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The Optimal Size of Hedge Funds: Conflict between Investors and Fund Managers

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The Optimal Size of Hedge Funds:
Conflict between Investors and Fund Managers

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Management

by

Chengdong Yin

Dissertation Committee:
Professor Lu Zheng, Chair
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2014

DEDICATION

To

Zhenrong Li

and

Mengbo Yin

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ABSTRACT OF THE DISSERTATION

The Optimal Size of Hedge Funds:

Conflict between Investors and Fund Managers

By

Chengdong Yin

Doctor of Philosophy in Management

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Professor Lu Zheng, Chair

This study examines whether the standard compensation contract in the hedge fund industry aligns managers' incentives with the interests of investors. We demonstrate empirically that managers' compensation increases when fund assets grow, even when there are diseconomies of scale in fund performance. Under the current fee structure, managers' compensation is maximized at a much larger size than is optimal for fund performance. Therefore, hedge fund managers have strong incentives to increase their assets under management. However, to avoid capital outflows and retain fund assets, managers are also motivated to restrict fund growth to maintain style-average performance, which explains why funds sometimes close themselves to new investment.

I. Introduction

One of the important ways in which hedge funds differ from traditional investment vehicles is in the design of managers' compensation contracts. One key difference is that, in contrast to their peers in the mutual fund industry, hedge fund managers charge an additional performance-based incentive fee. The incentive fee contract allows hedge fund managers to charge part of the profits as their compensation, which is supposed to motivate hedge fund managers to maximize fund performance.

However, does the standard compensation contract of hedge funds really align managers' incentives with investors' best interest? The evidence seems mixed. Like other investment vehicles, such as mutual funds, hedge funds are likely to suffer from diseconomies of scale. Limited investment opportunities, potential negative price impact from large block trading, and high transaction and administrative costs (such as the hierarchy cost discussed by Stein (2002)) may erode fund performance when funds grow large. This decline of performance generates a conflict of interest between investors and fund managers. If the design of managers' compensation contracts is effective, it would mitigate the conflict of interest, and fund assets should match the optimal size for fund performance. Indeed, many fund managers claim that they try to protect their investors by closing their funds to new investment.[1] However, we also observe that many hedge funds become too big to profit. One well known example is hedge funds under management of Paulson & Co. Inc. John Paulson's funds attracted huge capital inflows after his big success in 2007 and grew to more than $30 billion. In 2011, Paulson's funds suffered a significant loss, and the large fund size was believed to be one of the most important

[1] For example, see "RBC Closes Hedge Fund to New Investors" (http://dealbook.nytimes.com/2011/01/14/rbc-closes-off-hedge-fund-to-new-investors/), and "Some Hedge Funds, to Stay Nimble, Reject New Investors" (http://dealbook.nytimes.com/2011/09/07/some-hedge-funds-to-stay-nimble-reject-new-investors/) among others.

reasons.[2] In addition, previous research documents that diseconomies of scale still exist in the hedge fund industry.[3] In other words, it seems that the incentive fee contract does not give fund managers enough motives to restrict fund growth in order to protect fund performance.

This study seeks to reconcile these apparently contradictory facts. Previous literature commonly overlooks the fact that hedge fund managers' compensation depends on fund size as well as fund performance. Fund managers care about their total compensation in absolute dollar amounts, not just as a percentage of fund performance or fund assets. This study overcomes this shortcoming by examining how hedge fund managers' compensation is related to both fund performance and fund size. With a more accurate measure, we then examine whether the standard compensation contract in the hedge fund industry can align managers' incentives with investors' best interest, and if not, how fund managers' incentives will influence fund growth and investors' best interest under the current fee structure.

These questions are important for both the hedge fund investors and the future design of managers' compensation contracts. As we know, the hedge fund industry has been growing rapidly in the past two decades. For example, by the end of 2011, the total assets under management in the hedge fund industry are around 2 trillion dollars.[4] Understanding managers' incentives may help investors choose among different funds and better monitor fund performance. It can also shed light on the future compensation contract design in order to mitigate the conflict of interest between investors and fund managers.

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[2] For example, see "Billionaire John Paulson's Hedge Fund: Too Big To Manage" (http://www.forbes.com/sites/nathanvardi/2012/12/21/billionaire-john-paulsons-hedge-fund-too-big-to-manage/) and "John Paulson's Very Bad Year" (http://www.businessweek.com/printer/articles/59946-john-paulsons-very-bad-year) among others.

[3] Getmansky (2012) finds a concave relationship between fund returns and fund assets while Teo (2009) finds a convex relationship using risk-adjusted returns. Both studies document diseconomies of scale in the hedge fund industry. See Perold and Salomon (1991), Indro et al. (1999) and Chen et al. (2004) among others for a discussion of diseconomies of scale in the mutual fund industry.

[4] For example, see "Hedge-Fund Assets Rise to Record Level" (*Wall Street Journal*, April 19, 2012) and "Hedge Funds: A $2 Trillion Industry?" (http://www.forbes.com/sites/halahtouryalai/2012/03/01/hedge-funds-a-2-trillion-industry/) among others.

We first test whether there are diseconomies of scale in the hedge fund industry. In this study, we use style-adjusted returns as the performance measure since investors likely evaluate and compare funds within the same investment style.[5] Consistent with the previous literature, we document that diseconomies of scale do exist, but only for some style categories.[6] Since diseconomies of scale exist, we can identify the optimal fund size in terms of fund performance. Ideally, if the design of managers' compensation contracts is effective, we should observe that the optimal fund size for managers' compensation matches the optimal size for fund performance. In other words, an effective compensation contract design would align managers' incentives with investors' best interest.

Our empirical results, however, show that these two optimal sizes are different. By measuring managers' compensation in absolute dollar amounts, we find that fund managers' compensation increases as fund assets grow, even when diseconomies of scale exist. There are two possible explanations for this result. First, the performance-based incentive fee also depends on fund assets. If fund assets increase faster than fund performance decreases, it is possible for the incentive fee in absolute dollar amounts to increase even when performance declines.[7] Second, when fund assets grow, the management fee increases regardless of the changes in the incentive fee, and ultimately the management fee may become the more important part of managers' total compensation. Consequently, even if the incentive fee decreases due to the diseconomies of scale, managers' total compensation may still increase if the management fee grows faster. Therefore, fund managers likely have strong incentives to increase their assets

[5] The results are similar when we use different performance measures, such as raw returns and risk-adjusted returns. Please refer to Section VI Robustness Tests.
[6] Getmansky (2012) also find that the concave relationship between fund returns and fund assets only appears in certain styles.
[7] Liang and Schwarz (2011) show this is possible but they do not investigate this question thoroughly.

under management. As discussed earlier, this is not in the best interest of hedge fund investors when diseconomies of scale exist.

At the same time, to increase fund assets, fund managers need to attract capital inflows and avoid capital outflows. For this reason, we examine the association between capital flows and fund performance. Consistent with the literature, we find that investors chase performance with different sensitivities.[8] Investors are most sensitive when funds are in the poorest and the best performance groups, and they are least sensitive when funds have average performance. Since hedge fund investors likely evaluate and compare fund performance within the same style category, we expect that fund managers need to maintain style-average performance to avoid outflows. Therefore, managers would want to restrict fund growth by closing their funds to new investment when diseconomies of scale lead to style-average performance. Indeed, when we examine fund closure decisions, we find evidence that most funds close around the size at which they can provide style-average performance.

The key contributions of this paper are as follows. First, we show empirically that, under the current fee structure, hedge fund managers have strong incentives to increase fund assets in order to boost their compensation even when diseconomies of scale exist. The compensation contract in the hedge fund industry, especially the incentive fee contract and the high-water mark provision, has been studied analytically and empirically. However, previous research commonly focuses on how the compensation contract can motivate hedge fund managers to improve fund performance, how the fee structure would influence fund managers' risk-taking behavior, or how

[8] See Naik, Ramadorai, and Stromqvist (2007), Fung, Hsieh, Naik, and Ramadorai (2008), and Ding, Getmansky, Liang, and Wermers (2009) among others. Also see Chevalier and Ellison (1997), Sirri and Tufano (1998), and Berk and Green (2004) among others for a discussion of flow-performance relationship in the mutual fund industry.

fund managers would choose the fee structure strategically and signal their abilities.[9] Few of them examine how managers' compensation is related to fund size. One paper that is closely related to ours is Agarwal, Daniel, and Naik (2009). They propose to use delta, which is the total expected dollar increase in the manager's compensation for a 1% increase in the fund's NAV, to measure managerial incentives. They provide evidence that hedge funds with greater managerial incentives and higher degrees of managerial flexibility have superior performance. Although they realize that fund managers care about dollar incentives, they do not analyze the relationship between dollar incentives and fund assets. Goetzmann, Ingersoll, and Ross (2003) examine the division of wealth between investors and fund managers under the incentive fee contract and high-water mark provision. They argue that, due to diminishing returns to scale, hedge funds may not be able to take or even want new funds. However, they neglect the possibility that the incentive fee in absolute dollar amounts may increase if fund assets increase faster than performance declines. In this study, we calculate managers' dollar incentives, and our empirical results indicate that managers' compensation in absolute dollar amounts increases as fund assets grow. This causes the optimal size in terms of managers' compensation to differ substantially from the optimal size in terms of fund performance. Therefore, like their peers in the mutual fund industry, hedge fund managers are motivated to increase their assets under management, even at the expense of fund performance. In other words, the standard compensation contract does not solve the conflict of interest between fund investors and fund managers in the hedge fund industry.

