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Risking or Derisking: How Management Fees Affect Hedge Fund Risk-Taking Choices

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Hedge fund managers' risk-taking choices are influenced by their compensation structure. We differ from most studies that focus on incentive fees and the high-water mark by examining how management fees affect managers' risk-taking. Our simple model shows that managers' risk-taking is negatively related to their future management fees. Using fund-level data, we find that future management fees are the dominant component of managers' total compensation. When the contribution of future management fees increases, managers reduce risk-taking to increase survival probabilities. Moreover, funds with higher decreasing returns to scale are more sensitive to future management fees and reduce risk-taking even more. (*JEL* G20, G23, G29)

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Media articles routinely associate hedge funds with aggressive risk-taking.[1] According to these articles, hedge fund managers speculate on movements of all types of financial assets, which include stocks, currencies, interest rates, commodities, and even exotic ones, such as sporting events and lawsuits.[2] The characterizations in these articles are not completely unfounded. Unlike traditional investment vehicles, such as pension funds and mutual funds, hedge funds are significantly less regulated. Hedge fund managers have the freedom

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[1] See, for instance, McGee (2014).

[2] See, for instance, Barrett (2015).

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to use more weapons in the investment armory, including highly risky ones, such as leverage, derivatives, and short selling. Meanwhile, the compensation structure for hedge fund managers, especially the combination of the incentive fee and the high-water mark, is highly nonlinear and resembles a call option. Because the value of an option is likely to increase with uncertainty, hedge fund managers' compensation structure may encourage managers to take more risk. Thus, it is reasonable for the public to worry that hedge funds may take on excessive risk.

The landscape of the hedge fund industry clearly changed after the global financial crisis in 2008. With more regulations and less-than-stellar returns in recent years, many hedge funds have become more conservative and take less risk. One possible explanation for this "derisking" behavior is that hedge fund managers became more reliant on the management fee for their compensation. As discussed in Lan, Wang, and Yang (2013, LWY hereafter) and Yin (2016), the management fee might be the dominant component of many hedge fund managers' total compensation. Because fund managers can always collect the asset-based management fee as long as their funds are alive, fund survival becomes their first priority. Consequently, fund managers have incentives to take less risk to increase survival probabilities so that they can keep collecting the management fee in the future.

Understanding how hedge funds choose between more or less risk-taking is an interesting and important research topic. According to the long literature on fund managers' risk-taking choices, hedge fund managers choose their optimal levels of risk-taking to maximize their total future compensation. For instance, Merton (1969) suggests that a CRRA-type fund manager should maintain constant leverage over time, and Carpenter (2000) examines the impact of call options embedded in the incentive fee on managers' risk-taking. Most existing studies, including Goetzmann, Ingersoll, and Ross (2003, GIR hereafter), Hodder and Jackwerth (2007), and Panageas and Westerfield (2009), focus on the incentive fee and the high-water mark provision and neglect the management fee. More recent studies, such as LWY, Drechsler (2014), and Buraschi, Kosowski, and Sritrakul (2014), do consider managers' total compensation, but do not explicitly examine the impact of each component of managers' compensation on their risk-taking behavior. In this study, we take a unique perspective to examine how the management fee affects hedge fund managers' risk-taking choices.

Given that existing theoretical models either neglect the management fee or include the management fee without providing clear guidance on how it affects managers' risk-taking, we first introduce a simple model to illustrate the intuition and derive testable hypotheses regarding the impact of the management fee on managers' risk-taking behavior. To keep the model tractable, we simplify the model structure while retaining key assumptions from previous studies, such as GIR and LWY. The model predicts a negative relation between managers' risk-taking choices and the relative importance of future management fees. That is, hedge fund managers take less risk when their future management fees contribute more to their total compensation, possibly to increase survival probabilities and protect their future income. Meanwhile, we incorporate decreasing returns to scale in our model. When hedge funds suffer from decreasing returns to scale, they are more likely to rely on the management fee for compensation and thus are more sensitive to the relative importance of future management fees. Consistent with this possibility, our model suggests that funds with decreasing returns to scale reduce risk-taking even more than their peers when future management fees become more important.

Using fund-level data from the Lipper TASS database from 1994 to 2015, we empirically test our hypothesis that higher relative importance of future management fees is associated with lower risk-taking. Because managers' compensation is not directly observable in the data, we compute the present value of future compensation following the procedure outlined in Lim, Sensoy, and Weisbach (2016, LSW hereafter) and Agarwal, Daniel, and Naik (2009, ADN hereafter). We calculate the contribution of future management fees to managers' total compensation as the ratio of the present value of future management fees to the present value of managers' total compensation, which includes future management fees, future incentive fees, and managers' coinvestments.[3] Meanwhile, we measure hedge fund risk-taking using total fund return volatility, style beta, and style residual volatility, following Buraschi, Kosowski, and Sritrakul (2014).

Consistent with LWY, we find that future management fees comprise the largest portion of managers' total compensation. The mean contribution of future management fees to managers' total compensation is about 40% with a standard deviation of 18.30%. Meanwhile, about 30% of managers' total compensation comes from future incentive fees and the rest comes from managers' coinvestments. More importantly, when the contribution of future management fees to managers' total compensation increases, hedge fund managers take less risk, which supports the theoretical prediction from our simple model. For instance, an interdecile increase in the contribution of future management fees is associated with a decrease in total volatility of 0.2413% per month, a decrease in style beta of 0.2315, and a decrease in residual volatility of 0.2955% per month. Thus, we are the first to provide evidence of a negative relation between the management fee and managers' risk-taking behavior.

As mentioned earlier, one possible reason for the reduced risk-taking is to increase fund survival probabilities, so that fund managers can keep collecting the management fee in the future. Our empirical results show that termination probabilities of hedge funds significantly decrease when future management fees become more important, which is consistent with this mechanism.

[3] Hedge fund managers are commonly required to invest in their own funds. As in Aragon and Nanda (2011) and Gupta and Sachdeva (2019), managers' coinvestments (i.e., managers' investments in their own funds) are an important part of managers' total compensation.

Economically, if all other variables are set at their median values, an increase from the 10th to the 90th percentiles of the contribution of future management fees is associated with a 5% decrease in termination probability.

Next, we examine the impact of decreasing returns to scale on the relation between risk-taking choices and the importance of future management fees. Our model suggests that funds with decreasing returns to scale are more sensitive to the relative importance of future management fees. To test this hypothesis, we follow the literature and examine the behavior of large hedge funds and funds using strategies with capacity constraints, because these funds are more subject to decreasing returns to scale. We find that large hedge funds reduce risk-taking more than small funds when future management fees become the dominant component of their compensation package. Meanwhile, funds using capacity constrained strategies reduce risk-taking more than their peers, especially when they have large capital inflows. Thus, consistent with the hypothesis, decreasing returns to scale makes funds more sensitive and these funds reduce risk-taking more than their peers when future management fees contribute more to managers' compensation.

Finally, we conduct a comprehensive set of robustness tests. For instance, our results are robust when we control for other manager incentive measures, such as the contribution of future incentive fees, realized fee income as in Yin (2016), and direct incentives as in ADN.[4] Thus, our measure provides new insights into managers' incentives and their risk-taking behavior.

To the best of our knowledge, we are the first to empirically examine the impact of the management fee on hedge fund risk-taking. Our unique contribution is that we provide evidence that managers take less risk when the management fee contributes more to their total compensation, possibly because the potential downside losses of fund termination outweigh the potential upside gains of higher risk-taking when fund managers rely on the management fee for compensation.

One closely related work is LWY, which examines fund managers' optimal leverage choices against the cost of fund liquidation. They show theoretically that a risk-neutral manager becomes endogenously risk averse and decreases leverage following poor performance to increase the fund's survival likelihood. We borrow key ingredients from LWY and establish a simple model to derive a direct relation between the management fee and managers' risk-taking choices. The biggest difference between our study and LWY is that the LWY model does not provide direct implications for the relation between hedge fund managers' risk-taking behavior and future management fees. We study this relation empirically and provide significant evidence supporting our main hypothesis.

4 The direct incentives are the dollar change in the manager's current compensation for a hypothetically 1% increase in the fund's return.

Another closely related work is LSW, which calculates indirect incentives for fund managers.[5] They argue that good current performance attracts future inflows of capital and leads to higher future fees, and they show that these indirect incentives are more important than the direct incentives documented in ADN for hedge fund managers. We follow a similar procedure to calculate the present value of managers' future compensation. However, our paper is significantly different from LSW because we address very different research questions. First, we focus on the relative importance of the management fee in managers' future total compensation. In contrast, LSW focus on changes in managers' total compensation and do not examine individual components, such as the management fee. Second, LSW link indirect incentives to fund performance and capital flows, while we focus on how future management fees affect managers' risk-taking choices. Given the differences between our study and previous studies, we make a significant contribution to the literature and can help investors better understand hedge fund managers' risk-taking behavior.

1. A Simple Model on Risk-Taking and Management Fees

1.1 Literature review

Starting with Merton (1969) and Carpenter (2000), the manner in which hedge fund managers' compensation influences fund managers' risk-taking behavior has been studied both theoretically and empirically in the literature. However, because assumptions vary across theoretical models, they reach mixed conclusions regarding managers' risk-taking choices. In this section, we review several key papers that are relevant to our study.

One important early work is GIR, which examines the costs and benefits of high-water mark provisions in hedge fund managers' compensation contracts. The authors show that fund managers should reduce volatility when fund value is near liquidation to increase survival probabilities and increase volatility at higher asset levels to increase the value of the incentive fee. Several later papers, such as Hodder and Jackwerth (2007) and Panageas and Westerfield (2009), follow the path of GIR and examine the impact of the incentive fee contract and the high-water mark provision on managers' behavior.[6]

More recently, LWY provides a different perspective by quantitatively valuing both management fees and incentive fees in a model with endogenous leverage choice. They find that a risk-neutral manager becomes endogenously risk averse and decreases leverage following poor performance to increase

[5] The indirect incentives are the dollar change in the manager's expected future compensation for a hypothetical 1% increase in the fund's return.

[6] Hodder and Jackwerth (2007) find that fund managers increase their risk-taking when the fund's value falls below the high-water mark, and fund managers allocate a constant proportion of fund capital to the risky asset when the fund's value is above the high-water mark. Panageas and Westerfield (2009) show that fund managers allocate a constant fraction of capital to the risky asset when they have an infinite horizon, and they opt for unbounded volatility as they approach the termination time with a finite horizon.

the fund's survival likelihood. In their baseline model, fund managers have an infinite time horizon and try to maximize the present value of total fees (i.e., the incentive fee plus the management fee).[7] LWY's calibration results suggest that the management fee is the more important part of managers' total compensation, which implies that survival is more important for fund managers. Therefore, hedge fund managers choose to take less risk when fund value is below the high-water mark.[8]

The existing literature also has many empirical papers that test the implications of these theoretical models.[9] For instance, ADN shows that hedge funds have better performance when their managers have higher direct incentives. Most empirical studies in the recent literature adopt the algorithm in ADN to calculate the market value of investors' investments and track investors' high-water marks over time.

LSW provides additional empirical insights by designing an algorithm to calculate managers' indirect incentives (changes in managers' future compensation), mostly using the GIR model and the LWY model. Their empirical results show that with capital flows from new investors chasing good performance, the indirect incentives from future fees are much larger than direct incentives for hedge fund managers.

As we can see from above, many studies in the literature primarily focus on the incentive fee and the high-water mark provision, while the management fee is commonly neglected. However, both academics and practitioners have slowly begun to recognize the importance of the management fee in recent years.[10] In addition to the calibration results in LWY, Yin (2016) shows empirically that when funds grow large, the realized management fee in absolute dollar amounts becomes more important than the incentive fee.

1.2 A simple model on risk-taking and the management fee

How hedge fund managers make their risk-taking choices clearly depends on their compensation structure. While the performance-based incentive fee and the high-water mark provision are likely to motivate fund managers to take more risk and improve fund performance, the asset-based management fee provides a stable source of income for fund managers so long as their funds are not liquidated. When fund managers rely more on the management fee for compensation, would they reduce risk-taking to increase survival probabilities so that they can continue to collect the management fee in the future?

[7] LWY also extend their baseline model to include managers' coinvestments to examine the impact of managerial ownership on risk-taking.

[8] A different model in Buraschi, Kosowski, and Sritrakul (2014) indicates that fund managers increase risk-taking when the fund's value falls below the high-water mark but decrease risk-taking when funds are near termination. Drechsler (2014) shows that hedge fund managers' risk-taking depends on managers' outside option value, investors' termination policy, and management fees, among other factors.

[9] See also Agarwal, Aragon, and Shi (2019), among others.

[10] See Wilson (2012), among others.

The existing theoretical literature does not provide a ready answer to this question. Moreover, managers' decisions in extant theoretical models often involve many factors, and thus it is difficult to observe a direct relation between managers' risk-taking and the management fee. Therefore, we establish a simple model in this subsection to illustrate the direct relation between hedge fund managers' risk-taking and the relative importance of the management fee. This model is highly stylized to ensure tractability. We only keep the key ingredients and the most essential assumptions from the literature (e.g., the GIR model and the LWY model) to derive a testable relation between managers' risk-taking choices and the relative importance of the management fee.

Consider a hedge fund with a two-period horizon. At initiation (i.e., $t=0$), the total fund assets are W_0, with $V_0=(1-\phi)W_0$ from outside investors and the rest from the fund manager. That is, the fund manager's coinvestments in her own fund are $CoInvest_0=\phi W_0$, where ϕ represents managerial ownership and $0\leq\phi<1$.

