpha\right)+(b-q)+\epsilon$$

$$-q\left(\frac{2b}{p}\right)+2\alpha(k-1)\epsilon>\frac{1}{2}p(\alpha)$$

Which is not binding if:

$$-\frac{\alpha p(k-1)\epsilon}{b+\frac{1}{2}p}\left(\frac{2b}{p}\right)+2\alpha(k-1)\epsilon>\frac{1}{2}p(\alpha)$$

$$2\alpha(k-1)\epsilon\left(-\frac{b}{b+\frac{1}{2}p}+1\right)>\frac{1}{2}p(\alpha)$$

$$2\alpha(k-1)\epsilon>\frac{\frac{1}{2}p(\alpha)}{-\frac{b}{b+\frac{1}{2}p}+1}=(\alpha)\left(b+\frac{1}{2}p\right)$$

$$k>\frac{\left(b+\frac{1}{2}p\right)}{2\epsilon}+1$$

(Which is satisfied if $k>1.5$ since $\epsilon>b+p$)

2) To show that each of the posited choices meets the indicators in the relevant FOC.

Low Risk High Effort requires $e>-\epsilon+d$. But we have $e=b+\frac{p}{2}$ so we need:

$$b+\frac{p}{2}>-\epsilon+d$$

From 1a) we have a upper bound on d. So we have:$b+\frac{p}{2}>-\epsilon+b+\frac{1}{4}p+\epsilon$.

Low Risk Low Effort requires: $e<-\epsilon+d$. Or $b<-\epsilon+d$. We have that $b+\frac{1}{4}p+\epsilon<d$. Which implies that $b+\epsilon<d$.

High Risk High Effort requires: $e>-\epsilon+d+q$ But we have $e=b+\frac{p}{2}$ so we need:

$$b+\frac{p}{2}>-\epsilon+d+q$$

Substituting in we have:

$$b+\frac{p}{2}>-\epsilon+\frac{1}{2}p\left(\frac{1}{2}+\alpha\right)+(b-q)+\epsilon+q=\frac{1}{2}p\left(\frac{1}{2}+\alpha\right)+b$$

which since $\alpha<\frac{1}{2}$ is true.

High risk moderate effort requires:

$$e<-\epsilon+d+q$$

And

$$e>-k\epsilon+d+q$$

Or

$$b+\alpha p<-\epsilon+d+q$$

And

$$b + \alpha p > -k\epsilon + d + q$$

We have $\frac{1}{2}p\left(\frac{1}{2} + \alpha\right) + (b - q) + \epsilon < d$

So that it is sufficient to show that:

$$b + \alpha p < -\epsilon + q + \frac{1}{2}p\left(\frac{1}{2} + \alpha\right) + (b - q) + \epsilon = b + \frac{1}{2}p\left(\frac{1}{2} + \alpha\right) = b + \alpha p\left(\frac{1}{4\alpha} + \frac{1}{2}\right)$$

which since $\alpha < \frac{1}{2}$ is true.

We also have $-q\left(1 + \frac{b}{\alpha p}\right) + \left(b + \frac{\alpha p}{2} + k\epsilon\right) > d$ so that it is sufficient to show that:

$$b + \alpha p > -k\epsilon - q\left(1 + \frac{b}{\alpha p}\right) + \left(b + \frac{\alpha p}{2} + k\epsilon\right) + q = -\frac{qb}{\alpha p} + b + \frac{\alpha p}{2}$$

■

Result 2 follows from considering what increasing d does to any agent.

Consider an arbitrary agent with $b + \frac{1}{4}p + \epsilon > d$

Suppose that agent was, to begin with, in the Low Risk High Effort range. Increasing d moves it into either High Risk Moderate Effort or Low Risk Low Effort, if it changes behavior at all. This follows because conditions 1a) and 1c) in result 1 are upper bounds on d. Both of those other regions reflect strictly less effort and weakly more risk (High risk moderate effort is strictly more risk.)

Suppose that the agent was, to begin with, in the High Risk High Effort range. Increasing d moves it into the High Risk Moderate Effort range, if it changes behavior at all. This again follows because condition 2b) in result 1 is a lower bound on d. This reflects no change in risk-taking and less effort.