[9] For fund performance, see Ackermann, McEnally and Ravenscraft (1999), Liang (1999) among others. For fund managers' risk-taking behavior, see Hodder and Jackwerth (2007), Kouwenberg and Ziemba (2007), and Panageas and Westerfield (2009) among others. See Aragon and Qian (2010) and Pan, Tang, Zhang and Zhao (2012) among others about fee structure and managers' quality. Also see Carpenter (2000), Elton, Gruber and Black (2003), Golect and Starks (2004) among other about the incentive fee in the mutual fund industry.

Second, we demonstrate that hedge fund managers are also motivated to maintain style-average performance in order to avoid capital outflows and thus retain fund assets. It is widely documented in the literature that investors chase performance. In their seminal paper, Berk and Green (2004) provide a framework to study capital flows and investors' behavior in the mutual fund industry. In their model, investors chase performance and, in equilibrium, the abilities of managers will be fully extracted. Sirri and Tufano (1998) find a nonlinear relationship between capital flows and fund performance. While funds in the top performance quintile attract significant capital inflows, there is no relationship between fund performance and capital flows in the lowest quintile. Fung et al. (2008) analyze the flow-performance relationship using funds-of-funds data. They find that alpha-producing funds are less likely to be liquidated and enjoy greater and steadier flows of capital. However, the high capital inflows seem to erode future performance, exhibiting capacity constraint effects.[10] Consistent with the literature, we also find that investors chase performance with different sensitivities. We document that investors are most sensitive when funds are in the poorest and the best performance groups, and they are least sensitive when funds have average performance.

Since investors chase performance, fund managers face the following tradeoff: on the one hand, they have strong incentives to increase assets under management in order to maximize their compensation; on the other hand, they are also motivated to restrict fund growth in order to maintain style-average performance, given that diseconomies of scale exist. In other words, fund size is determined by both demand side and supply side. Fund managers want to raise capital and they attract capital inflows by allocating fund assets in order to generate good performance.

[10] Also see Naik, Ramadorai and Stromqvist (2007), Ding, Getmansky, Liang and Wermers (2009) among others for discussions about flow-performance relationship and capacity constraints in the hedge fund industry.

Investors provide capital and they invest in funds with superior performance until fund managers' abilities are fully extracted.

This notion is confirmed by fund closure decisions. We find that most funds close to new investment around the fund size at which they can provide style-average performance. These results are also consistent with previous research. Zhao (2004) studies mutual funds that are closed to new investment, and finds no evidence that fund closure can protect fund performance. Instead, he argues that fund closure decisions are more likely to be driven by a spillover effect: fund families are trying to attract investors' attention to other funds in the same family by closing the star funds. Bris et al. (2007) find that mutual funds close after a period of superior performance, but they do not outperform after closure. Fund managers are compensated by raising fees after closure. When funds reopen, they do not demonstrate superior performance. Liang and Schwarz (2011) find similar results in the hedge fund industry. They argue that the performance-based compensation is not strong enough to prevent overinvestment, and the primary goal of fund managers is to increase fund size.

Moreover, we document that there is a cubic relationship between fund performance and lagged fund size. This relationship is somewhat different from the literature. To our best knowledge, Getmansky (2012) is the first study that analyzes the optimal size of hedge funds. She finds a concave relationship between fund raw returns and assets under management, from which an optimal size can be obtained. Getmansky also argues that hedge funds in illiquid categories, which are subject to high market impact and have limited investment opportunities, are more likely to exhibit an optimal size behavior. She provides empirical evidence that this concave relationship appears only in certain style categories. Teo (2009) uses risk-adjusted returns as the performance measure, and finds a convex relationship between fund performance and assets under management.[11] He argues that this relationship is caused by two effects. One is the price impact of fund trading, especially funds with capacity constraints. The other is the hierarchy costs discussed by Stein (2002). Earlier research also finds diseconomies of scale in the mutual fund industry. Perold and Salomon (1991) argue that diseconomies of scale stem from the increased costs with larger transactions. They interpret this effect as a result of price impact. Indro et al. (1999) argue that mutual funds need to attain a minimum fund size to generate sufficient returns in order to justify their costs of acquiring and trading on information. They also find that there is an optimal fund size beyond which the marginal return will be negative. Chen et al. (2004) provide empirical evidence that fund size may erode performance in the mutual fund industry. They find that both before- and after-fee returns decline with fund growth. Similar to Teo (2009), they find that this relationship is more pronounced among funds that trade small and illiquid stocks and funds that are managed by multiple managers, i.e., this adverse scale effect may be explained by liquidity and hierarchy costs.

In this study, we find a cubic relationship between fund performance and fund size, and we believe that this relationship may depict the life cycle of hedge funds. When funds are relatively small, there is a convex relationship between fund performance and fund size. In this stage, funds may enjoy economies of scale. Possible reasons for this convex relationship include: fixed costs can be shared across different investment ideas (i.e., decreasing fixed costs) and funds enjoy lower commission fees and other transaction fees from their brokers. However, when funds grow large, the relationship between fund performance and fund assets becomes concave, and thus

[11] Getmansky (2012) and Teo (2009) use different performance measures and different samples in their analysis. Besides, Getmansky (2012) uses natural logarithm of fund assets as independent variable, while Teo (2009) uses fund assets in billion dollars as independent variable. Although the relationship is somewhat different, one thing in common is that funds suffer from diseconomies of scale when they grow large.

funds experience diseconomies of scale. This concave relationship may come from the negative price impact and some high transaction and administrative costs discussed earlier.

The rest of the paper proceeds as follows: Section II summarizes the data; Section III examines whether diseconomies of scale exist in the hedge fund industry; Section IV studies hedge fund managers' compensation; Section V analyzes the relationship between capital flows and fund performance; Section VI shows the robustness tests; and Section VII concludes upon the results.

II. Data

The data used in this study are from the Lipper TASS database. Following the literature, we only keep funds that report monthly net-of-fee returns in US dollars (USD). Observations with missing information about fund performance, assets under management, or investment styles are deleted. Funds in the Dedicated Short Bias, Options Strategy and Funds-of-Funds style categories are also excluded.[12]

To mitigate survivorship bias, we include defunct funds in our sample. Defunct funds include funds that have been liquidated, have been merged into other funds, and have stopped reporting. As documented in the literature, TASS began to include data of defunct funds since 1994. Thus, the time span in our study is from January 1994 to December 2009.

To mitigate backfill bias, we exclude the data before the date when the funds were added to the TASS database. This step can also mitigate a potential survivorship bias. As discussed in Aggarwal and Jorion (2010), around year 2000, another database was merged into the TASS database, and only funds that were alive at that time were added to TASS. Therefore, data from

[12] There are only a few funds in Dedicated Short Bias and Options Strategy styles (either style has less than 1% of all funds in the sample).

the other database may suffer from a potential survivorship bias. If the add-date information is not available, we exclude the first 18 months of data.

Since fund size is one of the key variables in our study, we carefully examine the data in the TASS database. First, it appears that the monthly time series of fund assets are very noisy. For example, some funds report the same assets under management for two or more consecutive months. This may not only bias the performance-size relationship, but also make it difficult to measure capital flows accurately. To mitigate this problem, we use quarterly frequency in this study. Monthly returns are converted into quarterly returns, and fund size is measured by assets under management reported at the end of each quarter. Second, there are some obvious outliers in the sample. For example, some funds report fund assets as low as $1. To eliminate the influence of those outliers, we delete observations with assets smaller than a predetermined cutoff point. At the same time, to avoid any possible impact that the cutoff point may have on the results, we use a simulation to investigate the effect of different cutoff points (please refer to Appendix A). In this simulation, we generate fund performance randomly, i.e., fund performance does not depend on fund size. However, when we use a high cutoff point for fund assets, the regression results suggest that there is a convex relationship between fund performance and fund size. Therefore, in order to avoid generating a relationship artificially, a lower cutoff point is preferred. Finally, another concern is that the attrition rates of smaller funds are relatively higher. In other words, smaller funds are more likely to drop out of the sample. This problem is not fixed by including the data of defunct funds. After examining attrition rates of different size groups (please refer to Appendix B), we choose $10 million as the lower bound for fund assets, and we further require each fund to have at least one year data to be included in the sample.