For both periods 1 and 2, the risk-neutral fund manager optimally invests a fraction of fund assets, π_t, in an alpha-generating strategy and the rest in a risk-free asset to maximize her expected compensation. For each period, the risk-free asset pays a constant interest r for each dollar invested, and the alpha-generating strategy pays $\alpha'+r+\varepsilon'$, where α' denotes the expected return in excess of the risk-free rate or the unlevered alpha, and $\varepsilon'\sim N(0,\sigma')$. Thus, the return of the fund for each period t is

$$r+\pi_t\left(\alpha'+\varepsilon'\right)=r+\alpha_t+\varepsilon_t. \tag{1}$$

Here, α_t is the levered alpha, and $\alpha_t=\pi_t\alpha'$. Similarly, $\varepsilon_t=\pi_t\varepsilon'$, $\varepsilon_t\sim N(0,\sigma_t)$, and $\sigma_t=\pi_t\sigma'$.

Then, fund assets at time t before any fees and capital flows are

$$\bar{W}_t=W_{t-1}(1+r+\alpha_t+\varepsilon_t)-\gamma(\pi_t W_{t-1})^2=W_{t-1}(1+r+\alpha_t+\varepsilon_t-\gamma\pi_t^2 W_{t-1}), \tag{2}$$

with the upper bar indicating that the value is before fees and flows. We follow Berk and Green (2004) and include a cost function, $\gamma(\pi_t W_{t-1})^2$, to consider the possibility that the hedge fund suffers from decreasing returns to scale when the manager invests more assets in the alpha-generating strategy.[11] The cost function is a quadratic function of fund assets and thus allows the costs to increase faster than profits, which leads to decreasing returns to scale when funds grow large. Parameter $\gamma>0$ is a constant, and a higher γ indicates that a fund suffers a higher degree of decreasing returns to scale. In later discussions, we choose different values for γ to examine how different degrees of decreasing returns to scale affect the model's predictions.

[11] Teo (2009), Getmansky (2012), and Yin (2016) document that hedge funds likely suffer from decreasing returns to scale.

Similarly, the market value of investors' investments in the fund before any fees and flows for each period t is

$$\bar{V}_t = V_{t-1}(1+r+\alpha_t+\varepsilon_t-\gamma\pi_t^2 W_{t-1}). \tag{3}$$

The manager's coinvestments in the fund for each period t become

$$CoInvest_t = CoInvest_{t-1} \times \left(1+r+\alpha_t+\varepsilon_t-\gamma\pi_t^2 W_{t-1}\right). \tag{4}$$

We further assume that when the market value of investors' investments before any fees and flows, $\bar{V}_t$, falls below a fraction $b(0<b<1)$ of its high-water mark, bH_{t-1}, the fund is liquidated. At liquidation, the fund manager loses all future fees but can recoup her coinvestments, $CoInvest_t$. The market value of investors' investments in the fund after fees and capital flows for period t is

$$V_t = \bar{V}_t - MFee_t - IFee_t + Flow_t. \tag{5}$$

Here, $MFee_t$, $IFee_t$, and $Flow_t$ are the management fee, the incentive fee, and capital flows for period t, respectively, which we will define below. Consequently, fund assets after fees and flows are $W_t = V_t + CoInvest_t$.

We follow LWY and assume that the fund attracts capital flows at the end of the first period after good performance,

$$Flow_1 = \max\left(i\left[\bar{V}_1 - H_0(1+g)\right], 0\right), \tag{6}$$

where $i>0$ measures the sensitivity of capital flows to fund profits; variable H_0 is the initial high-water mark and is set to be equal to investors' initial investments, that is, $H_0 = V_0$; and variable g is the growth rate of the high-water mark. We assume $g=r$, which ensures that the fund manager cannot charge the incentive fee by investing all money in the risk-free asset. Because we assume that the fund stops operating at the end of period 2 and returns the capital to investors, there are no capital flows from investors at the end of period 2 (i.e., $Flow_2 = 0$).

The management fee and the incentive fee for each period t are defined as

$$MFee_t = c\bar{V}_t, \tag{7}$$

$$IFee_t = \max\left(k\left[\bar{V}_t - H_{t-1}(1+g)\right], 0\right), \tag{8}$$

where variable c is the management fee percentage, and variable k is the incentive fee percentage. The incentive fee is collected only if fund value is above the high-water mark, $H_{t-1}(1+g)$. The manager's total compensation has three components, the management fee, the incentive fee, and her coinvestments. We now spell out the fund manager's total compensation in period 1 for different contingencies:

$$COMP_1 = \begin{cases} MFee_1 + IFee_1, \text{ if } \bar{V}_1 > H_0(1+g); \\ MFee_1, \text{ if } bH_0 < \bar{V}_1 \le H_0(1+g); \\ CoInvest_1, if\, 0 < \bar{V}_1 \le bH_0; \\ 0, if\, \bar{V}_1 \le 0. \end{cases} \tag{9}$$

For the first contingency, the fund value is above the high-water mark, so the manager receives the management fee and the incentive fee; for the second contingency, the fund value is below the high-water mark but above the liquidation boundary, so the manager receives the management fee; for the third contingency, the fund value is below the liquidation boundary, so the fund manager loses all the fees but can recoup her coinvestments; for the last contingency, the fund value is nonpositive, so the fund manager receives zero. For the first two contingencies, the fund is not liquidated, and thus the fund manager would keep her coinvestments in the fund.

As discussed above, there are no capital flows from investors at the end of period 2, and the fund manager also recoups her coinvestments. Similar to Equation (9), for different contingencies, the fund manager's total compensation in period 2 becomes, where $H_1 = \max(H_0(1+g),\ V_1)$:

$$COMP_2 = \begin{cases} CoInvest_2 + MFee_2 + IFee_2,\ if\ \bar{V}_2 > H_1(1+g); \\ CoInvest_2 + MFee_2,\ if\, bH_1 < \bar{V}_2 \le H_1(1+g); \\ CoInvest_2, if\, 0 < \bar{V}_2 \le bH_1; \\ 0, if\, \bar{V}_2 \le 0. \end{cases} \tag{10}$$

With our model's set up, the fund manager first chooses the optimal risk-taking level σ_1 (or the linearly related investment strategy π_1) at the beginning of the first period to maximize her expected total future compensation from both periods, that is, $COMP_1$ in Equation (9) and $COMP_2$ in Equation (10). At the beginning of the second period, the fund manager chooses the optimal risk-taking level σ_2 (or the linearly related investment strategy π_2) to maximize her expected compensation for the second period, that is, $COMP_2$ in Equation (10).[12]

A natural way to measure the relative importance of the management fee in this model, which is also the focus of our study, is the contribution of future management fees to the manager's expected total compensation at initiation, specified as

$$FutureMFee\% = \frac{E[MFee_1 + MFee_2]}{E[COMP_1 + COMP_2]}. \tag{11}$$

This variable directly measures the importance of the management fee for a fund in the time series and makes it easy to compare the management fee's importance across funds.

Our main research question is how managers' risk-taking choices are related to the importance of future management fees, and we intend to derive testable implications from the optimal solutions to our simple model. However, because of the complexity of the fee structure and the probability of fund liquidation, there are no closed-form solutions for σ_1 and σ_2. As an alternative, we find numerical solutions by combining Monte Carlo simulations in period 1 with nonlinear optimization in period 2.

12 For a multiperiod model, fund managers would maximize the present value of all future compensation. Because our model has only two periods, we do not discount the expected compensation back to time 0 for simplicity.

For the Monte Carlo simulations in period 1, we follow prior literature and set a subset of parameters to be constants, as presented in Table A.1 in Appendix A. The key varying parameter is the initial fund value, W_0, and we need to solve for the optimal σ_1 for each given W_0. We normalize W_0 to be between the liquidation boundary b and 1. Note that W_0 is a standardized variable, which mainly reflects the distance to the high-water mark rather than the absolute fund size. For σ_1, we use the linearly related investment strategy π_1 for the simulation. Following LWY, we assume that π_1 is in the range of $(0,4)$. Thus, we conduct our simulation on all possible combinations of W_0 and π_1. Within each combination, given the value of π_1, we generate 10,000 values of $\varepsilon_1 \sim N(0,\sigma_1)$, where $\sigma_1 = \pi_1 \sigma'$. For each set of $\{W_0, \pi_1, \sigma_1, \varepsilon_1\}$, we calculate the manager's compensation for the first period as in Equations (9). For period 2, we solve for the optimal risk-taking choice, σ_2^*, that maximizes expected $COMP_2$ in Equation (10) for each set of $\{W_0, \pi_1, \sigma_1, \varepsilon_1\}$. Finally, for each W_0, we find the optimal risk-taking choice in period 1, σ_1^*, as the one with the highest mean total compensation from both periods. Appendix A provides more calculation details.[13]

Our model delivers two intuitive and testable implications. The first implication is that the fund manager's optimal risk-taking choice in period 1, σ_1^*, is negatively related to the importance of future management fees, *FutureMFee%*. That is, when future management fees contribute more to their total future compensation, hedge fund managers take less risk. Note that we focus on the fund manager's risk-taking choices in period 1 instead of period 2 because period 2 is the termination period, and thus there is no *future* compensation to maximize. To illustrate the first implication, panel A of Figure 1 presents the relation between σ_1^* and *FutureMFee%*, and we observe a clear negative relation. That is, when the management fee becomes more important, the fund manager takes less risk. One possible reason for the manager's choice of lower risk-taking is to increase fund survival probabilities. In other words, the fund is more likely to survive when the fund manager takes less risk. Panel B of Figure 1 shows a generally negative relation between the manager's optimal risk-taking choice in period 1 and the fund's survival probability at the end of period 1.[14] In other words, the fund is more likely to survive when the fund manager takes less risk. These findings are consistent with LWY, but the LWY model does not provide direct implications for the relation between hedge fund managers' risk-taking behavior and future management fees.

13 In Section A of the Internet Appendix, we calibrate our model using an alternative approach, in which we perform Monte Carlo simulations for both periods and search for the pair of $\{\sigma_1, \sigma_2\}$ with the highest total compensation for a given starting fund size. Results are qualitatively similar under this alternative approach.

14 In panel B of Figure 1, some funds can take higher risk and still have high survival probabilities because their starting sizes are closer to the high-water mark.

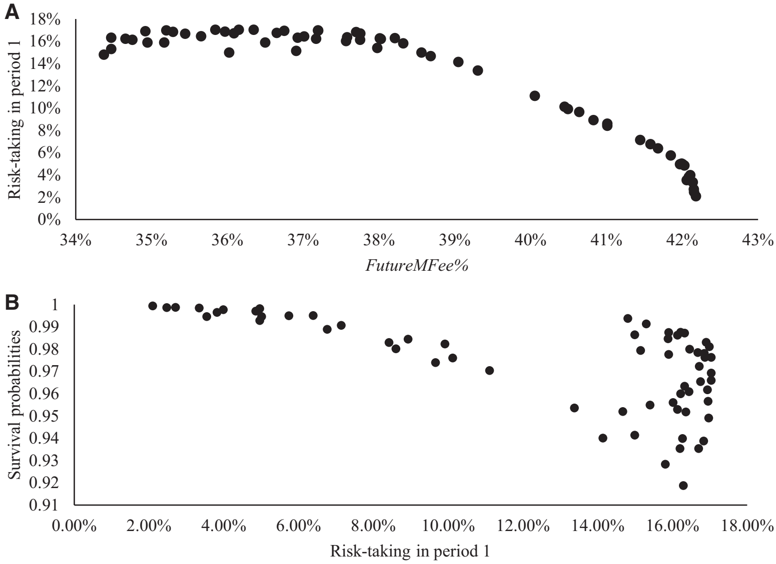

Figure 1
Calibration results for the two-period model
This figure shows the calibration results for our two-period model explained in Section 1.2. Panel A presents the relation between the optimal risk-taking choice in period 1 (i.e., σ_1^*) and the contribution of future management fees (i.e., *FutureMFee%*) to the manager's total compensation. Panel B reports the relation between the fund's survival probabilities at the end of period 1 and the manager's optimal risk-taking choice in period 1. Appendix A summarizes the parameter choices and calculation details.

The intuition for the first implication is quite simple. When the fund manager takes more risk, she faces a dilemma. On the one hand, taking more risk can boost her expected incentive fee because of increased expected performance. On the other hand, taking more risk increases the probability of fund liquidation, at which point she would lose all future fees. Thus, the fund manager's decision is associated with the importance of the management fee relative to total compensation. If the expected management fee is more important to the total compensation package, then the fund manager may want to reduce risk-taking because fund liquidation is quite costly to her. However, if the expected management fee is less important, then the fund manager may have stronger incentives to take more risk and boost fund performance. We examine this first implication empirically in Sections 3.1 and 3.2.

The second implication of our model is that funds with higher degrees of decreasing returns to scale (i.e., higher γ in our model) rely more on future management fees and thus take less risk. To clearly illustrate this result, we start by showing *FutureMFee%* for each W_0 in panel A of Figure 2. Here, we consider two cases for comparison: the solid dots represent the baseline fund from Figure 1 ($\gamma = 0.003$), and the circles represent a fund with higher decreasing returns to scale ($\gamma = 0.006$). Clearly, the fund with higher γ always has higher

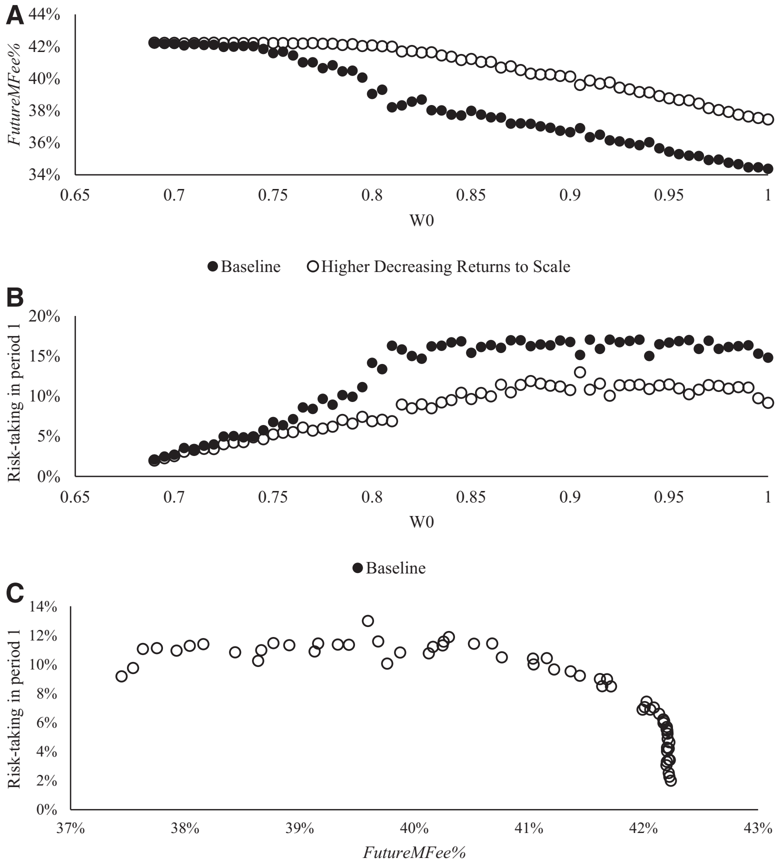

Figure 2
Impact of decreasing returns to scale
This figure examines the impact of decreasing returns to scale. In addition to the baseline fund from Figure 1, we also include a fund with a higher cost parameter ($\gamma = 0.006$). Panel A reports the contribution of future management fees to the manager's total compensation (i.e., *FutureMFee%*) for both funds. Panel B reports the optimal risk-taking choices in period 1 (i.e., σ_1^*) for both funds. Panel C examines the relation between the optimal risk-taking choices in period 1 and the contribution of future management fees to the manager's total compensation for the fund with higher decreasing returns to scale. Appendix A summarizes the parameter choices and calculation details for the calibration.