Suppose the agent, was, to begin with, in the High Risk Moderate Effort range. Increasing d as long as $b + \frac{1}{4}p + \epsilon > d$ does nothing, since the agent might only move to the Low Risk Low Effort range, but that requires that $b + \frac{1}{4}p + \epsilon < d$

That agent is not, to begin with, in the Low Risk Low Effort range, because d is too small.

So that increasing d moves the agent to more risk and less effort.

■

Result 3 follows by the same logic as result 2.

Consider an arbitrary agent with $b + \frac{1}{4}p + \epsilon < d$

The agent is, not, to begin with, in the Low Risk High Effort range, because d is too large.

Suppose that the agent was, to begin with, in the High Risk High Effort range. Increasing d moves it into the High Risk Moderate Effort range, if it changes behavior at all. This again follows because condition 2b) in result 1 is a lower bound on d. This reflects no change in risk-taking and less effort.

Suppose the agent, was, to begin with, in the High Risk Moderate Effort range. Increasing d moves the agent to the Low Risk Low Effort range, if changes behavior at all. This decreases both effort and risk.

Suppose that the agent was, to begin with, in the Low Risk Low Effort range, then increasing d does not change behavior, since this region only has lower bounds in d.

So that increasing d moves the agent to less risk and less effort.

■

Since the proofs of Results 2 & 3 are true for any arbitrary agent, specifying any distribution of agents is not necessary. Assumption 2 is a sufficient, simplifying condition for Results 4 & 5. To this, I first define the share of agents that take risk as a function of d.

For d below the first point of intersection, those with q low enough to prefer high risk effort over low risk effort, that is:

$$\frac{\alpha p(k-1)\epsilon}{\left(b+\frac{1}{2}p\right)} > q$$

So the share is:

$$F\left(\frac{\alpha p(k-1)\epsilon}{\left(b+\frac{1}{2}p\right)}\right)$$

For d between the first point of intersection and the second, this is defined by the High Risk Moderate Effort and Low Risk High Effort line:

$$\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}d + \frac{\alpha(k-1)\epsilon}{\left(\frac{b}{p}+\alpha\right)} - \frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}(b+\epsilon) - \frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right) > q$$

So the share is:

$$F\left(\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}d + \frac{\alpha(k-1)\epsilon}{\left(\frac{b}{p}+\alpha\right)} - \frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}(b+\epsilon) - \frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)\right)$$

For d between the second point of intersection and the third intersection, this is defined by the High Risk Moderate Effort to Low Risk Low Effort line:

$$\frac{\left(b+\frac{\alpha p}{2}+k\epsilon\right)}{\left(1+\frac{b}{\alpha p}\right)} - \frac{d}{\left(1+\frac{b}{\alpha p}\right)} > q$$

So the share is:

$$F\left(\frac{\left(b+\frac{\alpha p}{2}+k\epsilon\right)}{\left(1+\frac{b}{\alpha p}\right)} - \frac{d}{\left(1+\frac{b}{\alpha p}\right)}\right)$$

What are the intersections?

First intersection is $\frac{q\left(\frac{b}{p}+\alpha\right)}{\left(\frac{1}{2}-\alpha\right)} + (b+\epsilon) + \left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right) - \frac{\alpha}{\left(\frac{1}{2}-\alpha\right)}(k-1)\epsilon = d$ where $q = \frac{\alpha p(k-1)\epsilon}{\left(b+\frac{1}{2}p\right)}$

So we have:

$$\frac{\frac{\alpha p(k-1)\epsilon}{\left(b+\frac{1}{2}p\right)}\left(\frac{b}{p}+\alpha\right)}{\left(\frac{1}{2}-\alpha\right)}+(b+\epsilon)+\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)-\frac{\alpha}{\left(\frac{1}{2}-\alpha\right)}(k-1)\epsilon$$

$$\frac{(b+\alpha p)\alpha(k-1)\epsilon}{\left(b+\frac{1}{2}p\right)\left(\frac{1}{2}-\alpha\right)}+(b+\epsilon)+\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)-\frac{\alpha}{\left(\frac{1}{2}-\alpha\right)}(k-1)\epsilon$$

$$\frac{\left((b+\alpha p)-\left(b+\frac{1}{2}p\right)\right)\alpha(k-1)\epsilon}{\left(b+\frac{1}{2}p\right)\left(\frac{1}{2}-\alpha\right)}+(b+\epsilon)+\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)$$

$$\frac{\left((\alpha)-\left(\frac{1}{2}\right)\right)p\alpha(k-1)\epsilon}{\left(b+\frac{1}{2}p\right)\left(\frac{1}{2}-\alpha\right)}+(b+\epsilon)+\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)$$

$$d_1=\frac{-p\alpha(k-1)\epsilon}{\left(b+\frac{1}{2}p\right)}+(b+\epsilon)+\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)$$