We also winsorize both the highest and lowest 0.5% of raw returns and capital flows to mitigate the influence of outliers. Table 1 shows the summary statistics of our sample. Panel A provides a description of fund characteristics. Hedge funds commonly charge a management fee between 1% and 2% and an incentive fee of 20%. High-water mark provisions and leverage are widely used in the hedge fund industry. The redemption frequency is normally one month (30 days) or one quarter (90 days), with a 30-day notice period.[13] Most funds do not have lockup periods and are not open to the public. Following the literature, we assume that capital flows happen at the end of each quarter, and capital flows of fund i in quarter t are defined using the following equation, where AUM is assets under management:

$$Flow_{it} = \frac{AUM_{it} - AUM_{i,t-1} \times (1 + return_{it})}{AUM_{i,t-1}} \quad (1)$$

Panel B shows the number of distinct funds in our sample. About 40% of the funds belong to the Long/Short Equity Hedge style. The table also shows that there are more defunct funds than live ones. We believe this is due to the subprime crisis.[14]

[Please Insert Table 1 Here]

III. Performance Measure and Diseconomies of Scale

A. Performance Measure

In this study, we use style-adjusted returns to measure fund performance. Style-adjusted returns are defined as the difference between fund quarterly returns and the average return of all funds in the same investment style. Thus, for fund i in quarter t, its performance is defined as:

[13] In our sample, 46.47% of the funds have a redemption frequency of 30 days, and 39.25% have a redemption frequency of 90 days. The most common redemption notice periods in our sample are 30 days (36.09% of all funds), 45 days (11.24%), 60 days (13.46%) and 90 days (9.68%).

[14] There are 260 funds (18.01% of all defunct funds) that become defunct in 2007 and 321 funds (22.23%) in 2008 in our sample.

$$Style - adjusted\ Return_{it} = Return_{it} - \frac{1}{N}\sum_{j=1}^{N} Return_{jt} \quad (2)$$

We choose this measure for the following reasons. First, style-adjusted returns can be easily calculated from fund raw returns, which are directly observable by all investors. Therefore, style-adjusted returns are less noisy than measures such as risk-adjusted returns estimated from factor models.[15] Second, hedge funds in different style categories may face very different markets and use significantly different investment strategies. Thus, hedge fund investors likely evaluate and compare hedge funds and fund managers within the same style, and style-adjusted returns are a good measure of relative performance in this sense.

B. Performance-size Relationship

Using style-adjusted returns, we first want to test whether diseconomies of scale exist in the hedge fund industry. As discussed in Berk and Green (2004), we believe that different managers have different but limited abilities. When managers are given too much capital, they may need to invest the extra capital in less profitable ideas, or look outside their area of expertise for additional investment opportunities, or they may need to invest more than optimal in each investment opportunity. In addition, there are another two possible negative effects on performance when funds grow large. One is the negative price impact from large block trading. When funds grow large, their trading volumes may become so large that they have a significant price impact on the market. This effect is more significant when the market is illiquid. The other effect is the hierarchy cost discussed by Stein (2002). When funds grow large, they need to hire more than one manager to handle multiple investment ideas. In this case, fund managers, who are competing to get their investment ideas carried out, will give up opportunities supported by soft

[15] Risk-adjusted returns could be different due to using different factor models and different methods to estimate factor loadings. As a robustness test, we report results using risk-adjusted returns in Section VI.

information because this kind of information is hard to justify. As a result, many profitable ideas are abandoned. At the same time, managers need to spend more resources on analyzing hard information. This may increase expenses and erode fund performance. Therefore, we expect that hedge funds would suffer from diseconomies of scale when they grow large.

To examine the relationship between fund performance and fund size, we rank funds into five groups every quarter based on their lagged fund assets. Then we calculate average style-adjusted return for each group over time, and the results are presented in Figure 1. From the graph, we can see a convex relationship between fund performance and fund assets when funds are relatively small and a concave relationship when funds grow large.

[Please Insert Figure 1 Here]

B.1. Methodology

To examine the relationship econometrically and identify the nonlinear relationship, we use the polynomial regressions below. The dependent variable is style-adjusted returns. Following the literature, we use the natural log of lagged fund assets as the independent variable.

$$Performance_t = \beta_0 + \beta_1 \times ln(assets_{t-1}) + Control\ Variables \tag{3}$$

$$Performance_t = \beta_0 + \beta_1 \times ln(assets_{t-1}) + \beta_2 \times [ln(assets_{t-1})]^2 + Control\ Variables \tag{4}$$

$$Performance_t = \beta_0 + \beta_1 \times ln(assets_{t-1}) + \beta_2 \times [ln(assets_{t-1})]^2 + \beta_3 \times [ln(assets_{t-1})]^3 + Control\ Variables \tag{5}$$

In equation (4), we include the squared log of fund assets to test if the relationship between fund performance and fund size is quadratic. Equation (5) is used to test if the relationship is cubic, as shown in Figure 1. We also include the following control variables. Fund family size is the total assets under management of all other funds in the same fund family. The management fee percentage, the incentive fee percentage and the high-water mark provision dummy represent the compensation structure. Redemption frequency, subscription frequency, redemption notice periods and lockup periods represent the capital flow restrictions. We include dummy variables to indicate whether funds are open to the public and whether funds use leverage. Lag of fund age and lag of capital flows are also included. Fund age is defined as the number of months between fund inception date and current date.

B.2. Empirical Results: Diseconomies of Scale

Table 2 shows the results of the pooled regression for the hedge fund industry. Following Petersen (2009), we use clustering methods to adjust the standard errors of coefficients. We also include style dummies and year dummies in the regression (not reported in the table for simplicity).

[Please Insert Table 2 Here]

From the results, we can see that the coefficients of the lagged fund assets are all significant in the cubic equation. The negative coefficient before the cubic term indicates that the relationship between fund performance and fund assets is convex when funds are relatively small and the relationship becomes concave when funds grow large. The results in Table 2 are consistent with Figure 1 and demonstrate that there is a nonlinear relationship between fund performance and fund size. This cubic relationship indicates that hedge funds suffer from diseconomies of scale when funds grow large, i.e., when the relationship becomes concave.

In addition, we can see from Figure 1 that average fund age increases almost monotonically. Therefore, we believe that this cubic relationship depicts the life cycle of hedge funds. For emerging funds or young funds, they can focus on a few profitable ideas and move more nimbly without attracting much attention to their strategies.[16] Thus, they can generate good performance and attract capital inflows. When small funds grow larger, they may encounter certain fixed costs. For example, they need to hire more professionals to handle multiple investment ideas and manage risk, invest in latest trading software and spend more on research. However, their assets may not be large enough to generate sufficient fees to cover these costs, and therefore their performance declines.[17] Although these fixed costs may erode performance of smaller funds, they become more affordable for larger and more mature funds. Lager funds not only can generate sufficient fees to cover those fixed costs, but also can share these fixed costs across many different investment ideas and enjoy lower transaction costs (e.g., lower commission fees) from their brokers. In other words, they may enjoy economies of scale, and thus their performance increases again. However, when funds grow larger than their optimal size for performance, fund managers may need to invest extra capital in less profitable ideas or invest more than optimal in each investment opportunity. In addition, the negative price impact and hierarchy costs may also erode fund performance, as discussed earlier. As a result, funds suffer from diseconomies of scale at this stage.

Table 3 shows the polynomial regression results for each style. Since funds in different styles may face very different markets and opportunity sets, the results can help us better

[16] See Aggarwal and Jorion (2010) among others for a discussion about emerging hedge funds.
[17] For example, Wilson (2012) interviewed many family office executives (available at http://richard-wilson.blogspot.com/2012/09/hedge-fund-assets-under-management-aum.html). These investors mentioned some concerns about small funds: "For a fund with a low level of AUM… These funds also may not be able to afford the latest trading software or talented traders and risk management professionals and other expenses that become more feasible with a steady stream of revenue coming in from the management fees on a high-AUM fund."

understand the relationship between fund performance and fund size. Consistent with the literature, only certain styles show a significant relationship. Among these styles, funds in the Emerging Markets, Global Macro and Long/Short Equity Hedge styles show a significant cubic relationship, while a negative linear relationship can be found among funds in Managed Futures and Multi-Strategy styles. Although the relationship is somewhat different based on the regression results, one thing they have in common is that there are diseconomies of scale when funds grow large. In addition, these five styles cover about 71% of all the funds in our sample. In other words, more than two-thirds of the funds in our sample suffer from diseconomies of scale.