FutureMFee% for each W_0, indicating that funds with higher decreasing returns to scale rely more on future management fees for compensation. Panel B of Figure 2 presents the fund manager's optimal risk-taking choice in period 1, σ_1^*, for the baseline fund (solid dots) and the fund with higher γ (circles). The fund with higher γ clearly always takes less risk. Combining panels A and B, we infer that funds with higher γ rely more on management fees and managers tend to take less risk. Panel C presents the relation between future management fees and the optimal risk-taking choice for the fund with higher γ. The negative relation between *FutureMFee%* and σ_1^* is consistent with the model's first implication. To examine whether the risk-taking choices of the fund with higher γ are more sensitive to the importance of future management fees, we compute the slope of σ_1^* with respect to *FutureMFee%* at each W_0 for both funds. For the benchmark fund with $\gamma = 0.003$, the average slope is approximately -10. For the fund with $\gamma = 0.006$, the average slope becomes -24. This indicates that the fund with higher decreasing returns to scale takes even less risk when *FutureMFee%* becomes higher.

The intuition for the second implication is as follows. For hedge funds suffering from higher decreasing returns to scale, it becomes more difficult to generate good performance when they grow large. Thus, funds with higher decreasing returns to scale are more likely to rely on the management fee for compensation. Meanwhile, funds with higher decreasing returns to scale need to take extra risk to improve performance relative to their peers with lower decreasing returns to scale. Higher risk-taking leads to higher liquidation probabilities, thereby putting future compensation at greater risk. Thus, funds with higher decreasing returns to scale have lower incentives to take risk when future management fees are more important to their total compensation. Taken together, managers of funds with higher decreasing returns to scale tend to rely more on future management fees for compensation and consequently take less risk. We examine the impact of decreasing returns to scale on the relation between risk-taking and future management fees empirically in Section 3.3.

2. Data and Methodology

2.1 Data

We obtain data from the Lipper TASS database. Following prior literature, we apply the following eight filters to the data. First, to minimize the survivorship bias, we include defunct funds in our sample. Because TASS provides data on defunct funds dating back to 1994, the sample period in this study is from January 1994 to December 2015. Second, to mitigate the backfill bias, we exclude observations before the dates when funds were added to the TASS database. If a fund's add date is not available, we exclude the first 18 months of data. Third, we require each fund to have at least \$5 million of assets under management and 24 months of observations. Fourth, we only keep funds that report monthly net-of-fee returns in U.S. dollars (USD). Fifth, because our key compensation measures involve the management fee and the incentive fee, we require all funds in our sample to charge positive management fees and positive incentive fees. Fund-month observations with missing information about fund returns, assets under management, or investment styles are deleted. Sixth, we exclude the "Fund of Hedge Fund" style because funds in this style invest in other hedge funds rather than individual securities, and thus the risk-taking behavior of funds of hedge funds likely differs from the risk-taking behavior of regular hedge funds. Seventh, because the "Option Strategy" style includes only a few funds and begins reporting around the year 2000, we exclude this style from our tests. Eighth, we calculate capital flows of fund i over a 1-year period following Sirri and Tufano (1998),

$$Flow_{i,m+1,m+12} = \frac{AUM_{i,m+12} - AUM_{i,m} \times (1 + Cumulative\ Return_{i,m+1,m+12})}{AUM_{i,m}}, \tag{12}$$

where $AUM_{i,m}$ is assets under management of fund i in month m. To mitigate the influence of reporting errors and outliers, we winsorize fund returns and capital flows at the 1% and 99% levels.

Our final sample has 3,062 unique funds, and panel A of Table 1 reports the summary statistics for the fund characteristics. The mean fund size is above \$200 million, and the median size is only around \$60 million. Given that the median fund age is only 73 months, hedge funds are relatively short lived. The mean cumulative return is 7.91% per year. During our sample period, the mean flow is positive at 13.36% with a median of −1.90% per year. In terms of fee structure, hedge funds typically charge a management fee between 1% and 2% and an incentive fee of 20%. In our sample, 73% of all hedge funds have a high-water mark provision. Share restrictions are common in the hedge fund industry. Most hedge funds have a redemption frequency between 30 and 90 days and a notice period of 30 days. In our sample, lockup periods are not commonly used, as the median lockup period is zero months, while 64% of all funds use leverage. The low average of *Open to public* and the high minimum investment requirements suggest that only qualified investors can invest in hedge funds.

2.2 Risk-taking measures

Hedge fund risk-taking can be measured in many different ways. Many empirical studies, such as Aragon and Nanda (2011) and Kolokolova and Mattes (2018), use total volatility to measure hedge fund risk-taking. Thus, our first measure of risk-taking is the total volatility of fund i's monthly returns, $Ret_{i,m}$, computed over a 12-month period as follows:

$$vol_{i,m+1,m+12} = \sqrt{\frac{1}{11}\sum_{k=1}^{12}(Ret_{i,m+k} - \mu_i)^2}, \tag{13}$$

where μ_i is the average return over the 12 months.

Previous studies, such as Brown and Goetzmann (2003), have found that hedge fund return dynamics are well described by their investment style indexes. Therefore, hedge fund return volatility could be highly related to their styles. For example, hedge funds that bet on the direction of asset prices, such as the “Dedicated Short Bias” style, would have higher volatility than funds that aim to minimize market exposure, such as the “Fixed Income Arbitrage” style. To further decompose hedge fund risk-taking into a style-related component and

Table 1
Summary statistics

	Mean	Median	SD	Interdecile range
A. Fund characteristics				
Fund size ($million)	228.66	61.03	727.81	493.20
Fund age (month)	87.51	73.00	60.49	144.00
Cumulative return (%)	7.91	6.51	18.11	37.42
Annual flow (%)	13.36	−1.90	73.90	121.96
Management fee (%)	1.47	1.5	0.59	1
Incentive fee (%)	18.71	20	5.18	5
High-water mark	0.73	1	0.45	1
Redemption frequency (days)	74.80	30	88.68	60
Subscription frequency (days)	34.88	30	25.77	0
Redemption notice period (days)	38.81	30	30.94	85
Lockup period (months)	4.12	0	7.35	12
Leverage	0.64	1	0.48	1
Open to public	0.16	0	0.37	0
Minimum investment ($million)	1.08	0.5	2.72	1.90
B. Manager risk-taking measures				
Monthly total volatility (%)	3.22	2.59	2.36	5.82
Style beta	0.88	0.75	0.96	2.10
Monthly residual volatility (%)	2.45	2.00	1.80	4.29
C. Manager compensation				
FutureMFee%	39.23	41.61	18.30	49.25
FutureIFee%	29.09	29.78	12.77	33.82
CoInvest%	31.68	24.10	26.28	69.62
Managerial ownership (%)	9.14	4.21	14.15	21.72

This table shows summary statistics when we pool all fund-quarter observations together. The data come from the Lipper TASS database, and the sample period is from January 1994 to December 2015. Time-varying variables are reported at the fund-quarter level, and other time-invariant variables are reported at the fund level. Panel A reports the summary statistics for fund characteristics. *Fund size* is the total assets under management. *Fund age* is the number of months since the fund inception date. Cumulative return and annual flow are calculated over a 12-month period. *Capital flow* has been defined in Equation (12). *Management fee* is the percentage of fund assets that investors pay to fund managers. *Incentive fee* is the percentage of fund profits that investors pay to fund managers. *High-water mark* is equal to one if a fund has a high-water mark provision and zero otherwise. Redemption frequency is the frequency with which investors can withdraw money from the hedge fund. Subscription frequency is the frequency with which investors can invest in the hedge fund. Redemption notice periods specify how many days in advance investors have to notify the fund that they wish to redeem. A lockup period is a window of time during which investors of a hedge fund are not allowed to redeem shares. *Leverage* equals one when a fund uses leverage and zero otherwise. *Open to public* equals one if a fund is open to the public and zero otherwise. Minimum investment is the minimum amount of money an investor must invest to take part in a hedge fund. Panel B reports summary statistics for our risk-taking measures. Volatility is the standard deviation of fund monthly returns over a 1-year period as in Equation (13). To calculate the style beta and residual volatility, we regress fund returns on style index returns as in Equation (14). Style beta is the coefficient on style index returns, and residual volatility is the standard deviation of the error term. Panel C presents summary statistics for our manager compensation variables. *FutureMFee%* is defined as in Equation (15), that is, the ratio of the present value of future management fees to the present value of managers' total compensation, where the management fee and managers' total compensation are measured in absolute dollars. We estimate future management fees and managers' total compensation using the algorithm in Section 2.3, and we use $\alpha = 3\%, \delta + \lambda = 10\%$, and $b = 0.685$ for model calibration. *FutureIFee%* and *CoInvest%* are the contribution of future management fees and managers' coinvestments to managers' total compensation, respectively, and they are calculated similarly to *FutureMFee%*. Managerial ownership is the percentage of fund assets owned by fund managers and it is calculated as managers' coinvestments divided by fund assets.

a fund-specific component, we estimate the following specification for fund i in style j,

$$Ret_{i,m} = \alpha_i + \beta_i \times StyleReturn_{j,m} + \varepsilon_{i,m}. \tag{14}$$

We estimate the above regression for each fund using a rolling 12-month window of data. For the style index return, $StyleReturn_{j,m}$, we use the hedge fund return indexes provided by Credit Suisse, following Buraschi, Kosowski, and Sritrakul (2014).[15] Style beta, β_i, is the coefficient on the style index returns and measures the risk-taking of a hedge fund attributable to the nature of its style strategy. We compute fund-specific volatility, or residual volatility, as the standard deviation of the error term, $\varepsilon_{i,m}$, which measures fund-specific risk-taking. Style beta and residual volatilities reflect different aspects of managers' risk-taking: the fund style or the specific managers' behavior.

Panel B of Table 1 reports summary statistics for our risk-taking measures. During our sample period, the mean volatility of hedge fund returns is 3.22% per month, which is below the stock market volatility of 4.30% per month. This suggests that hedge funds provide some protection against stock market fluctuations. The style beta in our sample has a mean of 0.88 and a standard deviation of 0.96. These statistics suggest that hedge funds in the same style category share some commonality with an average style beta close to one, while the dispersion in managers' style betas is sizeable. This also can be seen in the residual volatility statistics. Compared to the mean total volatility of 3.22%, the mean residual volatility of 2.45% per month indicates that most hedge fund volatility is fund specific.

2.3 Managers' compensation

To examine the impact of hedge fund managers' compensation on their risk-taking behavior, we first need to quantify hedge fund managers' total compensation, which includes the management fee, the incentive fee, and managers' coinvestments in their own funds. Our two-period model in Section 1.2 is highly stylized and thus may not be able to fully capture the dynamics of managers' compensation in practice. Therefore, to better estimate each component of managers' total compensation and make our calculation comparable with the existing literature, we follow the empirical procedures in ADN and LSW and use the richer and more dynamic setups in LWY. To be specific, we first use the algorithm in ADN to estimate the market value of investors' investments, their individual high-water marks, and managers' coinvestments over time. Next, we follow the LSW procedure to calibrate the LWY model with capital flows and coinvestments and calculate present values of future management fees, future incentive fees, and managers' coinvestments.

[15] The Credit Suisse Hedge Fund indexes can be directly observed by investors and perfectly match the 10 hedge fund styles from the TASS database. More details are available at the Credit Suisse Hedge Fund Index website: https://secure.hedgeindex.com/hedgeindex/secure/en/documents.aspx?cy=GBP&indexname=HEDG.

We provide detailed discussions of the ADN algorithm and the LSW procedure in Appendix B and Appendix C, respectively.

For the calibration exercise, we need to set three key parameters: managers' skills, represented by levered alpha α, the total withdrawal rate, represented by investor redemption probability δ plus exogenous liquidation probability λ, and the liquidation boundary as a fraction of the high-water mark, represented by b.[16] For our benchmark case, we follow LWY and use their parameter values: managers' skills $\alpha=3\%$, total withdrawal rate $\delta+\lambda=10\%$, and liquidation boundary as a faction of the high-water mark $b=0.685$. Other combinations of parameter values are discussed later in our empirical results. We follow LSW and assume that fund managers reset their high-water marks every quarter, and thus we calculate the present value of their future compensation at the end of each quarter. For each fund, we first obtain the present value of future management fees and future incentive fees per investor in the fund, and the present value of managers' total future coinvestments for the fund. Then, we sum across all of the fund's investors to compute the present value of total future management fees and total future incentive fees for the fund. Fund managers' total compensation is the sum of the fund's total future management fees, total future incentive fees, and managers' total coinvestments.