Second intersection is where

$$\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}d+\frac{\alpha(k-1)\epsilon}{\left(\frac{b}{p}+\alpha\right)}-\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}(b+\epsilon)-\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)=\frac{\left(b+\frac{\alpha p}{2}+k\epsilon\right)}{\left(1+\frac{b}{\alpha p}\right)}-\frac{d}{\left(1+\frac{b}{\alpha p}\right)}$$

$$\frac{\left(\frac{b}{p}+\alpha\right)}{\alpha}\left(\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}d+\frac{\alpha(k-1)\epsilon}{\left(\frac{b}{p}+\alpha\right)}-\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}(b+\epsilon)-\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)\right)=\left(b+\frac{\alpha p}{2}+k\epsilon\right)-d$$

$$\frac{\left(\frac{1}{2}-\alpha\right)}{\alpha}d+\frac{\alpha(k-1)\epsilon}{\alpha}-\frac{\left(\frac{1}{2}-\alpha\right)}{\alpha}(b+\epsilon)-\frac{\left(\frac{1}{2}-\alpha\right)}{\alpha}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)=\left(b+\frac{\alpha p}{2}+k\epsilon\right)-d$$

$$\frac{\left(\frac{1}{2}-\alpha\right)}{\alpha}d+(k-1)\epsilon-\frac{\left(\frac{1}{2}-\alpha\right)}{\alpha}(b+\epsilon)-\frac{\left(\frac{1}{2}-\alpha\right)}{\alpha}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)=\left(b+\frac{\alpha p}{2}+k\epsilon\right)-d$$

$$\frac{\left(\frac{1}{2}-\alpha\right)}{\alpha}d+(-1)(b+\epsilon)-\frac{\left(\frac{1}{2}-\alpha\right)}{\alpha}(b+\epsilon)-\frac{\left(\frac{1}{2}-\alpha\right)}{\alpha}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)=\left(\frac{\alpha p}{2}\right)-d$$

$$\frac{\left(\frac{1}{2}-\alpha\right)}{\alpha}d+d-\frac{\left(\frac{1}{2}-\alpha\right)+\alpha}{\alpha}(b+\epsilon)-\frac{\left(\frac{1}{2}-\alpha\right)}{\alpha}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)=\left(\frac{\alpha p}{2}\right)$$

$$\frac{\left(\frac{1}{2}-\alpha\right)+\alpha}{\alpha}d-\frac{\left(\frac{1}{2}-\alpha\right)+\alpha}{\alpha}(b+\epsilon)-\frac{\left(\frac{1}{2}-\alpha\right)}{\alpha}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)=\left(\frac{\alpha p}{2}\right)$$

$$\frac{d}{2\alpha}-\frac{b+\epsilon}{2\alpha}-\frac{\left(\frac{1}{2}-\alpha\right)}{\alpha}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)=\left(\frac{\alpha p}{2}\right)$$

$$d-(b+\epsilon)-\left(\frac{1}{2}-\alpha\right)(p)\left(\frac{1}{2}+\alpha\right)=\alpha^2 p$$

$$d-(b+\epsilon)-\frac{\left(\frac{1}{2}-\alpha\right)p}{2}-\left(\frac{1}{2}-\alpha\right)p\alpha=\alpha^2 p$$

$$d-(b+\epsilon)-\frac{\left(\frac{1}{2}-\alpha\right)p}{2}-\left(\frac{1}{2}\right)p\alpha=0$$

$$d-(b+\epsilon)-\frac{\left(\frac{1}{2}\right)p}{2}=0$$

$$d_2=(b+\epsilon)+\frac{1}{4}p$$

The third intersection is where

$$\frac{\left(b+\frac{\alpha p}{2}+k\epsilon\right)}{\left(1+\frac{b}{\alpha p}\right)}-\frac{d}{\left(1+\frac{b}{\alpha p}\right)}=0$$