[Please Insert Table 3 Here]

IV. Hedge Fund Managers' Compensation

A. Compensation Contracts

Since diseconomies of scale exist, it seems that the standard compensation contract does not give hedge fund managers enough motives to restrict fund growth in order to protect fund performance. Then it is important to examine managers' incentives under the current fee structure. As rational agents, hedge fund managers care about their compensation in absolute dollar amounts, not just as a percentage of fund performance or fund assets. Therefore, we measure fund managers' incentives by calculating the total compensation they receive. As we know, hedge fund managers' compensation has two parts. One is the performance-based incentive fee, which is calculated using the following equation:

$$incentive\ fee = fund\ assets \times return \times incentive\ fee\ percentage \tag{6}$$

From the equation, we can see that even the performance-based incentive fee depends on both fund performance and fund assets.[18] When diseconomies of scale exist, fund growth will erode fund performance. However, if the increase in fund assets is faster than the decrease in fund performance, it is possible for the incentive fee in absolute dollar amounts to increase even when diseconomies of scale exist. The other part of hedge fund managers' compensation is the management fee. The management fee increases when fund assets grow, regardless of the changes in the incentive fee. And the management fee may become the more important part of managers' total compensation when funds grow large. Thus, even when the incentive fee decreases due to the diseconomies of scale, the total compensation may still increase if the management fee grows faster.

As a result, fund managers may have strong incentives to increase fund assets in order to maximize their compensation in absolute dollar amounts. In other words, the optimal size in terms of managers' compensation may be different from (i.e., larger than) the optimal size in terms of fund performance. Therefore, a conflict of interest between investors and fund managers may still exist under the current fee structure.

B. Compensation-Size Relationship

To estimate the relationship between managers' compensation and fund size, we first need to calculate the fees charged by fund managers in absolute dollar amounts. TASS database provides information about how often and how much hedge fund managers charge the

[18]Agarwal, Daniel and Naik (2009) argue that the incentive fee and high-water mark provision are normally set at the time when the funds are established and do not change over time. Agarwal and Ray (2011) document that about 8% of all hedge funds have changed their fee structure and 7% of all hedge funds only changed once. Therefore, managers' compensation contracts are relatively exogenous in the hedge fund industry.

management fee and their assets under management. Using these data, we can easily calculate the management fee.

To calculate the incentive fee, we assume that fund managers charge the incentive fee at the end of each year. For funds without a high-water mark provision, we assume that the incentive fee is charged if the annual return is positive. For funds with a high-water mark provision, we compare the year-end net asset value (NAV) to the highest historical NAV, i.e., the high-water mark. If current NAV is higher than the highest historical NAV, the incentive fee is charged and the current NAV becomes the new high-water mark. Hedge fund managers' total compensation is the sum of the management fee and the incentive fee.

[Please Insert Figure 2 Here]

To examine the compensation-size relationship, we rank funds into five groups based on lagged fund assets every year. Then we calculate the average compensation for each group across time. In Figure 2, we exhibit both the compensation-size relationship and the performance-size relationship. From the graph, we can see that managers' total compensation increases monotonically as fund assets grow, even when diseconomies of scale exist. To further test the relationship econometrically, we regress managers' total compensation on fund assets at the end of last year.

$$total\ compensation_t = \beta_0 + \beta_1 \times assets_{t-1} + \beta_2 \times (assets_{t-1})^2 + Control\ Variables \quad (7)$$

Here, total compensation and fund assets are in million dollars. The control variables are similar as before. The quadratic term is used to capture the possible nonlinear relationship. Due to diseconomies of scale, the incentive fee may reach its maximum at certain fund size. The decline of the incentive fee may lead to the decrease of managers' total compensation as well.

[Please Insert Table 4 Here]

The pooled regression results for the compensation-size relationship are reported in Table 4. From the results in Panel A, we can see that there is a significant positive linear relationship between managers' compensation and fund size. For every $1,000 increase in fund assets, there will be a $38 increase in managers' total compensation. The regression results are consistent with Figure 2 and demonstrate that managers' compensation increases as fund assets grow. This relationship explains why hedge fund managers are not motivated to restrict fund growth in order to protect fund performance.

Table 4 Panel B shows the regression results for each individual style. Funds in all style categories show a significant positive linear relationship, while funds in five styles also exhibit a significant concave relationship. For funds with concave relationships, the optimal size in terms of managers' compensation can be identified. Earlier, we document that diseconomies of scale exist in the hedge fund industry. Thus we can identify the optimal size for fund performance. This allows us to compare the optimal size for managers' compensation with the optimal size for fund performance. The results are summarized in Table 5. If the compensation contract is effective, fund managers would restrict fund growth and set fund assets to match the optimal size for fund performance. However, under the current fee structure, it is clear that the optimal size for managers' compensation is much larger than the optimal size for fund performance. Thus, fund managers have strong incentives to increase their assets under management, even when the fund growth erodes fund performance. In other words, the conflict of interest between fund managers and investors still exists in the hedge fund industry.

[Please Insert Table 5 Here]

C. Discussion

The results above show that hedge fund managers' compensation increases as fund assets grow under the current fee structure. Earlier, we discussed two possibilities that may lead to this relationship. First, if fund assets grow faster than fund performance declines, the incentive fee may still increase even when diseconomies of scale exist. Second, even when the incentive fee decreases due to diseconomies of scale, managers' total compensation may still increase if the management fee grows faster. In this section, we would like to test these possibilities. The results would provide more insights about the standard compensation contract in the hedge fund industry and shed light on the future compensation contract design.

To test the first possibility, we regress the incentive fee on lagged fund assets. Here the incentive fee and fund assets are in million dollars, and the control variables are similar as before. Table 4 Panel A shows that there is a significant positive linear relationship between the incentive fee and fund size. The results indicate that the incentive fee in absolute dollar amounts increases as fund assets grow. Since we document that diseconomies of scale exist, this implies that the increase in fund assets is faster than the decline of fund performance, which is consistent with the first possibility.

$$incentive\ fee_t = \beta_0 + \beta_1 \times assets_{t-1} + \beta_2 \times (assets_{t-1})^2 + Control\ Variables \quad (8)$$

At the same time, diseconomies of scale may lead to slower increase in the incentive fee. As a result, the management fee may become the more important part of managers' total compensation. To test this hypothesis, we calculate a ratio, which is the management fee divided by managers' total compensation. This measure reflects the importance of the management fee to hedge fund managers. Figure 3 shows how the ratio changes with fund size. From the graph, we can see that the ratio decreases first but increases sharply when funds grow really large. This pattern, especially the increase part, provides some support to our hypothesis. In addition, the graph shows that, on average, more than half of managers' total compensation comes from the management fee. Since the management fee only depends on fund assets, it provides a more stable source of compensation for hedge fund managers. Therefore, when the management fee becomes the more important part of managers' total compensation, fund managers may have stronger incentives to increase their assets under management and less incentives to improve fund performance.[19]

[Please Insert Figure 3 Here]

Our empirical results above suggest two possible problems in the standard compensation contract. First, when fund assets grow faster than fund performance declines, diseconomies of scale do not necessarily lead to decrease of the incentive fee. Second, under current fee structure, the management fee becomes the more important part of managers' total compensation when funds grow large. However, the fixed costs of hedge funds, which are normally covered by the management fee, do not increase proportionally as fund assets grow. Therefore, future compensation contract design needs to consider both fund performance and fund size.

V. Capital Flows and Optimal Fund Size

A. Flow-performance Relationship

In the compensation-size regressions above, we do not consider capital flows explicitly.[20] To increase fund assets, fund managers need to attract capital inflows and avoid capital outflows.

[19] In Wilson's (2012) interview (available at http://richard-wilson.blogspot.com/2012/09/hedge-fund-assets-under-management-aum.html), some family office executives also expressed the following concern: "For funds with several billions of dollars under management, another fear grows among investors, that the management team is not motivated to achieve high returns and is content risking little and "getting fat" off the management fees."

[20] Capital flows are implicitly included in the fund assets. However, the compensation-size regression only looks at how the change of fund assets will influence managers' compensation. It does not consider what will cause the change in capital flows.