Following the intuition of the simple model in Section 1.2, we define our key variable, *FutureMFee%*, as the contribution of future management fees to the fund manager's total compensation of fund i at the end of quarter q,

$$FutureMFee\%_{i,q} = \frac{PV_{i,q}(Future\ Management\ \ Fees)}{PV_{i,q}(Future\ Total\ Compensation)} \times 100, \qquad (15)$$

where future management fees and managers' total compensation are in absolute dollars. Following a similar approach, we can calculate the contribution of future incentive fees, *FutureIFee*. Then the contribution of managers' coinvestments is simply $(CoInvest = 1 - FutureMFee - FutureIFee)$.

Table 1, panel C, presents summary statistics for our key compensation variables using the benchmark parameter choices (i.e., $\alpha=3\%$, $\delta+\lambda=10\%$, and $b=0.685$). We find that the mean and median of *FutureMFee%* are 39.23% and 41.61%, respectively. Thus, on average, about 40% of managers' total future compensation comes from future management fees. At the same time, the average contributions of future incentive fees (*FutureIFee%*) and managers' coinvestments (*CoInvest%*) are 29.09% and 31.68%, respectively.[17]

[16] We borrow the notations from LWY and LSW, and Appendix C provides detailed definitions.

[17] From the baseline model in LWY, the management fee and the incentive fee account for about 75% and 25% of total compensation, respectively. Our calibration results are different from the baseline model because we include capital flows and managerial ownership when we calculate the present value of managers' future compensation. LWY also provides calibration results with the managerial ownership extension. The contribution of future management fees, future incentive fees, and managers' coinvestments to managers' total compensations are about 48%, 18%, and 34%, respectively, when managerial ownership is 10%. Their numbers are comparable to our results.

These numbers indicate that future management fees are the most important part of managers' total compensation, consistent with the prediction in LWY. Prior literature has shown that managerial ownership (i.e., the percentage of fund assets contributed by fund managers) significantly affects managers' risk-taking.[18] Therefore, we calculate managerial ownership in their own funds as managers' coinvestments divided by fund assets. On average, close to 10% of fund assets come from managers' coinvestments in our sample.

One important feature of our two-period model is decreasing returns to scale. The original LWY model does not directly consider decreasing returns to scale, but LWY (p. 321) state that "… the key results that we emphasize in this paper tend to remain valid even with decreasing returns to scale." The LSW procedure also does not include decreasing returns to scale, possibly because including this additional feature requires solving complicated partial differential equations (PDEs) for each fund in each period, and thus significantly increases the difficulty of estimating managers' compensation. To employ decreasing returns to scale in our empirical analysis, we take three steps. First, we make sure that our theoretical predictions from the two-period model remain intact with the LWY model setup with decreasing returns to scale. Hence, we calibrate the LWY model with the feature of decreasing returns to scale and present the results in Internet Appendix Section B. The calibration results support both predictions from our simpler two-period model.[19] Second, given the complication of directly estimating the LWY model with decreasing returns to scale for each fund in each period, we follow LSW's choice and mainly use the original LWY model for our empirical analysis. Third, we carefully examine the impact of decreasing returns to scale on the relation between managers' risk-taking and future management fees in Section 3.3, by focusing on fund-level properties, which are directly connected to decreasing returns to scale.

3. Empirical Results

In this section, we examine the general relation between hedge fund risk-taking behavior and the contribution of future management fees to managers' total compensation. We start in Section 3.1 with a baseline regression analysis of the impact of future management fees on managers' risk-taking behavior. In Section 3.2, we will examine whether this relation is connected to survival probability. In Section 3.3, we will study how decreasing returns to scale affect

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[18] See Aragon and Nanda (2011) and Gupta and Sachdeva (2019), among others, for a discussion about the impact of managerial ownership on risk-taking in the hedge fund industry. See also Ma and Tang (2019), among others, for a similar discussion in the mutual fund industry.

[19] To make sure that our results are robust to different sets of assumptions, we use the GIR model as an alternative to the LWY model when estimating managers' compensation. The results based on the GIR model are presented in Internet Appendix Section C. Our results are similar when using either the LWY model or the GIR model.

the relation between managers' risk-taking behavior and future management fees.

3.1 Baseline regression

The first implication of our simple model is that hedge fund managers take less risk when future management fees become a more prominent part of managers' total compensation. To examine this hypothesis, we estimate the following specification:

$$RiskTaking_{i,q+1,q+4} = b_0 + b_1 \times FutureMFee\%_{i,q} + b_2 \times RiskTaking_{i,q-3,q} + b_3' Controls_{i,q} + \varepsilon 1_{i,q}. \tag{16}$$

The dependent variable is one of the following risk-taking measures for fund i: total volatility, style beta, or residual volatility over the next year. The independent variable, *FutureMFee%*, is the contribution of future management fees to managers' total compensation for fund i at the end of quarter q. If our hypothesis is correct, then we expect the coefficient b_1 to be significantly negative. As discussed in Section 2, we assume that fund managers reset their high-water marks every quarter and thus we compute *FutureMFee%* at the end of each quarter. Therefore, we use quarterly frequencies for our regressions, and all time-variant variables are calculated at the end of each calendar quarter.

Regarding control variables, given that a manager might prefer a certain level of volatility and that her risk-taking might be persistent over time, we include a lagged measure of risk-taking. To capture other relevant fund characteristics, we include fund size and fund age at the end of quarter q, fund performance and capital flows over the past year, fee structure, share restrictions, and managerial ownership at the end of quarter q. We also include style-quarter fixed effects in all regressions. We estimate Equation (16) using a pooled regression over funds and quarters. Following Petersen (2009), we cluster standard errors at both the fund and the quarter level.

Table 2 reports the regression results when we estimate *FutureMFee%* using the benchmark parameter choices (i.e., $\alpha = 3\%$, $\delta + \lambda = 10\%$, and $b = 0.685$). In the first column of Table 2, when we use total volatility as the risk-taking measure, the coefficient on *FutureMFee%* is -0.0049 with a t-statistic of -2.99. The significant negative coefficient supports our theoretical hypothesis. In terms of magnitude, an interdecile increase in *FutureMFee%* at the end of quarter q is associated with a decrease in total volatility of 0.2413% per month over the next year, while the average monthly volatility is 3.22%. The magnitude of our finding is comparable to the literature. For instance, Aragon and Nanda (2011) show that a drop in relative performance rank from 100% to 0% is associated with a 0.12% per month increase in volatility for funds without incentive pay, and a 0.76% per month increase for funds with incentive pay. Thus, the decrease in total volatility that we document is economically significant.

Table 2
Baseline regression: Relation between risk-taking and future management fees

	Total volatility	Style beta	Residual volatility
FutureMFee%$_q$	−0.0049***	−0.0047***	−0.0060***
	(−2.99)	(−5.44)	(−4.14)
$Volatility_{q-3,q}$	0.6966***		
	(33.35)		
$Style\ beta_{q-3,q}$		0.4530***	
		(18.70)	
$Residual\ volatility_{q-3,q}$			0.6607***
			(32.43)
$ln(Fund\ size_q)$	−0.0290***	−0.0003	−0.0508***
	(−2.69)	(−0.04)	(−5.46)
$Fund\ return_{q-3,q}$	0.0023	0.0036***	−0.0010
	(1.40)	(2.83)	(−0.78)
$Capital\ flow_{q-3,t}$	−0.0003**	−0.0001	−0.0002
	(−1.96)	(−0.99)	(−1.54)
$ln(Fund\ age_q)$	−0.0169	0.0073	−0.0483**
	(−0.65)	(0.42)	(−2.03)
$Managerial\ ownership_q$	−0.0015	−0.0020**	−0.0027**
	(−1.14)	(−2.42)	(−2.12)
Management fee	0.0879**	0.0173	0.1282***
	(2.27)	(0.81)	(3.34)
Incentive fee	0.0120*	−0.0099***	0.0119**
	(1.83)	(−2.70)	(2.22)
High-water mark	0.0186	−0.0043	0.0358
	(0.48)	(−0.19)	(1.03)
Redemption frequency	0.0002	0.0003**	0.0000
	(0.80)	(2.32)	(0.18)
Subscription frequency	−0.0003	−0.0002	−0.0003
	(−0.67)	(−0.51)	(−0.82)
Redemption notice period	−0.0004	−0.0004	−0.0005
	(−0.75)	(−1.13)	(−0.94)
Lockup period	0.0013	0.0004	0.0012
	(0.67)	(0.33)	(0.71)
Leverage	0.0059	0.0123	0.0081
	(0.19)	(0.64)	(0.32)
Open to public	−0.0262	−0.0269	−0.0128
	(−0.72)	(−1.18)	(−0.35)
ln(Minimum investment)	−0.0347***	−0.0074	−0.0257***
	(−2.91)	(−1.06)	(−2.59)
Style-quarter FE	Yes	Yes	Yes
N	38,335	36,961	36,961
Adj. R-sq.	.6592	.2904	.5795

This table shows regression results of our baseline model as in Equation (16). The data come from the Lipper TASS database, and the sample period is from January 1994 to December 2015. *FutureMFee%* is defined as in Equation (15), that is, the ratio of the present value of future management fees to the present value of managers' total compensation, where the management fee and managers' total compensation are measured in absolute dollars. We estimate future management fees and managers' total compensation using the algorithm in Section 2.3, and we use $\alpha=3\%, \delta+\lambda=10\%$, and $b=0.685$ for model calibration. Volatility is the standard deviation of fund monthly returns over a 1-year period as in Equation (13). To calculate the style beta and residual volatility, we regress fund returns on style index returns as in Equation (14). Style beta is the coefficient on the style index returns, and residual volatility is the standard deviation of the error term. We include the following control variables. *Fund size* is the total assets under management at time t. *Fund age* is the number of months from the fund inception date. *Capital flow* is defined as in Equation (12). *Fund returns* and *capital flows* are calculated over the past 12 months ending in quarter q. *Management fee* is the percentage of fund assets that investors pay to fund managers. *Incentive fee* is the percentage of fund profits that investors pay to fund managers. *High-water mark* is a dummy variable that is equal to one if a fund has a high-water mark provision and zero otherwise. *Managerial ownership* is the percentage of fund assets owned by fund managers. *Redemption frequency* is the frequency with which investors can withdraw money from the hedge fund. *Subscription frequency* is the frequency with which investors can invest in the hedge fund. *Redemption notice period* specifies how many days in advance investors must notify that they wish to redeem. *Lockup period* is the window of time when investors of a hedge fund are not allowed to redeem shares. *Leverage* equals one when a fund uses leverage and zero otherwise. *Open to public* equals one if a fund is open to the public and zero otherwise. *Minimum investment* is the minimum amount of money an investor must invest to take part in a hedge fund. In all regressions, style-quarter fixed effects are included. Standard errors are clustered at both the fund and quarter level, and t-statistics are reported in parentheses. *$p<.1$; **$p<.05$; ***$p<.01$.

In the second and third columns, where we use style beta and residual volatility, respectively, as risk-taking measures, we find similar patterns: the coefficients for *FutureMFee%* are both negative and highly significant. An interdecile increase in *FutureMFee%* at the end of quarter q is associated with a decrease in style beta of 0.2315 and a decrease in residual volatility of 0.2955% per month over the next year. The results show that fund managers take less risk when the management fee becomes the dominant component of their compensation package. This supports our hypothesis that when the management fee becomes more important in the overall compensation package, fund managers reduce risk-taking to increase survival probabilities.

For completeness, we also present the coefficients for all control variables in Table 2. The positive and significant coefficients for lagged risk-taking confirm the persistence in managers' risk-taking behavior. Hedge funds with larger size, lower past performance, lower management fee percentages, and higher minimum investment requirements take less risk. The signs on the incentive fee percentage coefficients are mixed but mostly positive. It is possible that funds with higher incentive fee percentages rely less on the management fee and thus are likely to take more risk. The coefficients for managerial ownership are all negative, and they are significant for style beta and residual volatility. Our results are consistent with Aragon and Nanda (2011) and Gupta and Sachdeva (2019) and suggest that managerial ownership makes a hedge fund manager more conservative with regard to risk-taking. Other characteristics are mostly insignificant.

To investigate whether our findings are sensitive to our calibration parameter choices, we follow LSW and estimate *FutureMFee%* using different parameter combinations, with the managers' skills parameter (α) being 3% or 0%, the total withdrawal rate ($\delta+\lambda$) being 10% or 5%, and the liquidation boundary of fund value as a fraction of the high-water mark (b) being 0.685 or 0.8. In panels A through C of Table 3, we present results using the eight possible combinations of the three parameters, and each panel reports results using total volatility, beta, and residual volatility as the risk-taking measure, respectively.