$$b+\frac{\alpha p}{2}+k\epsilon=d_3$$

So, the share of types that choose Risk (at any effort level) is:

$$Prob(Risky)$$
$$=\left\{\begin{array}{c} F\left(\frac{\alpha p(k-1)\epsilon}{\left(b+\frac{1}{2}p\right)}\right)\ if\ 0\le d\le d_1 \\ F\left(\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}d+\frac{\alpha(k-1)\epsilon}{\left(\frac{b}{p}+\alpha\right)}-\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}(b+\epsilon)-\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)\right)\ if\ d_1<d\le d_2 \\ F\left(\frac{\left(b+\frac{\alpha p}{2}+k\epsilon\right)}{\left(1+\frac{b}{\alpha p}\right)}-\frac{d}{\left(1+\frac{b}{\alpha p}\right)}\right)\ if\ d_2<d\le d_3 \\ 0, if\ d_3<d \end{array}\right\}$$

Effort undertaken is:

$$b + \frac{1}{2}p \; if \; 0 \leq d \leq d_1$$

Between d_1 and d_2, high effort $\left(b + \frac{1}{2}p\right)$ is undertaken by all except the triangle of those taking moderate effort $(b + \alpha p)$:

$$F\left(\frac{1}{2}p\left(\frac{1}{2}+\alpha\right) + (b-d) + \epsilon\right)\left(b + \frac{1}{2}p\right) + \left(F\left(\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}d + \frac{\alpha(k-1)\epsilon}{\left(\frac{b}{p}+\alpha\right)} - \frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}(b+\epsilon) - \frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)\right) - F\left(\frac{1}{2}p\left(\frac{1}{2}+\alpha\right) + (b-d) + \epsilon\right)\right)(b + \alpha p) + \left(1 - F\left(\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}d + \frac{\alpha(k-1)\epsilon}{\left(\frac{b}{p}+\alpha\right)} - \frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}(b+\epsilon) - \frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)\right)\right)\left(b + \frac{1}{2}p\right) \; if \; d_1 < d \leq d_2$$

Or

$$b + \frac{1}{2}p - \left(\frac{1}{2}-\alpha\right)p\left(F\left(\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}d + \frac{\alpha(k-1)\epsilon}{\left(\frac{b}{p}+\alpha\right)} - \frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}(b+\epsilon) - \frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)\right) - F\left(\frac{1}{2}p\left(\frac{1}{2}+\alpha\right) + (b-d) + \epsilon\right)\right) \; if \; d_1 < d \leq d_2$$

$$b+\frac{1}{2}p-\left(\frac{1}{2}-\alpha\right)p\left(F\left(\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}d+\frac{\alpha(k-1)\epsilon}{\left(\frac{b}{p}+\alpha\right)}-\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}(b+\epsilon)-\frac{\left(\frac{1}{2}-\alpha\right)}{\left(\frac{b}{p}+\alpha\right)}\left(\frac{1}{2}p\right)\left(\frac{1}{2}+\alpha\right)\right)\right.$$
$$\left.-F\left(\frac{1}{2}p\left(\frac{1}{2}+\alpha\right)+(b-d)+\epsilon\right)\right)\ if\ d_1<d\leq d_2$$

The next range, we have high $\left(b+\frac{p}{2}\right)$effort by a few moderate effort $(b+\alpha p)$ by some, and low effort b by the rest

$$b+F\left(\frac{1}{2}p\left(\frac{1}{2}+\alpha\right)+(b-d)+\epsilon\right)\left(\frac{1}{2}p\right)$$
$$+\left(F\left(\frac{\left(b+\frac{\alpha p}{2}+k\epsilon\right)}{\left(1+\frac{b}{\alpha p}\right)}-\frac{d}{\left(1+\frac{b}{\alpha p}\right)}\right)-F\left(\frac{1}{2}p\left(\frac{1}{2}+\alpha\right)+(b-d)+\epsilon\right)\right)\alpha p\ \ if\ d_2<d$$
$$<d_2'$$