Previous research shows that investors chase performance. In their rational model, Berk and Green (2004) argue that investors use past performance as a measure of managers' abilities. Investors will invest more money in funds with good performance until managers' abilities are fully extracted. Therefore, in order to avoid capital outflows and thus retain fund assets, we expect that hedge fund managers are also motivated to maintain a certain level of performance. To test the flow-performance relationship, we run the following two regressions.

$$Flow_t = \beta_0 + \beta_1 \times Performance_{t-1} + Control\ Variables \quad (9)$$

$$Flow_t = \beta_0 + \beta_1 \times Performance\ Rank\ 1 + \beta_2 \times Performance\ Rank\ 2 + \cdots$$
$$+ \beta_5 \times Performance\ Rank\ 5 + Control\ Variables \quad (10)$$

In equation (9), we regress capital flows on lagged fund performance. The control variables are similar to those in the previous regressions. We include the standard deviation of past performance to measure the risk. Lagged capital flows are used to capture factors that are not related to fund characteristics. However, the literature shows that investors chase performance with different sensitivities. To capture this possible nonlinear relationship, we use a piecewise regression as in equation (10). Following Sirri and Tufano (1998), we rank funds within the same style category from 0 to 1 based on their lagged performance and divide them into five groups. The bottom quintile is defined as Performance Rank 1 = min (0.2, performance rank), and the 2^{nd} quintile is defined as Performance Rank 2 = min (0.2, performance rank – rank1), and so on. Another thing we need to consider when we analyze capital flows in the hedge fund industry is the share restrictions. In our sample, most hedge funds have a redemption frequency of 30 days or 90 days, with an additional notice period commonly varying from 30 days to 90 days.[21] To

[21] The most common combinations of redemption frequency and notice periods in our sample are: 30 days of redemption frequency with 30 days of notice periods (19.70% of all funds), 90 days with 30 days (13.81%), 90 days with 45 days (7.53%), 90 days with 60 days (7.37%) and 90 days with 90 days (5.35%).

take the delayed capital flows into consideration, we include fund performance in time t-2 and t-3 in the regressions as well.

Table 6 shows the results of the pooled regression for the flows-performance relationship. The results in Panel A indicate that investors chase performance: the coefficient of lagged fund performance is positive and significant. Since capital flow is scaled by the lagged fund assets, it is not surprising to see that the coefficient of the lagged fund assets is negative and significant. The significant negative coefficient of the standard deviation of the lagged fund performance indicates that investors do care about risk. The results also show that funds with a high-water mark provision and funds with longer redemption notice periods enjoy higher capital flows. We find similar results when we include fund performance over the past three quarters. All three coefficients of lagged performance are positive and significant. This is also consistent with our conjecture that certain capital flows are delayed by the share restrictions.

[Please Insert Table 6 Here]

Panel B reports the results of the piecewise regression. When we only include fund performance of last quarter in the regression, all the coefficients of performance ranks are positive and significant, confirming that investors chase performance. However, investors' sensitivities to the past performance are different. Investors are most sensitive when funds are in the worst performance group (Performance Rank 1) and the best performance group (Performance Rank 5), and they are least sensitive when funds have average performance (Performance Rank 3).

When we include fund performance over the past three quarters, all the coefficients of performance ranks are still positive, indicating that investors chase performance. However, there are some interesting changes in investors' sensitivities. First, the insignificant coefficient of performance rank 3 in time t-1 suggests that investors are insensitive to average performance. Second, investors are more sensitive to bad performance in time t-2. This is consistent with the fact that subscription frequency is shorter than redemption restrictions, i.e., it is easier to invest in hedge funds than to withdraw your money. Third, investors are not very sensitive to fund performance in time t-3. One possible explanation is that hedge fund investors are sophisticated and they react to fund performance very fast.[22] Thus, the results in time t-3 are driven by few funds with long share restrictions.[23]

Since investors chase performance, fund managers need to improve fund performance in order to attract capital inflows, if they want to maximize their compensation by increasing fund assets as discussed earlier. But fund growth will erode fund performance when diseconomies of scale exist. So there is a tradeoff for fund managers: on the one hand, fund managers have strong incentives to increase fund assets in order to boost their compensation; on the other hand, in order to avoid capital outflows and thus retain fund assets, they are also motivated to maintain a certain level of performance. We can also view this from a supply and demand perspective. Fund managers want to raise capital. They attract inflows by allocating their assets under management to deliver superior performance. Investors look for investment opportunities and provide their capital to managers with skills. In other words, fund size is determined by the supply and demand of both fund performance and capital flows.

In Berk and Green's (2004) model, investors will stop investing when fund managers' abilities are fully extracted. Since hedge fund investors likely evaluate and compare funds within the same style category, we expect that fund managers may want to maintain style-average

[22] Based on the combination of most common subscription frequency, redemption frequency and notice periods, we believe that most investors are able to invest in a hedge fund within a quarter and withdraw their money within two quarters.

[23] In our sample, less than 10% of the funds have a share restriction (sum of redemption frequency and notice periods) that is longer than two quarters (180 days).

performance. This hypothesis is consistent with our regression results for the flow-performance relationship: investors are least sensitive when funds are in the average performance group (Performance Rank 3).

B. The Optimal Size and Fund Closure/Reopen Decision

So far, we have shown that the optimal size for managers' compensation differ substantially from the optimal size for fund performance under the current fee structure. Thus, hedge fund managers have strong incentives to increase their assets under management in order to maximize their compensation. At the same time, to avoid capital outflows and retain fund assets, fund managers need to maintain a certain level of performance. Since hedge fund investment styles differ significantly from each other, investors likely evaluate and compare funds within the same style category. Therefore, we expect that fund managers may want to maintain style-average performance. In other words, fund managers may want to increase fund assets to the point at which they can provide style-average performance.

One way to test this prediction is to look at the fund closure and reopening decisions. Closing a fund to new investment is a direct way to restrict fund growth. In addition, fund closure/reopening decisions reflect fund managers' opinions about the optimal size of their funds. If fund managers really care about investors' best interest, they should close the funds to new investment when further growth will erode fund performance, and they should reopen closed funds only when fund growth can improve fund performance.

The TASS database provides the dates when funds close/reopen to new investment.[24] Using this information, we can examine fund managers' closure/reopening decisions and

[24] For some funds in the TASS database, the exact dates of closure/reopening are not clear. These funds are not included in our calculation.

compare closed/reopened funds with other funds in the same style category. In the first approach, we rank funds within the same style category into percentiles based on their performance and assets under management every quarter. Then we calculate the summary statistics of funds' performance rankings and size rankings in the quarter when they chose to close/reopen. Panel A of Table 7 shows the results. On average, only funds in the Global Macro style provide above average performance when they close. When they reopen, only funds in Long/Short Equity Hedge style outperform. Panel A also shows that funds in Global Macro and Long/Short Equity Hedge styles have assets above average when they close. When they reopen, funds in Global Macro style are still larger than average. Moreover, funds in the Managed Futures style have even higher size rankings when they reopen. This suggests that closed funds may still accept capital from their existing investors after closure.

[Insert Table 7 Here]

In the approach above, we only look at fund performance and fund assets in the quarter when they chose to close/reopen. However, fund managers may choose the timing of closure/reopening strategically. Liang and Schwarz (2011) argue that fund managers may choose to close the funds after a period of good performance. Therefore, in our second approach, we calculate the average performance ranking and average size ranking in the one year time period right after the closure/reopening decision for each individual fund. Then we calculate the summary statistics for each style category. The results are reported in Panel B of Table 7. Funds in all five styles do not have performance rankings above average. The results are consistent with our hypothesis that fund managers will close funds to new investment when they can only provide style-average performance. After funds reopen, their performance does not significantly improve. In terms of fund assets, Panel B shows that after closure, funds in Global Macro and Long/Short Equity Hedge style categories still have assets significantly larger than average.

The results above support our hypothesis that fund managers have incentives to increase fund assets until they can only provide style-average performance. In other words, the optimal fund size for managers' compensation differs from the optimal size for fund performance. We also find some weak evidence that fund managers have incentives to accept capital even after the funds are closed to new investment.

VI. Robustness Test

A. Different Performance Measures

In this study, we have documented that the diseconomies of scale exist in the hedge fund industry and have identified the optimal size in terms of fund performance using style-adjusted returns. However, does this effect still exist when we use different performance measures? To test this question, we utilize several different measures. The first one is net-of-fee raw returns. This measure is directly observable by all hedge fund investors. The second measure is risk-adjusted returns. Hedge fund investors are more sophisticated than their peers in the mutual fund industry, and thus, they may care more about risk-adjusted returns. Here we use alpha calculated from Fung and Hsieh's (2004) seven-factor model as the risk-adjusted return.[25] To take hedge funds' dynamic trading strategies into account, we use a three-year rolling window to estimate the factor loadings (we require at least 24 observations for each fund during the three-year period). Then we define the alpha of fund i in month t as following, where the excess return is fund return in excess of the risk-free rate:

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[25] Thanks to William Fung and David A. Hsieh for providing the data. http://faculty.fuqua.duke.edu/~dah7/DataLibrary/TF-FAC.xls

$$alpha_{it} = excess\ return_{it} - (\beta_1 S\&P + \beta_2 SML + \beta_3 BD10Y + \beta_4 CredSpr$$
$$+\beta_5 PTFSFX + \beta_6 PTFSCOM + \beta_7 PTFSBD) \quad (11)$$

The set of factors comprises: the equity market factor measured as Standard & Poors 500 index monthly total return (S&P); the size spread factor (SML) constructed as the difference between Russell 2000 index monthly total return and Standard & Poors 500 monthly total return; the bond market factor which is the monthly change in the 10-year treasury constant maturity yield; the credit spread factor calculated as the monthly change in the Moody's Baa yield less 10-year treasury constant maturity yield; and three trend-following risk factors which are the excess returns on portfolios of look-back straddle options on currencies (PTFSFX), commodities (PTFSCOM), and bonds (PTFSBD).