For example, the first column of each panel in Table 3 repeats the analysis reported in Table 2. In the last column of each panel, we use the parameter choices in GIR, that is, $\alpha = 0$, $\delta+\lambda = 5\%$, and $b = 0.8$. Zero alpha indicates that managers' compensation mainly depends on future management fees and their coinvestments; the lower $\delta+\lambda$ suggests that funds are expected to survive longer; and the higher b means that investors are less tolerant when a fund has poor performance. In this case, an interdecile increase in *FutureMFee%* at the end of quarter q is associated with a decrease of 0.2315% per month in total volatility, a decrease of 0.1724 in style beta, and a decrease of 0.2660% per month in residual volatility over the next year, respectively. Across all panels and for all combinations of the parameters in Table 3, the coefficient on

Table 3
Baseline regression: Relation between risk-taking and future management fees with alternative calibration parameters

	$b=0.685$				$b=0.8$			
	$\alpha=3\%$		$\alpha=0$		$\alpha=3\%$		$\alpha=0$	
	$\delta+\lambda=10\%$	$\delta+\lambda=5\%$	$\delta+\lambda=10\%$	$\delta+\lambda=5\%$	$\delta+\lambda=10\%$	$\delta+\lambda=5\%$	$\delta+\lambda=10\%$	$\delta+\lambda=5\%$
***A. Dependent variable:* Total volatility**								
$FutureMFee\%_q$	−0.0049***	−0.0050***	−0.0039***	−0.0053***	−0.0037***	−0.0041***	−0.0042***	−0.0047***
	(−2.99)	(−3.28)	(−3.54)	(−4.15)	(−3.80)	(−3.73)	(−4.63)	(−4.93)
$TotalVolatility_{q-3,q}$	0.6966***	0.6786***	0.6960***	0.6938***	0.7010***	0.6999***	0.6919***	0.6906***
	(33.35)	(31.87)	(32.85)	(32.70)	(32.11)	(30.39)	(32.65)	(32.86)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	38,335	28,280	38,259	38,139	37,073	34,537	37,418	37,298
Adj. R-sq.	.6592	.6080	.6600	.6600	.6567	.6524	.6590	.6594
***B. Dependent variable:* Style beta**								
$FutureMFee\%_q$	−0.0047***	−0.0023***	−0.0035***	−0.0044***	−0.0009	−0.0012*	−0.0032***	−0.0035***
	(−5.44)	(−2.58)	(−6.01)	(−6.63)	(−1.58)	(−1.79)	(−6.14)	(−6.34)
$StyleBeta_{q-3,q}$	0.4530***	0.4294***	0.4534***	0.4494***	0.4576***	0.4506***	0.4490***	0.4472***
	(18.70)	(16.63)	(18.85)	(18.68)	(19.08)	(19.08)	(19.03)	(18.91)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	36,961	27,256	36,889	36,770	35,764	33,324	36,099	35,987
Adj. R-sq.	.2904	.2757	.2911	.2905	.2877	.2843	.2908	.2912
***C. Dependent variable:* Residual volatility**								
$FutureMFee\%_q$	−0.0060***	−0.0046***	−0.0047***	−0.0061***	−0.0041***	−0.0045***	−0.0049***	−0.0054***
	(−4.14)	(−3.31)	(−4.99)	(−5.54)	(−4.42)	(−4.30)	(−6.22)	(−6.47)
$ResidualVolatility_{q-3,q}$	0.6607***	0.6395***	0.6598***	0.6575***	0.6647***	0.6635***	0.6562***	0.6554***
	(32.43)	(28.77)	(31.58)	(31.53)	(32.18)	(29.76)	(31.71)	(31.71)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	36,961	27,256	36,889	36,770	35,764	33,324	36,099	35,987
Adj. R-sq.	.5795	.5197	.5801	.5801	.5752	.5697	.5799	.5804

This table shows the regression results of our baseline model as in Equation (16) when we use different parameter values to estimate our key independent variable, *FutureMFee%*. The data come from the Lipper TASS database, and the sample period is from January 1994 to December 2015. *FutureMFee%* is defined as in Equation (15), that is, the ratio of the present value of future management fees to the present value of managers' total compensation, where the management fee and managers' total compensation are measured in absolute dollars. We estimate future management fees and managers' total compensation using the algorithm in Section 2.3, and we use different parameter value combinations for model calibration: $\alpha=3\%$ or 0, $\delta+\lambda=10\%$ or 5%, and $b=0.685$ or 0.8. Volatility is the standard deviation of fund monthly returns over a 1-year period as in Equation (13). To calculate style beta and residual volatility, we regress fund returns on style index returns as in Equation (14). Style beta is the coefficient on the style index returns, and residual volatility is the standard deviation of the error term. Control variables are defined similarly as in Table 2. In all regressions, style fixed effects and year fixed effects are included. Standard errors are clustered at both the fund and quarter level, and t-statistics are reported in parentheses. $^{*}p<.1$; $^{**}p<.05$; $^{***}p<.01$.

FutureMFee% ranges between −0.0061 and −0.0009 and is significant in 22 of 24 cases.[20]

One potential concern with our test design is that we apply the same parameter values to all funds in our sample, when in reality, parameter values can vary significantly across funds. To ease this concern, we conduct two experiments. In the first experiment, to allow for cross-fund variation in parameter values, we assign funds randomly to groups with different parameter value combinations. With two choices of the managers' skill parameter value (α), two choices of the withdrawal rate ($\delta+\lambda$), and two choices of the liquidation boundary (b), we have eight groups as in Table 3. After each fund is randomly assigned to a group, we calculate *FutureMFee%* for each fund and conduct our baseline regression using this new sample. Table 4, panel A, reports the results. The coefficients for *FutureMFee%* are negative and significant in all regressions. An interdecile increase in *FutureMFee%* at the end of quarter q is associated with a decrease of 0.1034% per month in total volatility, a decrease of 0.0936 in style beta, and a decrease of 0.1182% per month in residual volatility over the next year, respectively.

For the second experiment, we conduct three additional calibrations based on the LWY model, but with parameter values that differ from those used in prior literature. In the first group, we set managers' skills at $\alpha=1.5\%$. This value is between the values used in the LWY model and GIR model, and we keep the other parameters at the same values as in LWY (i.e., $\delta+\lambda=10\%$ and $b=0.685$). Because α reflects managers' skills, this allows us to examine whether managers with different skills have similar risk-taking behavior. In the second group, we set investors' withdrawal rate at $\delta+\lambda=20\%$ and keep the other parameters at the same values as in LWY (i.e., $\alpha=1.5\%$ and $b=0.685$). Higher withdrawal rates indicate shorter average life spans for hedge funds. This allows us to examine whether managers still care about their future management fees when their funds are expected to be liquidated sooner. In the third group, we lower the liquidation boundary to $b=0.5$ and keep the other parameters at the same values as in LWY (i.e., $\alpha=1.5\%$ and $\delta+\lambda=10\%$). A lower boundary means that a fund can suffer a higher loss before liquidation. In other words, a lower liquidation boundary may motivate fund managers to take more risk, and we want to examine whether managers still reduce risk-taking when future management fees become more important. Panels B to D of Table 4 summarize the results. The coefficients for *FutureMFee%* are negative in all regressions, and they are statistically significant in 8 of 9 regressions. Thus, the negative relation between managers' risk-taking and future management fees is robust when we use parameter values different from those used in prior literature.

[20] In the Internet Appendix Section C, we use the closed-form solution in GIR to calculate the present value of future fees and *FutureMFee%*. The results are qualitatively similar to those reported in Tables 2 and 3.

Table 4
Baseline regression: Two experiments on the relation between risk-taking and future management fees

	Total volatility	*Style beta*	*Residual volatility*
A. Random assignment of parameter values			
FutureMFee%$_q$	−0.0021***	−0.0019***	−0.0024***
	(−2.70)	(−4.26)	(−3.61)
Lagged risk-taking	Yes	Yes	Yes
Control variables	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes
N	38,315	36,941	36,941
Adj. R-sq.	.6590	.2901	.5791
B. $\alpha = 1.5\%$, $\delta+\lambda = 10\%$, b = 0.685			
FutureMFee%$_q$	−0.0034**	−0.0036***	−0.0046***
	(−2.50)	(−4.98)	(−4.01)
Lagged risk-taking	Yes	Yes	Yes
Control variables	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes
N	38,315	36,941	36,941
Adj.R-sq.	.6590	.2901	.5791
C. $\alpha = 3\%$, $\delta+\lambda = 20\%$, b = 0.685			
FutureMFee%$_q$	−0.0030*	−0.0059***	−0.0054***
	(−1.85)	(−6.49)	(−3.80)
Lagged risk-taking	Yes	Yes	Yes
Control variables	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes
N	38,421	37,046	37,046
Adj. R-sq.	.6588	.2918	.5793
D. $\alpha = 3\%$, $\delta+\lambda = 10\%$, b = 0.5			
FutureMFee%$_q$	−0.0028	−0.0117***	−0.0102***
	(−1.30)	(−10.29)	(−5.85)
Lagged risk-taking	Yes	Yes	Yes
Control variables	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes
N	38,905	37,513	37,513
Adj. R-sq.	.6616	.3021	.5823

This table shows the regression results of our two experiments on the relation between managers' risk-taking and future management fees. The data come from the Lipper TASS database, and the sample period is from January 1994 to December 2015. *FutureMFee%* is defined as in Equation (15), that is, the ratio of the present value of future management fees to the present value of managers' total compensation, where the management fee and managers' total compensation are measured in absolute dollars. We estimate future management fees and managers' total compensation using the algorithm in Section 2.3. Volatility is the standard deviation of fund monthly returns over a 1-year period as in Equation (13). To calculate style beta and residual volatility, we regress fund returns on style index returns as in Equation (14). Style beta is the coefficient on the style index returns, and residual volatility is the standard deviation of the error term. In panel A, to allow for cross-fund variation in parameter values, we assign funds randomly to eight groups, each of which uses a different set of parameter values as in Table 3 to calculate *FutureMFee%*. In panels B to D, we calculate *FutureMFee%* using parameter values that differ from those used in prior literature. Control variables are defined similarly as in Table 2. In all regressions, style fixed effects and year fixed effects are included. Standard errors are clustered at both the fund and quarter level, and t-statistics are reported in parentheses. *$p < .1$; **$p < .05$; ***$p < .01$.

In summary, the results from our two experiments are consistent with those reported in Tables 2 and 3 and suggest that regardless of parameter value choices, hedge fund managers take less risk when future management fees become more important to their total compensation.

3.2 Future management fees and fund survival

In this subsection, we examine a potential mechanism behind the negative relation between hedge fund risk-taking and future management fees. LWY argue that when the management fee becomes the dominant part of managers' total compensation, fund managers might take less risk to increase survival probabilities, because fund liquidation becomes so costly, and survival becomes the priority. Our model in Section 1.2 generates similar results. As shown in panel B of Figure 1, when the fund manager takes more risk, the survival probability of her fund decreases.

We examine this survival probability mechanism using a probit regression, following the specification in Aragon and Nanda (2011),

$$Termination_{i,q+1,q+4} = c_0 + c_1 FutureMFee\%_{i,q} + c_2' Controls_{i,q} + \varepsilon 2_{i,q}. \quad (17)$$

The dependent variable, *Termination*, is an indicator variable that is equal to one if a fund is alive at the end of quarter q but becomes liquidated over the next year, and zero otherwise. The key independent variable is *FutureMFee%*. If fund managers reduce risk-taking to increase survival probabilities when future management fees become more important, then we expect the coefficient on *FutureMFee%* to be negative.[21] Following Aragon and Nanda (2011), we also include the following control variables: fund assets and fund age at the end of quarter q, fund performance over the past year, volatility of fund returns over the past year, a high-water mark indicator, and style fixed effects. Following Petersen (2009), we cluster the standard errors at both the fund and the quarter level.

Table 5 presents the estimation results. The coefficient on *FutureMFee%* is −0.0041 with a statistically significant t-statistic of −9.96. Economically, if all other variables are set at their median values, then an increase in *FutureMFee%* from the 10th to the 90th percentiles is associated with a 5% decrease in termination probability. As for the other variables, similar to Aragon and Nanda (2011), funds with larger size, older age, better past performance, and a high-water mark provision are less likely to be liquidated.

Our earlier results in Table 2 indicate that hedge fund managers take less risk when future management fees contribute more to their total compensation. Thus, consistent with LWY and our model, the results in Tables 2 and 5 suggest that when future management fees become more important, fund managers take less risk and their expected survival probabilities increase.

3.3 Risk-taking and decreasing returns to scale

In this subsection, we examine how decreasing returns to scale is related to managers' risk-taking behavior and test the second implication of our simple

[21] We also conduct a probit regression using induced risk-taking as the independent variable. Induced risk-taking is estimated based on our regression results in Table 2. Results in Internet Appendix Section D show that lower induced volatility is associated with lower termination probability.

Table 5
Termination probabilities and managers' compensation

$FutureMFee\%_q$	−0.0041***
	(−6.22)
$ln(Fund\ size_q)$	−0.1021***
	(−5.14)
$ln(Fund\ age_q)$	0.0735***
	(2.76)
$Fund\ return_{q-3,q}$	−0.0059***
	(−5.35)
$Volatility_{q-3,q}$	−0.0327***
	(−4.60)
High-water mark	−0.0339
	(−0.91)
Style FE	Yes
N	59,084
Pseudo-R-sq.	.0261

This table examines a potential mechanism behind the relation between hedge fund risk-taking and the contribution of future management fees to managers' total compensation using a Probit regression. The data are from the Lipper TASS database, and the sample period is from January 1994 to December 2015. *FutureMFee%* is defined as in Equation (15), that is, the ratio of the present value of future management fees to the present value of managers' total compensation, where the management fee and managers' total compensation are measured in absolute dollars. We estimate future management fees and managers' total compensation using the algorithm in Section 2.3, and we use $\alpha=3\%$, $\delta+\lambda=10\%$, and $b=0.685$ for model calibration. The dependent variable is a dummy variable that is equal to one if a fund is alive at the end of quarter q but becomes liquidated within 1 year, and zero otherwise. We then examine the impact of future management fees on termination probabilities as in Equation (17). Control variables are defined similarly as in Table 2. Style fixed effects are also included. Standard errors are clustered at both the fund and quarter level, and t-statistics are reported in parentheses. $^{*}p<.1$; $^{**}p<.05$; $^{***}p<.01$.

model. Previous studies have suggested that hedge funds are likely to suffer from decreasing returns to scale. Funds with higher decreasing returns to scale are more likely to rely on the management fee for compensation when they grow large, as in Figure 2, panel A. Moreover, as shown in panel B of Figure 2, funds with higher decreasing returns to scale tend to take less risk for the same starting fund size. Therefore, funds with higher decreasing returns to scale are likely to reduce risk-taking more when future management fees become more important.