Where $d_2'=\frac{1}{2}p\left(\frac{1}{2}+\alpha\right)+(b)+\epsilon=d_2+\frac{1}{2}p\alpha$

Or

$$b+F\left(\frac{1}{2}p\left(\frac{1}{2}+\alpha\right)+(b-d)+\epsilon\right)\left(\frac{1}{2}-\alpha\right)p+F\left(\frac{\left(b+\frac{\alpha p}{2}+k\epsilon\right)}{\left(1+\frac{b}{\alpha p}\right)}-\frac{d}{\left(1+\frac{b}{\alpha p}\right)}\right)\alpha p\ \ if\ d_2<d<d_2'$$

The next range, we have Moderate effort by some, and low effort by the rest, so

$$b+F\left(\frac{\left(b+\frac{\alpha p}{2}+k\epsilon\right)}{\left(1+\frac{b}{\alpha p}\right)}-\frac{d}{\left(1+\frac{b}{\alpha p}\right)}\right)\alpha p\ \ if\ d_2'<d<d_3$$

Finally, we have low effort by all

$$b\ if\ d_3<d$$

So we have, average effort as a function of d:

$$E(e|d) = \begin{cases} b + \frac{1}{2}p \; if \; 0 \leq d \leq d_1 \\ b + \frac{1}{2}p - \left(\frac{1}{2} - \alpha\right)p\left(F\left(\frac{\left(\frac{1}{2} - \alpha\right)}{\left(\frac{b}{p} + \alpha\right)}d + \frac{\alpha(k-1)\epsilon}{\left(\frac{b}{p} + \alpha\right)} - \frac{\left(\frac{1}{2} - \alpha\right)}{\left(\frac{b}{p} + \alpha\right)}(b+\epsilon) - \frac{\left(\frac{1}{2} - \alpha\right)}{\left(\frac{b}{p} + \alpha\right)}\left(\frac{1}{2}p\right)\left(\frac{1}{2} + \alpha\right)\right) - F\left(\frac{1}{2}p\left(\frac{1}{2} + \alpha\right) \cdots \right.\right. \\ b + F\left(\frac{1}{2}p\left(\frac{1}{2} + \alpha\right) + (b-d) + \epsilon\right)\left(\frac{1}{2} - \alpha\right)p + F\left(\frac{\left(b + \frac{\alpha p}{2} + k\epsilon\right)}{\left(1 + \frac{b}{\alpha p}\right)} - \frac{d}{\left(1 + \frac{b}{\alpha p}\right)}\right)\alpha p \; if \; d_2 \cdots \\ b + F\left(\frac{\left(b + \frac{\alpha p}{2} + k\epsilon\right)}{\left(1 + \frac{b}{\alpha p}\right)} - \frac{d}{\left(1 + \frac{b}{\alpha p}\right)}\right)\alpha p \; if \; d_2' < d < d_3 \\ b \; if \; d_3 < d \end{cases}$$

With assumption that q is distributed uniformly. Then we have $f(\cdot) = f$

$$\frac{\partial Prob(Risk)}{\partial d} = \begin{Bmatrix} 0 \; if \; 0 \leq d \leq d_1 \\ \frac{\left(\frac{1}{2} - \alpha\right)}{\left(\frac{b}{p} + \alpha\right)} f \; if \; d_1 < d \leq d_2 \\ \frac{-\alpha}{\left(\frac{b}{p} + \alpha\right)} f \; if \; d_2 < d \leq d_3, \\ 0, if \; d_3 < d \end{Bmatrix}$$

$$\frac{\partial E(e|d)}{\partial d} = \begin{Bmatrix} 0 \; if \; 0 < d < d_1 \\ -\left(\frac{1}{2} - \alpha\right)p\frac{\left(\frac{1}{2} + \frac{b}{p}\right)}{\left(\frac{b}{p} + \alpha\right)} f \; if \; d_1 < d < d_2, \\ -f\left(\frac{\left(\frac{1}{2}\right)\left(p + \frac{b}{\alpha}\right) - b}{\left(1 + \frac{b}{\alpha p}\right)}\right) \; if \; d_2 < d < d_2', \\ -f\frac{\alpha p}{\left(1 + \frac{b}{\alpha p}\right)} \; if \; d_2' < d < d_3, \\ 0, otherwise \end{Bmatrix}$$

Recreating results 2 & 3.