The last measure is style-adjusted returns using asset-weighted average as the benchmark. This measure can test whether our results are driven by performance of smaller funds. Table 8 Panel A shows the results of polynomial regressions using three different measures. The results indicate that there is a cubic relationship between fund performance and fund assets, and the relationship is robust when we use different performance measures. The significant negative coefficient before the cubic term indicates that the relationship between fund performance and fund size becomes concave when funds grow large. In other words, diseconomies of scale exist in the hedge fund industry.

[Insert Table 8 Here]

B. Different Fund Assets Cut-Off Points

Since fund size is one of the key variables in our study, we have tried several different cutoff points for the assets under management: $5 million, $20 million and $50 million. The results are reported in Table 8 Panel B. We document a significant nonlinear relationship between fund performance and fund size using cutoff points below $50 million. The relationship becomes negative linear when we use $50 million as the lower bound for fund size.

Panel C summarize the relationship between fund performance and fund size using different performance measures and different cutoff points of fund assets for different investment styles. The results are consistent in most cases using raw returns and style-adjusted returns. This is not very surprising since the two measures are highly correlated. Although the performance-size relationship using risk-adjusted returns is somewhat different, one thing in common is that funds suffer from diseconomies of scale when they grow large.

C. Different Sub-Periods

We also divide the sample period into four sub-periods. Following the literature, we pick three events as the break points: the bankruptcy of LTCM in September 1998; the peak of the tech bubble in March 2000; and the beginning of the subprime crisis in June 2007 (the bankruptcy of two hedge funds of Bear Stearns).[26] Then we regress fund performance on fund assets using different performance measures for different sub-periods.[27] The results are shown in Table 9.

The results using raw returns and style-adjusted returns are consistent, especially in sub-periods 3 and 4. We find significant cubic relationship between fund performance and fund size in both periods using different cut-off points for fund assets. The results using risk-adjusted returns are similar in sub-period 3. However, we find significant negative linear relationship in

[26] See Fung and Hsieh (2004), Fung, Hsieh, Naik and Ramadorai (2008) among others.
[27] The second sub-period (from Oct. 1998 to Mar. 2000) is very short. Therefore, we skip this sub-period since the regression may not have enough power. For the first sub-period, the starting date is the same for raw return and style-adjusted return, which is March 1994. The starting date for risk-adjusted return is Jan 1997 since we use a three-year rolling window to estimate the alpha. In general, we do not have much data in sub-period 1 and 2.

sub-period 4 when we use risk-adjusted returns. This may be because the whole economy was in recession and it was difficult for all funds to make abnormal returns under this market condition.

[Insert Table 9 Here]

D. Piecewise Regression

Piecewise regressions provide another way to detect the nonlinear relationship between fund performance and fund size. Following Sirri and Tufano (1998), we rank lagged fund assets from 0 to 1 and divide funds into five groups. The bottom quintile is defined as Size Rank 1 = min (0.2, size rank), and the 2nd quintile is defined as Size Rank 2 = min (0.2, size rank – size rank 1), and so on. Then we run the following piecewise regression:

$$Performance_t = \beta_0 + \beta_1 \times Size\ Rank\ 1 + \beta_2 \times Size\ Rank\ 2 + \beta_3 \times Size\ Rank\ 3 + \beta_4 \times Size\ Rank\ 4 + \beta_5 \times Size\ Rank\ 5 + Control\ Variables \quad (12)$$

The dependent variable is style-adjusted returns and the control variables are the same as before. The regression results for the hedge fund industry are presented in Table 10 Panel A. The coefficient of the smallest size group (size rank 1) is negative, and the coefficient of the three groups in the middle (size rank 2~4) is positive. This change of sign indicates a convex relationship between fund performance and fund size. The performance-size relationship becomes concave when fund grow large, since the coefficient of the largest size group (size rank 5) is negative and significant. This concave relationship indicates that diseconomies of scale exist in the hedge fund industry. Panel B presents the piecewise regression results for each style. Consistent with the literature, we only find significant relationship in certain styles, and the regression results are consistent with our polynomial regression in Table 3.

[Insert Table 10 Here]

VII. Conclusion

Traditional investment vehicles, such as mutual funds, normally charge an asset-based management fee. The design of the management fee motivates fund managers to increase their assets under management and thus maximize their compensation. Since mutual funds suffer from diseconomies of scale, increasing fund assets will erode fund performance. This erosion, or decline of performance, generates a conflict of interest between fund managers and investors. In contrast to their peers in the mutual fund industry, hedge fund managers charge an additional performance-based incentive fee. This incentive fee is expected to motivate fund managers to care about fund performance, including restricting fund growth to protect fund performance when diseconomies of scale exist. In other words, if the design of the compensation contract is effective, it would mitigate the conflict of interest between investors and fund managers.

In this study, however, we find that hedge fund managers actually have strong incentives to increase fund assets, even if fund growth hurts fund performance. Thus, the conflict of interest between investors and fund managers still exists in the hedge fund industry under the standard compensation contract.

We document this conflict of interest in several ways. First, we find that diseconomies of scale exist in the hedge fund industry, and thus optimal size in terms of fund performance can be identified. Second, our empirical results show that the optimal size for managers' compensation is larger than the optimal size for fund performance. As a result, fund managers have strong incentives to increase fund assets, even when fund growth will erode fund performance. At the same time, to avoid capital outflows and thus retain fund assets, fund managers need to maintain style-average performance. This prediction is confirmed by managers' fund closure decisions.

Most funds close to new investment around the size at which they can provide style-average performance. Thus, although fund managers would prefer more assets, fund sizes are also limited by investors' behavior of chasing performance.

This study has several implications for the hedge fund investors and the future design of managers' compensation contracts. For example, hedge fund investors should realize that, under the current fee structure, fund managers have incentives to increase fund assets and sacrifice fund performance in order to boost their compensation. Therefore, investors need to monitor fund performance more closely and avoid long lockup periods. This also applies to funds of hedge funds. Funds of hedge funds need to take fund size into consideration when they evaluate different hedge funds, since large funds may not outperform in the future. In terms of the design of compensation contracts, future designs need to consider both fund performance and fund size. The current compensation contract is not effective because it ignores the fact that managers' compensation also depends on fund assets, even in the case of performance-based fees.

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Appendix A

In this simulation, we examine the impact of different cutoff points of fund assets on the relationship between fund performance and fund size.

We generate monthly returns for 16 years (192 observations; the length of our sample period) for 1000 funds. The returns are drawn randomly from a normal distribution, $N(\mu, \sigma^2)$, where mean is 0.5648% and standard deviation is 5.6451%.[28] The starting fund sizes are randomly generated between \$1 million and \$50 million. Using generated fund performance and starting sizes, we then calculate fund assets at the end of each month using the following equation.

$$Fund\ Assets_{i,t} = Fund\ Assets_{i,t-1} \times \left(1 + r_{i.t} + Flow_{i,t}\right) \tag{A1}$$

We assume that funds will be liquidated when their assets reach half of their starting assets. We also assume that investors chase performance. Following Getmansky (2012), we assume that capital flows have the following form (here capital flows are defined as a percentage of lagged fund assets).

$$Flow_{i,t} = \begin{cases} 1 - \exp\left(-r_{i,t-1}\right)\ if\ r_{i,t-1} \geq 0 \\ -1 + \exp\left(r_{i,t-1}\right)\ if\ r_{i,t-1} < 0 \end{cases} \tag{A2}$$

Finally, we use different cutoff points to clean the generated data, and then run the following OLS regression. The regression results are reported in Table A1 Panel A.

$$return_{i,t} = \beta_0 + \beta_1 \ln(asset_{i,t-1}) + \beta_2 [\ln\left(asset_{i,t-1}\right)]^2 \tag{A3}$$

However, the approach above does not consider share restrictions in the hedge fund industry. Thus, in the second approach, we assume that, for half of the funds, capital flows happen every three months. To calculate flows for these funds, we replace monthly returns in

[28] The mean and standard deviation of fund monthly returns are based on the summary statistics of our sample before we put any size restrictions.

equation (A2) by average return over the past three months. Then we repeat the process and regression above. The results are presented in Panel B.

Since we generate fund returns randomly, there should be no relationship between fund performance and fund size. However, using higher cut-off points for fund assets, we can create a convex relationship artificially. Therefore, to limit the impact on the performance-size relationship, a small cutoff point might be preferred.