However, decreasing returns to scale are not observable in the data. Thus, we follow the literature and examine the impact of decreasing returns to scale using two approaches. In the first approach, we examine the behavior of managers of large hedge funds.[22] As documented in Teo (2009), Getmansky (2012), and Yin (2016), large funds are more likely to suffer from decreasing returns to scale. Meanwhile, large hedge funds collect more management fees in absolute dollars than small funds because the management fee mainly depends on fund

[22] Large hedge funds play an important role in the industry. Over our sample period, the total assets of the largest 10% of hedge funds are more than 100 times larger than the total assets of the smallest 10% of funds on average. For instance, the year-end total assets of the smallest 10% of funds reached \$1.176 billion in 2007, while the year-end total assets of the largest 10% of funds were over \$237 billion. Based on our estimation, the present value of future management fees for the smallest 10% of funds were about \$140 million at the end of 2007, while the present value of future management fees for the largest 10% were over \$40 billion.

size. Thus, large hedge funds might be more sensitive to future management fees and have more incentive to reduce risk-taking to increase survival probabilities.

To empirically investigate the behavior of managers of large funds, we divide all hedge funds into two groups based on fund size at the end of each quarter. We define a dummy variable, *LargeFund*, to equal one if a fund's size is above the median in quarter q, and zero otherwise. Then we include the *LargeFund* dummy and an interaction term between *FutureMFee%* and *LargeFund* in our baseline regression, as follows:

$$RiskTaking_{i,q+1,q+4} = d_0 + (d_1 + d_2 LargeFund_{i,q}) \times FutureMFee\%_{i,q} + d_3' Controls_{i,q} + \varepsilon 3_{i,q}. \quad (18)$$

If large funds are more sensitive to future management fees, then we expect the coefficient on the interaction term, d_2, to be negative.

Table 6, panel A, presents the estimation results. As in Table 2, the coefficients for *FutureMFee%* are all negative and significant. More importantly, the coefficients for the interaction term are negative, and they are significant when we use style beta and residual volatility as the risk-taking measure. The results suggest that, relative to small funds, for an interdecile increase in *FutureMFee%*, large funds reduce volatility by an additional 0.1084% per month, reduce beta by an additional 0.1034, and reduce residual volatility by an additional 0.1379% per month. In summary, risk-taking by large funds is more sensitive to *FutureMFee%* than it is for small funds. When future management fees contribute more to managers' total compensation, large funds reduce risk-taking more than do small funds.

Our second approach to examine the impact of decreasing returns to scale is based on strategy scalability. LSW suggest that fund strategies that involve illiquid instruments cannot be easily replicated, and thus funds using these strategies are more likely to suffer from capacity constraints. Following their method, we define a new variable, *Constrained*, as an indicator that equals one if the style of a fund is Convertible Arbitrage, Emerging Markets, Event Driven, or Fixed Income Arbitrage, and zero otherwise.[23] These "constrained" strategies are less scalable and funds in these styles are more likely to suffer from decreasing returns to scale.

To examine the impact of strategy scalability on managers' sensitivity to future management fees, we include the *Constrained* dummy and an interaction term between *FutureMFee%* and *Constrained* in the regression, and panel B of Table 6 summarizes the results. The coefficients for the *Constrained* indicator are negative and mostly significant, suggesting that funds take less risk if their investment styles are more likely to suffer from capacity constraints. However, the coefficients for the interaction terms between *FutureMFee%*

[23] In the Internet Appendix Section E, we measure strategy scalability using the methodology in Kolokolova and Mattes (2018). The results are qualitatively similar.

Table 6
Impact of decreasing returns to scale

	Volatility	Style beta	Residual volatility
A. Large funds			
FutureMFee%$_q$	−0.0037**	−0.0037***	−0.0045***
	(−2.13)	(−3.87)	(−2.76)
FutureMFee%$_q$ ×Large fund	−0.0022	−0.0021**	−0.0028**
	(−1.64)	(−2.32)	(−2.23)
Large fund	0.0207	0.0542	0.0333
	(0.34)	(1.39)	(0.56)
Lagged risk-taking	Yes	Yes	Yes
Control variables	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes
N	38,335	36,961	36,961
Adj. R-sq.	.6593	.2908	.5798
B. Capacity constraints			
FutureMFee%$_q$	−0.0077***	−0.0057***	−0.0076***
	(−4.20)	(−6.02)	(−5.43)
FutureMFee%$_q$ ×Constrained	0.0035**	0.0015	0.0016
	(2.01)	(1.37)	(1.06)
Constrained	−0.2316**	−0.0495	−0.1607**
	(−2.25)	(−0.94)	(−2.05)
Lagged risk-taking	Yes	Yes	Yes
Control variables	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes
N	38,335	36,961	36,961
Adj. R-sq.	.6234	.2534	.5604
C. Capacity constraints and style flows			
FutureMFee%$_q$	−0.0078***	−0.0060***	−0.0078***
	(−3.27)	(−4.39)	(−5.25)
FutureMFee%$_q$ ×Constrained	0.0048	0.0023	0.0030
	(1.36)	(1.19)	(1.31)
FutureMFee%$_q$ ×High style flow	0.0002	0.0004	0.0005
	(0.15)	(1.37)	(0.59)
FutureMFee%$_q$ ×Constrained × High style flow	−0.0031	−0.0017**	−0.0032**
	(−1.23)	(−2.05)	(−2.04)
Constrained	−0.2962	−0.0691	−0.2115
	(−1.07)	(−0.79)	(−1.16)
High style flow	0.0188	−0.0471*	−0.0157
	(0.31)	(−1.71)	(−0.49)
Constrained × High style flow	0.1611	0.0464	0.1249
	(1.00)	(0.94)	(1.43)
Lagged risk-taking	Yes	Yes	Yes
Control variables	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes
N	38,335	36,961	36,961
Adj. R-sq.	.6234	.2536	.5602

This table examines the impact of decreasing returns to scale on the relation between managers' risk-taking and future management fees. The data come from the Lipper TASS database, and the sample period is from January 1994 to December 2015. *FutureMFee%* is defined as in Equation (15), that is, the ratio of the present value of future management fees to the present value of managers' total compensation, where the management fee and managers' total compensation are measured in absolute dollars. We estimate future management fees and managers' total compensation using the algorithm in Section 2.3, and we use $\alpha = 3\%$, $\delta + \lambda = 10\%$, and $b = 0.685$ for model calibration. Volatility is the standard deviation of fund monthly returns over a 1-year period as in Equation (13). To calculate style beta and residual volatility, we regress fund returns on style index returns as in Equation (14). Style beta is the coefficient on the style index returns, and residual volatility is the standard deviation of the error term. Panel A examines the behavior of managers of large funds. *Large fund* is a dummy variable that is equal to one if fund i's assets are above the median in quarter q and zero otherwise. Panel B examines fund managers' behavior when they use strategies with capacity constraints. *Constrained* is a dummy variable and is equal to one if the style of a fund is Convertible Arbitrage, Emerging Markets, Event Driven, or Fixed Income Arbitrage, and zero otherwise. In panel C, we examine the behavior of funds with capacity constraints when they have large capital inflows. *High Style Flow* is an indicator and is equal to one if the capital flows to the style of a fund are above median among all styles and zero otherwise. Control variables are defined similarly as in Table 2. Style-quarter fixed effects are included in panel A, and style fixed effects are included in panels B and C. Standard errors are clustered at both the fund and quarter level, and t-statistics are reported in parentheses. $^*p < .1$; $^{**}p < .05$; $^{***}p < .01$.

and *Constrained* are mostly insignificant. The insignificant coefficients for the interaction terms do not necessarily mean that strategy scalability has no impact on the relation between risk-taking and *FutureMFee%*. Capacity constraints of a strategy are more likely to affect fund managers' behavior when the strategy receives large capital inflows. To test this possibility, we employ an additional variable, *High style flow*, which is an indicator that is equal to one if the capital flows to the style of a fund are above the median among all styles, and zero otherwise. Then, we use a three-way interaction term ($FutureMFee\% \times Constrained \times High\ Style\ Flow$) to examine the impact of scalability when a strategy attracts large inflows. In panel C of Table 6, the negative and significant coefficients for the three-way interaction terms indicate that funds are more sensitive to *FutureMFee%* when they use constrained strategies and have large capital inflows. Note that the coefficients for *FutureMFee%* are still negative and significant in all regressions.

Overall, the results in Table 6 are consistent with our earlier discussion and with the second implication of our model in Section 1.2 that funds with higher decreasing returns to scale are more sensitive to future management fees.

4. Further Discussions

In this section, we provide a set of discussions and robustness tests regarding the relation between managers' risk-taking behavior and the contribution of future management fees to managers' total compensation. In Section 4.1, we examine the relation, while controlling for other manager incentive measures. We present robustness checks in Section 4.2.

4.1 Other measures of managers' compensation

In addition to future management fees, managers' compensation includes future incentive fees and managers' coinvestments. To examine how these other components affect the results in Table 2, we include the contribution of future incentive fees to managers' total compensation, *FutureIFee%*, in our baseline regression. We do not include the contribution of managers' coinvestments in the specification because it is simply ($1 - FutureMFee\% - FutureIFee\%$), and including all three variables in one regression would lead to collinearity. In panel A of Table 7, the coefficients for *FutureMFee%* are all negative and significant, after controlling for future incentive fees. The coefficients for *FutureIFee%* are negative, but only significant when we use style beta and residual volatility as dependent variables. This result indicates that fund managers take less risk when the contribution of future incentive fees increases as well.[24]

[24] We need to interpret the results in Table 7 with caution. First, the correlation between *FutureMFee%* and *FutureIFee%* is 0.4135. The high correlation may lead to multicollinearity problems. Thus, we only include *FutureMFee%* in most of our regressions. Second, the relation between risk-taking and future incentive fees

Table 7
Other manager incentive measures

	Volatility	Style beta	Residual volatility
***A. Baseline regression with* FutureIFee%**			
$FutureMFee\%_q$	−0.0044***	−0.0038***	−0.0050***
	(−2.74)	(−4.15)	(−3.47)
$FutureIFee\%_q$	−0.0035	−0.0054***	−0.0055***
	(−1.62)	(−4.21)	(−2.72)
Lagged risk-taking	Yes	Yes	Yes
Control variables	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes
N	38,334	36,960	36,960
Adj. R-sq.	.6593	.2919	.5799
***B. Baseline regression with* CurrentMFee%**			
FutureMFee% $_q$	−0.0046***	−0.0046***	−0.0056***
	(−2.78)	(−5.31)	(−3.83)
$1_{\text{CurrentIFee}>0} \times \text{CurrentMFee\%}_q$	−0.0016***	−0.0010***	−0.0018***
	(−4.87)	(−4.79)	(−6.10)
Lagged risk-taking	Yes	Yes	Yes
Control variables	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes
N	38,235	36,863	36,863
Adj. R-sq.	.6591	.2910	.5803
C. Baseline regression with direct incentives			
$FutureMFee\%_q$	−0.0086***	−0.0074***	−0.0084***
	(−4.18)	(−7.02)	(−4.60)
$\ln\left(\delta(Incentive\ fee)_q\right)$	−0.0135***	−0.0026*	−0.0101***
	(−3.06)	(−1.66)	(−2.93)
$\ln\left(\delta(Mgmt\ fee)_q\right)$	−0.0046	−0.0102	0.0040
	(−0.10)	(−0.43)	(0.10)
$\ln\left(\delta(Coinvestment)_q\right)$	−0.0755***	−0.0492***	−0.0492***
	(−4.06)	(−4.38)	(−3.31)
Lagged risk-taking	Yes	Yes	Yes
Control variables	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes
N	38,179	36,819	36,819
Adj. R-sq.	.6611	.2908	.5817
D. Baseline regression with distance to high-water mark			
$FutureMFee\%_q$	−0.0039**	−0.0035***	−0.0047***
	(−2.37)	(−4.12)	(−3.20)
High-water mark $\times \left\lvert Distance_q \right\rvert$	1.8106***	1.3531***	1.7724***
	(5.63)	(7.99)	(6.60)
Lagged risk-taking	Yes	Yes	Yes
Control variables	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes
N	38,335	36,961	36,961
Adj. R-sq.	.6611	.2970	.5826

In this table, we include other manager incentive measures in our baseline regression. The data are from the Lipper TASS database, and the sample period is from January 1994 to December 2015. *FutureMFee%* is defined as in Equation (15), that is, the ratio of the present value of future management fees to the present value of managers' total compensation, where the management fee and managers' total compensation are measured in absolute dollars. We estimate future management fees and managers' total compensation using the algorithm in Section 2.3, and we use $\alpha=3\%$, $\delta+\lambda=10\%$, and $b=0.685$ for model calibration. Volatility is the standard deviation of fund monthly returns over a 1-year period as in Equation (13). To calculate the style beta and residual volatility, we regress fund returns on style index returns as in Equation (14). Style beta is the coefficient on the style index returns, and residual volatility is the standard deviation of the error term. In Panel A, we include *FutureIFee%*, which is the contribution of future incentive fees to managers' total compensation, in the regression. *FutureIFee%* is calculated similar to *FutureMFee%*. Panel B examines the impact of realized fees at the end of quarter q on managers' risk-taking. *CurrentMFee%* is the contribution of the current management fee to managers' total compensation in quarter q. The detailed calculation is reported in Appendix D. In Panel C, we take managers' direct incentives into consideration, measured as the expected dollar change in the manager's compensation for a one-percentage-point increase in the fund's return, following Agarwal, Daniel, and Naik (2009). We compute direct incentives for each component of managers' total compensation, and the details are summarized in Appendix D. In Panel D, we first calculate the distance to the high-water mark for each investor as $distance=S/X-1$, where S is the market value of each investor's investment in the fund and X is her high-water mark. Then we calculate the weighted average of distance across all investors for each fund, and the weight is the market value of each investors' investment in the fund. To facilitate interpretation, we use the absolute value of distance in the regression, because distance is nonpositive. *High-water Mark* is a dummy variable that is equal to one if a fund has a high-water mark provision and zero otherwise. Control variables are defined similarly as in Table 2. In all regressions, style-quarter fixed effects are included. Standard errors are clustered at both the fund and quarter level, and t-statistics are reported in parentheses. $*p<.1$; $**p<.05$; $***p<.01$.