And cross partials:

$$\frac{\partial^2 Prob(Risk)}{\partial d \partial b} = \left\{ \begin{array}{c} 0\ if\ 0 \leq d \leq d_1 \\ -\frac{\left(\frac{1}{2}-\alpha\right)}{p\left(\frac{b}{p}+\alpha\right)^2} f\ if\ d_1 < d \leq d_2 \\ \frac{\alpha}{p\left(\frac{b}{p}+\alpha\right)^2} f\ if\ d_2 < d \leq d_3, \\ 0\ otherwise \end{array} \right\}$$

$$\frac{\partial^2 Prob(Risk)}{\partial d \partial p} = \left\{ \begin{array}{c} 0\ if\ 0 \leq d \leq d_1 \\ \frac{b\left(\frac{1}{2}-\alpha\right)}{p^2\left(\frac{b}{p}+\alpha\right)^2} f\ \ if\ d_1 < d \leq d_2 \\ -\frac{\alpha b}{p^2\left(\frac{b}{p}+\alpha\right)^2} f\ if\ d_2 < d \leq d_3, \\ 0, otherwise \end{array} \right\}$$

$$\frac{\partial^2 E(e|d)}{\partial d \partial b} = \left\{ \begin{array}{c} 0\ if\ 0 \leq d \leq d_1 \\ \frac{\left(\frac{1}{2}-\alpha\right)^2}{\left(\frac{b}{p}+\alpha\right)^2} f \quad if\ d_1 < d < d_2 \\ f\frac{1}{\left(1+\frac{b}{\alpha p}\right)^2}\ if\ d_2 < d < d_2' \\ f\frac{1}{\left(1+\frac{b}{\alpha p}\right)^2}\ if\ d_2' < d < d_3 \\ 0, otherwise \end{array} \right\}$$

$$\frac{\partial^2 E(e|d)}{\partial d \partial p} = \begin{Bmatrix} -\frac{\left(\frac{1}{2}-\alpha\right)^2}{\left(\frac{b}{p}+\alpha\right)^2}\left(\left(\frac{b}{p}+\alpha\right)+\frac{1}{p}\right)f \;\; if\; d_1 < d < d_2\,, \\ -f\left(\left(\frac{1}{2}-\alpha\right)+\frac{2b+\alpha p}{\left(1+\frac{b}{\alpha p}\right)^2 p}\right) \;\; if\; d_2 < d < d_2', \\ -f\frac{2b+\alpha p}{\left(1+\frac{b}{\alpha p}\right)^2 p} \;\; if\; d_2' < d < d_3, \\ 0\; otherwise \end{Bmatrix}$$

Yield results 4&5.

■

Corollaries 2.1, 4.1& 5.1 follow since the risk-taking and effort comparative statics have opposite signs and more risk-taking lowers performance.

■

Corollary 3.1 balances the comparative statics. If q is large, then the improved performance from reduced risk-taking outweighs the decline in performance from the effort reduction.

■

The assumption that the high risk project has a lower expected outcome than the low risk project is worth more discussion. First, note that if a project with higher risk than the high risk project and higher expected value than the low risk project at the same effort level was available, because this manager is risk-neutral, then that project would dominate both other projects. What exactly does it mean that the manager cannot find a riskier project with a higher expected return than the low risk project? There are several points to consider. First, the usual derivation of why the risk return frontier should be upward sloping comes from the expectation that investors would demand higher return for riskier investments, and not something about the underlying projects that can be undertaken. Indeed, these type of threshold incentives show that this is not always the case. The other, related derivation is that investors would never choose a higher risk lower reward project because they could always borrow and increase their exposure to the low risk project and increase the risk and reward simultaneously. However, when there are scale limits, either due to borrowing costs or finite scale projects, this may not be an option.[28] Alternatively, this can be seen as a stylization of risk-aversion. If both the manager and the principal are equally risk-averse, we can think of the expected performance of the model as representing the risk-adjusted performance.

[28] Indeed, this is a particular concern of hedge funds. Industry participants describe not wanting to own more than 5 or 10% of a particular asset so that managers of large funds or heavily leveraged funds are not able to make investments of the scale they would like.