Table A1

This table shows the regression results using generated data. The dependent variable is fund performance, and independent variable is natural log of lagged fund assets. Fund returns are drawn randomly from a normal distribution, $N(\mu,\sigma^2)$. We assume that investors chase performance, and thus generate capital flows using the following algorithm: $flow_{i,t} = 1 - \exp(-r_{i,t-1})\ if\ r_{i,t-1} \geq 0$; $flow_{i,t} = -1 + \exp(r_{i,t-1})\ if\ r_{i,t-1} < 0$. Starting fund assets are randomly generated between $1 million and $50 million. With generated data, we calculate fund monthly assets as $Fund\ Assets_{i,t} = Fund\ Assets_{i,t-1} \times (1 + r_{i.t} + flow_{i,t})$. In Panel A, we assume capital flows happen every month. In Panel B, we take share restrictions into consideration and assume capital flows happen every quarter for half of the funds.

Panel A. Monthly Flow

Cutoff Point	No Cutoff Point		$1 million		$5 million		$10 million		$20 million	
	Estimate	Std Err	Estimate	Std Err	Estimate	Std Err	Estimate	Std Err	Estimate	Std Err
Intercept	1.7090	1.6260	3.7828**	1.6719	11.7375***	2.3116	21.7485***	2.9732	43.5685***	4.0230
Log Lagged Assets	-0.1155	0.1827	-0.3338*	0.1876	-1.1818***	0.2546	-2.2241***	0.3229	-4.4593***	0.4297
Square of Log Lagged Assets	0.0029	0.0051	0.0086	0.0053	0.0311***	0.0070	0.0581***	0.0087	0.1152***	0.0114

Panel B. Quarterly Flow

Cutoff Point	No Cutoff Point		$1 million		$5 million		$10 million		$20 million	
	Estimate	Std Err	Estimate	Std Err	Estimate	Std Err	Estimate	Std Err	Estimate	Std Err
Intercept	0.3231	2.2007	5.4937**	2.2955	16.1902***	3.2245	31.7528***	4.1649	56.5656***	5.7341
Log Lagged Assets	0.0534	0.2494	-0.4887*	0.2595	-1.6419***	0.3581	-3.2884***	0.4563	-5.8433***	0.6176
Square of Log Lagged Assets	-0.0023	0.0071	0.0119	0.0073	0.0429***	0.0099	0.0862***	0.0125	0.1518***	0.0166

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level

Appendix B

The attrition rates of hedge funds in different size groups may be significantly different. One concern is that smaller funds are more likely to drop out of the sample, and thus only remain in the sample for a short period of time. This may bias the relationship between fund performance and fund size, and this problem is not fixed by including the data of defunct funds.

In this section, we examine the attrition rates of funds with assets under management below $50 million. Every quarter, we divide funds into different size groups using the following break up points: $1 million, $5 million, $10 million and $20 million. Then we calculate the quarterly attrition rates for each group across time using the following equation.

$$Attrion\ Rate_t = \frac{Number\ of\ Funds\ Liquidated\ in\ time\ t}{Number\ of\ Funds\ at\ the\ beginning\ of\ time\ t}$$

The summary statistics and results of t-test comparing attrition rates of different size groups are presented in Table A2. From the first four columns, we can see that attrition rates of funds smaller than $5 million are much higher. However, simply excluding observations with assets below $5 million may not fully mitigate the problem. Therefore, we further require each fund to have at least one year of data. The last four columns of Table A2 show that the attrition rates of the three size groups between $5 million and $50 million become smaller, and there is no significant difference between them.

Table A2

This table shows that summary statistics of quarterly attrition rates of different size groups, and the results of t-test between different groups. Every quarter we divide funds smaller than $50 million into groups using the following break up points: $1 million, $5 million, $10 million and $20 million. Then we calculate quarterly attrition rate for each group as $Attrion\ Rate_t = Number\ of\ Funds\ Liquidated\ in\ time\ t / Number\ of\ Funds\ at\ the\ beginning\ of\ time\ t$. In column IV and VIII, we compare attrition rates between different size groups.

	No Restriction				At Least 1 Year Data			
	I	II	III	IV	V	VI	VII	VIII
	Mean	Median	Std	Diff	Mean	Median	Std	Diff
Fund Size < $ 1 million	13.20%	12.50%	11.59%	3.51%	8.46%	4.55%	10.50%	1.75%
$1 million <= Fund Size < $5 million	9.69%	10.36%	4.56%	3.93%**	6.71%	6.50%	4.37%	2.58%***
$5 million <= Fund Size < $10 million	5.76%	5.27%	4.97%	0.73%	4.13%	3.43%	4.30%	0.95%
$10 million <= Fund Size < $20 million	5.03%	5.56%	3.28%	1.23%**	3.17%	2.60%	2.80%	0.60%
$20 million <= Fund Size < $50 million	3.80%	4.15%	2.69%		2.57%	2.45%	2.27%	

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level

Figure 1 Relationship between Fund Performance and Fund Size

Every quarter, we rank funds into 5 groups based on their lagged fund assets. Then we calculate the average of style-adjusted returns, fund ages and lagged fund assets for each group over time. From the graph, we can see that there is a convex relationship between fund performance and fund size when funds are relatively small and a concave relationship when funds grow large.

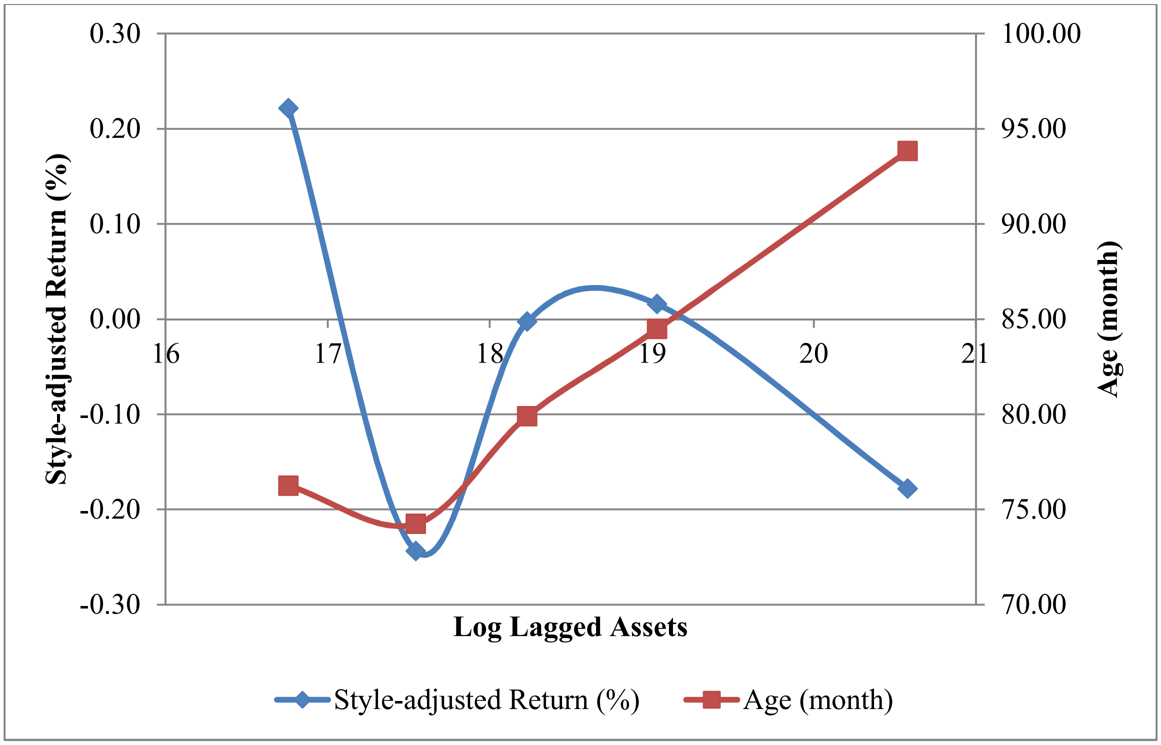

Figure 2 Managers' Compensation

Every year, we rank funds into five groups based on their lagged fund assets. Then we calculate the average of managers' compensation for each group over time. This figure compares the compensation-size relationship with the performance-size relationship as in Figure 1. From the graph, we can see that managers' total compensation increases monotonically as fund assets grow, even when diseconomies of scale exist.