Both *FutureMFee%* and *FutureIFee%* refer to expected future compensation for fund managers. In contrast, current fees (or realized fees) in quarter q reflect how well a hedge fund performed in the most recent quarter. Do current fees affect the relation between future management fees and managers' risk-taking behavior? To answer this question, we first calculate the current management fee and the current incentive fee from each investor using the market value of investors' investments and their high-water marks estimated in Section 2. Total fees in quarter q equals the sum of fees across all investors in a fund. Then we compute *CurrentMFee%* as the contribution of the current management fee to current total fees for fund i in quarter q. Appendix D summarizes the details of our calculation.

When fund managers can only charge the management fee for the current quarter, *CurrentMFee%* is equal to 100%, which is a less interesting case. Thus, we include an interaction term between *CurrentMFee%* and an indicator $1_{CurrentIFee>0}$ in our baseline model. The indicator equals one if fund managers can collect the current incentive fee from at least one investor. In panel B of Table 7, the coefficients for *CurrentMFee%* are negative and significant in all three regressions. Thus, when the current management fee becomes more important, fund managers tend to take less risk. More importantly, after controlling for managers' realized compensation in quarter q, we still find negative and significant coefficients for *FutureMFee%* in panel B of Table 7, with magnitudes similar to those in Table 2.

Next, we control for direct incentives as in ADN, defined as the expected dollar change in the manager's compensation for a 1% increase in fund performance. We follow ADN and calculate direct incentives as the delta of managers' compensation due to the hypothetical increase in fund performance for each component of managers' compensation separately. We report the computation details in Appendix D.[25] In panel C of Table 7, after controlling for managers' direct incentives, the coefficients for *FutureMFee%* are all negative and significant, indicating that managers reduce risk-taking when future management fees contribute more to managers' total compensation.

might be more complicated and nonlinear. While the management fee mainly depends on fund assets, the option-like incentive fee also depends on fund performance and fund value relative to its high-water mark. Thus, the relation between managers' risk-taking and future incentive fees may require some further research and is out of the scope of this study.

25 We follow LSW and calculate direct incentives over one-quarter. The average direct incentives from investors in our study are around \$0.2 million, which is comparable to \$0.1 million in ADN and \$0.142 million in LSW. In this study, we do not include *FutureMFee%* and indirect incentives in the same regression because the two measures are correlated (the correlation between *FutureMFee%* and the indirect incentives from the management fee is 0.2681). Both our measure and the indirect incentives need to estimate the present value of managers' future compensation. However, we focus on the components of managers' future compensation, especially the contribution of the management fee to the total compensation, while indirect incentives focus on changes in managers' future compensation for some hypothetical performance increase. In the Internet Appendix Section F, we examine how *FutureMFee%* is related to fund characteristics and other manager incentive measures, such as direct incentives and indirect incentives. We do not find evidence that *FutureMFee%* is subsumed by other incentive measures in the literature. Thus, *FutureMFee%* provides new insight into hedge fund managers' behavior.

Interestingly, we also find that the coefficients for the delta of the incentive fee and the delta of managers' coinvestments are negative and significant. That is, more direct incentives, less risk-taking from the fund managers.

Last, we include the distance to the high-water mark in our baseline regression, which is a key variable in many theoretical models. The theoretical literature on the impact of the distance to the high-water mark on risk-taking has mixed results. For instance, Hodder and Jackwerth (2007) and Panageas and Westerfield (2009) find that fund managers increase risk-taking when fund value falls below the high-water mark; conversely, LWY argue that fund managers take less risk after bad performance; and Buraschi, Kosowski, and Sritrakul (2014) find a concave relation between distance and risk-taking.

We first calculate the distance to the high-water mark for each investor as $distance = S/X - 1$, where S is the market value of each investor's investment and X is her high-water mark. Then, the distance to the high-water mark for each fund is the weighted average across all investors, and the weight is the market value of each investors' investment. Because the distance measure is only meaningful for funds with high-water marks, we include an interaction term between the high-water mark dummy and the distance measure. In addition, because the distance measure is nonpositive by definition, we use the absolute value of the distance in our regressions for easier interpretation.

In panel D of Table 7, after controlling for distance, the coefficients for our key variable, *FutureMFee%*, are all negative and significant. Thus, we still find a negative relation between the contribution of future management fees to managers' total compensation and managers' risk-taking behavior. The coefficients for the interaction term between the high-water mark dummy and the distance measure are positive and significant, suggesting that fund managers take more risk when fund value falls further below the high-water mark. This result is more consistent with Hodder and Jackwerth (2007) and Panageas and Westerfield (2009), and one possible explanation is that fund managers take more risk when their funds are near termination. We would like to point out that our empirical setup does not strictly follow all assumptions in the theoretical models, so our findings should be interpreted with caution when comparing with these models' predictions.[26]

As we saw above, the relation between managers' risk-taking choices and their future management fees holds when we control for other manager incentive measures in the literature. Thus, our measure provides new insights into managers' incentives and their risk-taking behavior.

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[26] Our *FutureMFee%* variable contains more information than the distance measure, and thus we use the *FutureMFee%* as the main independent variable in our study. Here is why. First, the distance to the high-water mark for hedge funds without high-water marks is always zero and thus there is no variations for these funds. Second, the distance to the high-water mark does not reflect managers' coinvestments in the fund. In contrast, our *FutureMFee%* measure considers all three components of managers' compensation, and funds with the same distance to the high-water mark can have different *FutureMFee%* due to managerial ownership and capital flows. Therefore, we use the *FutureMFee%* measure in the main results and consider the distance measure as a robustness check.

4.2 Robustness tests

In this subsection, we conduct additional robustness tests regarding the relation between hedge fund managers' risk-taking behavior and their future compensation.[27] Table 8 reports all the results.

Hedge funds without high-water marks can charge incentive fees when they make positive profits and they do not need to make up for past losses. As a result, the management fee might be less important for these hedge funds, and they may behave differently from their peers with high-water marks. In Table 2, we include a high-water mark dummy, which equals one if a hedge fund has a high-water mark provision, and zero otherwise. To further test whether hedge funds with high-water mark provisions have different risk-taking sensitivities to *FutureMFee%*, we include an interaction term between *FutureMFee%* and the high-water mark dummy. Table 8, panel A, shows that the coefficients for the high-water mark dummy and the interaction terms are all insignificant. At the same time, the coefficients for *FutureMFee%* are still negative and significant. The results suggest that hedge funds with and without high-water marks behave similarly, that is, they take less risk when future management fees contribute more to managers' total compensation.

In Equation (14), we only consider one factor, the style index return. An alternative is to use multifactor models to capture managers' systematic risk exposure. To examine this alternative, we use the Fung and Hsieh (2004) seven-factor model, and we make two modifications when we compute risk-taking measures for tractability. First, when there are seven factors on the right-hand side, we estimate factor loadings over a 2-year period to increase degrees of freedom and to reduce potential noise. Second, to facilitate interpretation, we focus on the beta on the equity market factor, rather than presenting results on all seven factors. Panel B of Table 8 presents regression results when we use 2-year volatility, beta of the equity market factor, and residual volatility as dependent variables. Consistent with Table 2, we find that fund managers take significantly less risk when future management fees contribute more to managers' total compensation.

In panel C of Table 8, we examine the within-fund time-series effect by including fund fixed effects in the regression. After we include fund fixed effects, we only control for fund assets, fund age, and managerial ownership at the end of quarter q, and fund performance and fund flows over the past year, because other fund characteristics (e.g., fee structure) are fixed within a fund. One empirical issue is that to make the analysis meaningful, we need to have a

[27] We provide additional robustness tests in the Internet Appendix. In the Internet Appendix Section G, we examine the relation between managers' risk-taking behavior and future management fees using alternative risk-taking measures, such as the intended risk-taking measure discussed in Kempf, Ruenzi, and Thiele (2009) and Huang, Sialm, and Zhang (2011) and downside risk measures discussed in Liang and Park (2007). The negative relation remains when we use alternative risk-taking measures. In Internet Appendix Section H, we find that the relation between risk-taking and managers' future management fees are robust when we consider the tournament behavior and the recent financial crisis.

Table 8
Robustness tests

A. High-water mark

	Volatility	*Style beta*	*Residual volatility*
$FutureMFee\%_q$	-0.0051^{**}	-0.0053^{***}	-0.0080^{***}
	(-2.22)	(-4.05)	(-3.87)
$FutureMFee\%_q \times High\text{-}water\ mark$	0.0002	0.0006	0.0022
	(0.12)	(0.51)	(1.32)
High-water mark	0.0113	−0.0236	−0.0357
	(0.14)	(−0.50)	(−0.50)
Lagged risk-taking	Yes	Yes	Yes
Control variables	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes
N	38,335	36,961	36,961
Adj. R-sq.	.6592	.2904	.5796

B. FH seven-factor model

	Volatility	$Beta_{Market}$	*Residual volatility*
$FutureMFee\%_q$	-0.0051^{***}	-0.0034^{***}	-0.0065^{***}
	(-2.79)	(-5.13)	(-3.49)
Lagged risk-taking	Yes	Yes	Yes
Control variables	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes
N	28,712	21,087	21,087
Adj. R-sq.	.7019	.3259	.6702

C. Fund fixed effects

	5 years of data			10 years of data		
	Total volatility	*Style beta*	*Residual volatility*	*Total volatility*	*Style beta*	*Residual volatility*
$FutureMFee\%_q$	-0.0051^{*}	-0.0008	-0.0046^{*}	-0.0178^{***}	-0.0066^{***}	-0.0144^{***}
	(-1.90)	(-0.56)	(-1.95)	(-3.28)	(-2.74)	(-3.07)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Style-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
N	26,917	26,237	26,237	10,620	10,467	10,467
Adj. R-sq.	.7799	.5108	.7399	.7641	.4720	.7379

This table reports the results of our robustness tests. The data are from the Lipper TASS database, and the sample period is from January 1994 to December 2015. *FutureMFee%* is defined as in Equation (15), that is, the ratio of the present value of future management fees to the present value of managers' total compensation, where the management fee and managers' total compensation are measured in absolute dollars. We estimate future management fees and managers' total compensation using the algorithm in Section 2.3, and we use $\alpha = 3\%$, $\delta + \lambda = 10\%$, and $b = 0.685$ for model calibration. Volatility is the standard deviation of fund monthly returns over a 1-year period as in Equation (13). To calculate the style beta and residual volatility, we regress fund returns on style index returns as in Equation (14). Style beta is the coefficient on style index returns, and residual volatility is the standard deviation of the error term. In Panel A, we examine whether hedge funds with high-water mark provisions behave differently. *High-Water Mark* is a dummy variable that is equal to one if a fund has a high-water mark provision and zero otherwise. Panel B shows regression results using alternative risk-taking measures based on the Fung and Hsieh (2004) seven-factor model. We use total volatility over the past 2 years, beta on the equity market factor, and residual volatility as dependent variables. Panel C presents regression results when we include fund fixed effects in our baseline regression. To make the analysis meaningful, we require a sufficiently long performance record for each fund. Control variables are defined similarly as in Table 2. In all regressions, style-quarter fixed effects are included. Standard errors are clustered at both the fund and quarter level, and t-statistics are reported in parentheses. $^{*}p < .1$; $^{**}p < .05$; $^{***}p < .01$.

sufficiently long performance record for each fund. Thus, we conduct several regressions that require a different number of observations for each fund. The coefficients for *FutureMFee%* are negative in all regressions, and they become highly significant when we require each fund to have at least 10 years of data. The results provide another piece of evidence that hedge fund managers take less risk when their future management fees become more important.

In summary, the comprehensive set of robustness checks in this section shows that our main results are robust. In all cases, hedge fund managers reduce risk-taking when future management fees contribute more to managers' total compensation.

5. Conclusions

Our study examines how hedge fund managers' compensation affects their risk-taking behavior. We build a simple model to show that hedge fund managers' risk-taking is negatively related to their future management fees. Using fund-level data, we find that hedge fund managers become conservative and reduce risk-taking when the contribution of future management fees to their total compensation increases. We also find that fund liquidation probabilities decrease when future management fees become more important in the total compensation package. Thus, our results suggest that fund managers care more about survival when future management fees become the dominant part of their total compensation. Moreover, we find that funds with higher decreasing returns to scale rely more on future management fees for compensation and thus tend to take less risk. Our findings are robust when we control for other manager incentive measures.

This study has several important implications for investors and for future compensation contract design. For example, investors should realize that even with the incentive fee contract and the high-water mark provision, fund managers take less risk when future management fees become the more important part of their total compensation. Fund managers are more sensitive to future management fees when their funds suffer from decreasing returns to scale. Thus, fund managers of large funds may behave like mutual fund managers. In other words, they care more about retaining fund assets and fund survival than about improving fund performance. For compensation contract design, future designs should take into consideration the importance of the management fee. Most recently, because of mediocre performance, some hedge funds have started to charge zero management fees to attract new investors. Without management fees, hedge fund managers are likely to be hungrier and take more risk. However, whether this will improve investors' stake requires further research.

Appendix A. Calibration of the Two-Period Model

Because our two-period model in Section 1.2 does not have closed-form solutions, we use calibration to examine the relation between hedge fund managers' risk-taking behavior and their future compensation. For the parameter choices, we normalize fund starting size, W_0, to be between the liquation boundary (b) and one for simplicity, while fixing the initial high-water mark at $H_0 = 1-\phi$. We choose a cost parameter $\gamma = 0.003$ for our baseline case so that the unconditional expected profit of the fund is positive. In this way, the fund manager would have incentives to invest in the risky strategy. Other parameters are similar to those in LWY, and the table below summarizes the details.

Table A.1
Parameter choices

This table summarizes the parameters we use to calibrate our two-period model in Section 1.2.

Unlevered alpha (α')	0.0122
Unlevered sigma (σ')	0.0426
Managers' leverage choice (π)	$0 \le \pi \le 4$
Risk-free rate (r)	0.05
Management fee percentage (c)	0.02
Incentive fee percentage (k)	0.2
Liquidation boundary (b)	0.685
Managerial ownership (ϕ)	0.05
Flow sensitivity (i)	0.8
Cost parameter (γ)	0.003

For period 1, we use Monte Carlo simulation. Because the simulation results rely on the fund starting size (i.e., W_0), we partition the range of W_0 into 63 intervals; that is, W_0 changes from 0.69 to 1 by a step of 0.005. In terms of σ_1, we use the linearly related investment strategy π_1 for the simulation. As shown in Table A.1, we assume that π_1 is in the range of (0, 4) following LWY, and we partition the range of π_1 into 41 intervals; that is, π_1 changes from 0 to 4 by a step of 0.1. Consequently, we partition the parameter space into $63 \times 41 = 2,583$ grids based on all possible combinations of W_0 and π_1. For each grid, $\{W_0, \pi_1\}$, we randomly draw a $\varepsilon_1 \sim N(0, \sigma_1)$, where $\sigma_1 = \pi_1 \sigma'$. Then we generate a fund gross return for period 1 based on Equation (1). With generated fund performance, we can calculate the fund manager's compensation (i.e., $COMP_1$ in Equation (9)), her coinvestments (i.e., $CoInvest_1$ in Equation (4)), and the market value of investors' investments (i.e., V_1 in Equation (5)) at time $t = 1$.

For period 2, we use the optimization method to estimate the fund manager's optimal risk-taking choice (i.e., σ_2^*) for each pair of simulated $\{V_1, CoInvest_1\}$ above. We can do this because the fund stops operating at the end of period 2 in our model. Thus, the fund manager's objective is simply to maximize her fee income in period 2. In other words, we solve for the σ_2 that maximizes $COMP_2$ in Equation (10).

The manager's expected total compensation at initiation is the sum of management fees and incentive fees from both periods and her coinvestments, as in Equations (9) and (10). For each $\{W_0, \sigma_1\}$, we draw 10,000 values of ε_1 and repeat the calculation above. Finally, we compute the mean total compensation over the 10,000 values of ε_1 for each σ_1, and the optimal risk-taking choice in period 1 (i.e., σ_1^*) is the choice with the highest mean total compensation for a given W_0. After we identify the optimal risk-taking choice, we can calculate the contribution of the management fee to the manager's total compensation at time $t = 0$ as in Equation (11).

Appendix B. Algorithm from Agarwal, Daniel, and Naik (2009)

One key variable to calibrate the LWY model is ω, which is defined as S/X. S and X are the market value of investors' investments and their high-water marks, respectively. To estimate S and X, we follow LSW and use the algorithm in ADN with the following assumptions.

(1) The first investor enters the fund at inception (beginning of quarter 1). There is no capital investment by the manager at inception. Therefore, all assets at inception come from a single investor.

(2) All cash flows, including fee payments, investors' capital allocations, and the manager's reinvestment, take place once per quarter at the end of each calendar quarter.

(3) The high-water mark (X) for each investor is reset at the end of each quarter and applies to the following quarter.

(4) All new capital inflows come from a single new investor.

(5) When capital outflows occur, we adopt the first-in-first-out (FIFO) rule to decide which investor's money leaves the fund. In particular, the asset value of the first investor is reduced by the magnitude of outflow. If the absolute magnitude of outflow exceeds the first investor's net asset value, then the first investor is considered as liquidating her stake in the fund, and the balance of outflow is deducted from the second investor's assets, and so on.

(6) Managers reinvest all of their incentive fees, after paying a 35% personal tax, into the fund.

Then we calculate S and X using the following algorithm:

(1) First, we solve the following recursive problem iteratively to back out gross returns (gross), using observable information on net-of-fee returns (net), assets under management (AUM):

$$net_t = \frac{\sum_i \left[S_{i,t-1}(1+gross_t) - ifee_{i,t} - mfee_{i,t}\right] + CoInvest_{t-1}(1+gross_t)}{AUM_{t-1}} - 1, \quad \text{(B1)}$$

where the incentive fee (ifee) and the management fee (mfee) of investor i at time t are calculated as

$$ifee_{i,t} = Max\left[\left(S_{i,t-1}(1+gross_t) - X_{i,t-1}\right), 0\right] \times k, \quad \text{(B2)}$$

$$mfee_{i,t} = S_{i,t-1} \times c. \quad \text{(B3)}$$

The initial values are set as $S_{1,0} = X_{1,0} = AUM_0;\ CoInvest_0 = 0.$

(2) We update the market value of the manager's coinvestments (*CoInvest*) as follows:

$$CoInvest_t = CoInvest_{t-1}(1+gross_t) + \sum_i ifee_{i,t} \times (1-35\%). \quad \text{(B4)}$$

(3) Then we update S and X of investor i as follows:

$$S_{i,t} = S_{i,t-1}(1+gross_t) - ifee_{i,t} - mfee_{i,t}, \quad \text{(B5)}$$

$$X_{i,t} = \begin{cases} Max\left[S_{i,t},\ X_{i,t-1}\right],\ if\ with\ HWM \\ S_{i,t},\ if\ without\ HWM \end{cases} \quad \text{(B6)}$$

(4) The net flow into the fund is defined as the difference between the reported value of quarter-end AUM and the current market value of all existing investors' assets and the manager's assets:

$$Flow_t = AUM_t - \left(\sum_i S_{i,t} + CoInvest_t\right). \quad \text{(B7)}$$

If $Flow_t$ is positive, then we assume that a new investor enters the fund, and her assets and high-water mark are equal to $Flow_t$. If $Flow_t$ is negative, then we apply the FIFO rule above.

With the information above, we can calculate $\omega_{it} = S_{it}/X_{it}$ for each investor. We can also calculate the percentage managerial ownership as $Mgr\ Ownership_t = CoInvest_t / Fund\ Assets_t$.

Appendix C. The LSW Procedure to Calibrate the LWY Model with Capital Flows and Managers' Coinvestments

In this study, we follow the procedure in LSW to calibrate the LWY model. In addition to the baseline model of LWY, we also incorporate two extensions, that is, managers' coinvestments in their own funds and capital flows from investors. This allows us to better estimate managers' future compensation. The LWY model assumes that hedge fund managers are risk neutral with infinite horizons. Hedge fund managers have two investment opportunities, a risk-free asset (risk-free rate r) and an alpha-generating strategy. Managers are paid via the management fee and the incentive fee. The management fee is a constant fraction (denoted by c) of the assets under management (AUM, denoted by W). The incentive fee is a constant fraction (denoted by k) of the profit, which is the change of the high-water mark (denoted by X). The high-water mark is the running maximum of W, and the high-water mark grows at a rate of g, the hurdle rate. Investors continuously redeem capital at the rate of δ. When fund value drops to a fraction b of its high-water mark, X, investors lose confidence, and the fund is liquidated. In addition, the fund can be exogenously liquidated with a probability of λ.

Hedge fund managers maximize the present value (PV) of future fees with a discount rate of β by changing the leverage π, which is a function of the fund's moneyness, $\omega = \frac{S}{X}$, where S is an investors' stake in the fund and X is her high-water mark.[28] The PV of future total fees for each dollar in the fund, $f(\omega)$, solves the following ordinary differential equation (ODE),

$$(\beta - g + \delta + \lambda) f(\omega) = c\omega + \left[\pi(\omega)\alpha' + r - g - c\right]\omega f'(\omega) + \frac{1}{2}\pi(\omega)^2 \sigma'^2 \omega^2 f''(\omega), \tag{C1}$$

subject to the boundary conditions,

$$f(b) = 0, \tag{C2}$$

$$f(1) = (k+1) f'(1) - k, \tag{C3}$$

where σ ($\sigma = \pi(\omega) \times \sigma'$) and σ' are the levered and unlevered volatility, respectively, and α ($\alpha = \pi(\omega) \times \alpha'$) and α' are the levered and unlevered alpha, respectively. We can further divide $f(\omega)$ into the present value of future management fees, $m(\omega)$, and the present value of future incentive fees, $n(\omega)$, which solve ODEs similar to Equations (C1)–(C3).

LWY provide two extensions to their baseline model to incorporate managers' coinvestments in the fund and capital flows, which we include in our calculation of managers' total compensation. The first extension incorporates managerial ownership in the fund. Then managers' total value, $q(\omega)$, includes both the total fees (i.e., $f(\omega)$) and the managers' share of investors' value (i.e., $p(\omega)$),

$$q(\omega) = f(\omega) + \phi p(\omega), \tag{C4}$$

where ϕ is the percentage ownership. LWY show that $q(\omega)$ solves the following ODE,

$$(\beta - g + \delta + \lambda) q(\omega) = [c + \phi(\delta + \lambda)]\omega + [\pi(\omega)\alpha + r - g - c]\omega q'(\omega) + \frac{1}{2}\pi(\omega)^2 \sigma^2 \omega^2 q''(\omega), \tag{C5}$$

subject to the boundary conditions

$$q(b) = \phi b, \tag{C6}$$

$$q(1) = (k+1) q'(1) - k. \tag{C7}$$

[28] The model's parameterization is quite flexible. By setting $\pi(\omega) = 1$ at all times and $\beta = r$, where r is the risk-free rate, the LWY model can be reduced to the GIR model. By assuming no liquidation boundary (i.e., $b = 0$) and no management fees (i.e., $c = 0$), the LWY model can be reduced to the Panageas and Westerfield (2009) model.

The PV of investors' value per dollar in the fund, $p(\omega)$, solves the following ODE,

$$(r-g+\delta+\lambda)p(\omega)=(\delta+\lambda)\omega+\left[\pi(\omega)\alpha'+r-g-c\right]p'(\omega)+\frac{1}{2}\pi(\omega)^2\sigma'^2\omega^2 f''(\omega), \tag{C8}$$

subject to the boundary conditions,

$$p(b)=b, \tag{C9}$$

$$p(1)=(k+1)p'(1). \tag{C10}$$

The second extension incorporates capital flows. LWY define the new capital inflows *dIt* over time increment $(t, t+\Delta t)$ as

$$dI_t = i\,[dH_t-(g-\delta)H_t dt], \tag{C11}$$

where the constant parameter $i>0$ is the sensitivity of flows with respect to the fund's profits (i.e., performance). Then the PV of total fees $f(\omega)$ satisfy the ODE above subject to the following new boundary conditions:

$$f(b)=0, \tag{C12}$$

$$f(1)=\frac{(k+1)f'(1)-k}{1+i}. \tag{C13}$$

Using the baseline model and the two extensions above, we can estimate $f(\omega), m(\omega)$, and $n(\omega)$. The table below summarizes the parameter choices for the calibration. Then the present value of future management fees in absolute dollar amounts is $\sum_i [m_i(\omega)\times S_i]$. The present value of future incentive fees can be calculated similarly. To calculate the present value of managers' coinvestments, we need to know the present value of investors' value as in Equation (C4). To do so, we first treat managers' coinvestments in the fund as another ordinary investor. The only difference is that ω is always equal to one for managers' coinvestments. Then we can estimate the present value of investors' investments in absolute dollar terms as $\sum_i [p_i(\omega)\times S_i]+CoInvest\times p(1)$. As a result, the contribution of future management fees to managers' total compensation would be

$$FutureMFee\% = \frac{\sum_i [m_i(\omega)\times S_i]}{\sum_i f_i(\omega)\times S_i+\phi\{\sum_i [p_i(\omega)\times S_i]+CoInvest\times p(1)\}}. \tag{C14}$$

$\omega=S/X$	Fund-quarter-investor specific; see Appendix B
c	Management fee rate; fund specific; annual rate/4
k	Incentive fee rate; fund specific
σ	Quarterly volatility = standard deviation of monthly returns over the prior 12-month period $\times\sqrt{3}$
σ'	Unlevered volatility $=\sigma/2.13$
α	Quarterly equivalent of 0%, 3%
α'	Unlevered alpha $=\alpha/2.13$
$\delta+\lambda$	Quarterly equivalent of 5%, 10%
b	Lowest acceptable fraction of the high-water mark; 0.685, 0.8
r	Risk-free rate; 3-month LIBOR
g	Growth rate of the high-water mark; $=r$
β	Managers' discount rate; $=r$
ϕ	Managerial ownership; fund-quarter specific; see Appendix B
i	Sensitivity of flows to fund performance; 0.8

Appendix D. Calculation of Other Measures of Managers' Compensation

In Section 4.1, we consider two measures of managers' compensation in the literature, that is, *CurrentMFee%* and direct incentives. For *CurrentMFee%*, we first compute fees from each investor in the current quarter and then sum across all investors for each fund. For the current management fee from each investor, we multiply the investor's investment (S) by the management fee percentage (c).[29] For the current incentive fee for each investor, we multiply an investor's profit by the incentive fee percentage (k). If a fund does not have a high-water mark provision, the incentive fee is charged when the fund return is positive in quarter q, and an investor's profit is her investment multiplied by fund returns. If a fund has a high-water mark provision, then the incentive fee is charged when an investor's investment is above her high-water mark, and her profit is the difference between the investor's investment and her high-water mark. Managers' total compensation in quarter q is the sum of the current management fee and the current incentive fee. Thus, *CurrentMFee%* is calculated as the current management fee divided by current total compensation.

For direct incentives, we compute the delta of the management fee as $\delta(Mgmt\ fee) = S \times c \times 0.01$, where S is the market value of investors' investments, and c is the management fee percentage and is one-quarter of the annual management fee percentage. The delta of managers' coinvestments is calculated as $\delta(Co-investments) = CoInvet \times 0.01$, where *CoInvet* is managers' coinvestments before the performance increase. The incentive fee contract resembles a call option, and thus the delta of the incentive fee can be calculated using the Black-Scholes formula as

$$\delta(Incentive\ fee) = N(Z) \times S \times k \times 0.01, \text{ with } Z = \frac{ln\frac{S}{X} + T(R+\sigma^2/2)}{\sigma T^{0.5}}, \tag{D1}$$

where variable X is the high-water mark for each investor, variable T is one-quarter, R is the natural logarithm of one plus the LIBOR rate over the next quarter, σ is the quarterly volatility of fund returns, k is the incentive fee percentage, and N is the cumulative distribution function of the standard normal distribution.

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29 Because we calculate quarterly management fees, c is one-quarter of the annual management fee percentage reported in the TASS database.

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