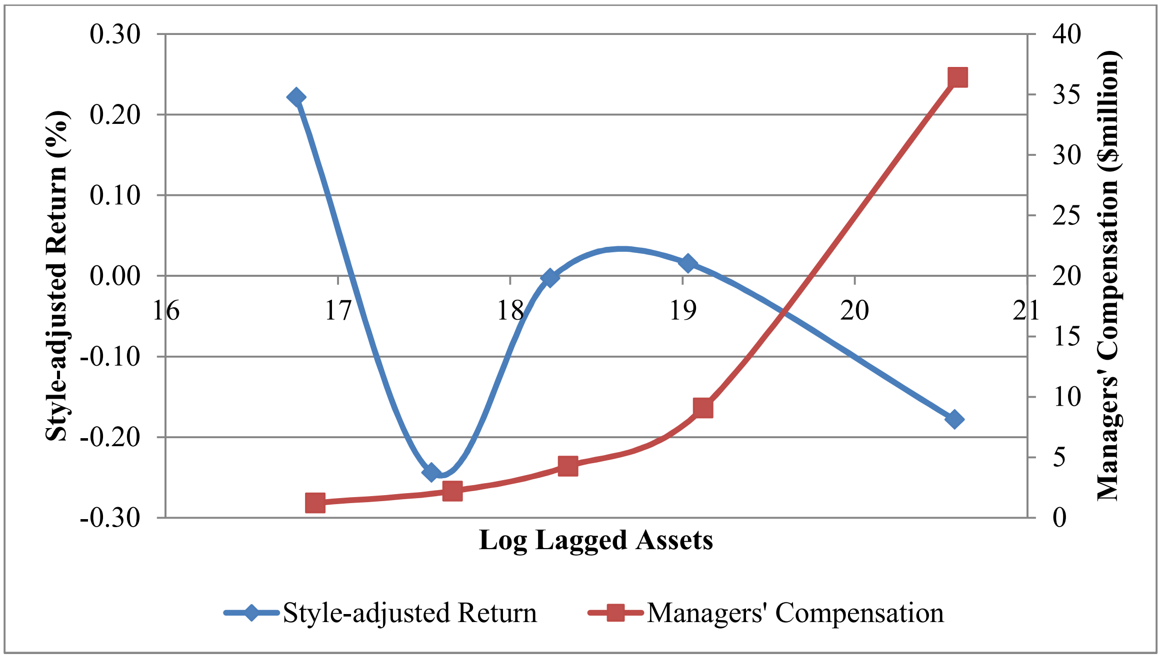

Figure 3 the Management Fee Ratio

Every year, we rank funds into five groups based on their lagged fund assets. Then we calculate a ratio=management fee/total compensation for each size group. This ratio reflects the importance of the management fee to hedge fund managers. The graph shows that the ratio declines first but increases sharply when funds grow large. This indicates that the management fee becomes the more important part of managers' total compensation.

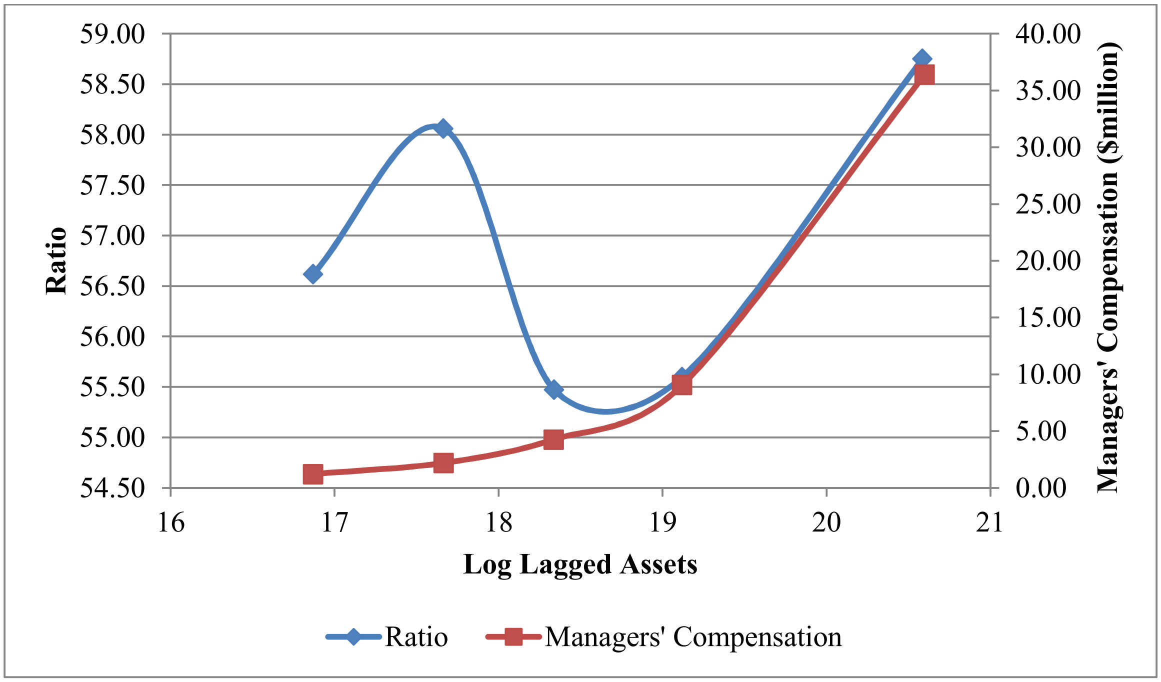

Table 1 Summary Statistics

Panel A shows the summary statistics of the whole sample. The rate of return is the raw net-of-fee return. Incentive fee is the percentage of fund profits that investors pay to the fund manager. Management fee is the percentage of fund assets that investors pay to the fund manager. High-water mark equals one if the high-water mark provision is used by a fund, and zero otherwise. Open to public equals one if the funds are open to the public and zero otherwise. Leverage equals one when leverage is used by the fund and zero otherwise. Panel B shows the number of funds in total and for each style. The percentage is the number of funds in each style divided by the total number of funds.

Panel A. Summary Statistics

	Mean	Median	Min	Max	Std	Mode
Rate of Return (%)	1.9758	1.8776	-33.1698	42.1142	8.6620	
Fund Assets	242,992,048	79,395,000	10,000,000	13,000,000,000	564,492,483	
Capital Flows (%)	0.8684	-0.0272	-61.6394	125.5980	20.2653	
Minimum Investment	1,037,903	500,000	-	50,000,000	2,266,440	1,000,000
Incentive Fee (%)	18.9836	20	0	50	4.7485	20
Management Fee (%)	1.4542	1.5	0	7	0.5833	1
High-Water Mark	0.7335	1	0	1	0.4422	1
Redemption Frequency (days)	77.9824	30	1	1080	90.6838	30
Subscription Frequency (days)	36.0432	30	1	360	26.6252	30
Redemption Notice Period (days)	38.3324	30	0	365	28.6542	30
Lock-Up Period (months)	4.1217	0	0	90	7.0608	0
Open To Public	0.1588	0	0	1	0.3656	0
Leverage	0.6492	1	0	1	0.4773	1

Panel B. Number of Funds

	Defunct	Live	Total	Percentage
Convertible Arbitrage	89	34	123	4.80%
Emerging Markets	108	169	277	10.81%
Equity Market Neutral	119	53	172	6.71%
Event Driven	208	116	324	12.64%
Fixed Income Arbitrage	86	28	114	4.45%
Global Macro	89	60	149	5.81%
Long/Short Equity Hedge	588	437	1025	39.99%
Managed Futures	76	136	212	8.27%
Multi-Strategy	81	86	167	6.52%
	1444	1119	2563	100.00%

Table 2 Performance-Size Relationship

This table shows the results of the pooled regression between fund performance and fund size. The dependent variable is style-adjusted returns, which are the differences between fund monthly returns and the average return of all funds in the same style category. Following Petersen (2009), we use the clustering method to adjust standard errors of the coefficients. The standard errors are clustered by fund. The fund family assets are the total assets under management of all other funds in the same fund family. Model I tests for cubic relationship, Model II tests for quadratic relationship, and Model III tests for linear relationship. In all the regressions, style category dummies and year dummies are included but not reported for simplicity.

	I		II		III	
Parameter	Estimate	Std Err	Estimate	Std Err	Estimate	Std Err
Intercept	329.0242***	83.6415	5.6319	7.1870	0.1910	0.7743
Log Lagged Assets	-52.3735***	13.3506	-0.6851	0.7639	-0.1011***	0.0347
Square of Log Lagged Assets	2.7572***	0.7081	0.0157	0.0203		
Cubic of Log Lagged Assets	-0.0483***	0.0125				
Log Lagged Family Assets	-0.0088*	0.0046	-0.0084*	0.0046	-0.0085*	0.0046
Lagged Capital Flows	0.0015	0.0019	0.0013	0.0019	0.0012	0.0019
Incentive Fee	0.0066	0.0102	0.0065	0.0103	0.0061	0.0102
Management Fee	0.3076***	0.1048	0.2980***	0.1070	0.2995***	0.1063
High-water Mark	0.0047	0.1118	0.0057	0.1123	0.0031	0.1121
Log Minimum Investment	0.0654	0.0410	0.0602	0.0411	0.0624	0.0410
Redemption Frequency	0.0010**	0.0005	0.0010**	0.0005	0.0010**	0.0005
Subscription Frequency	-0.0013	0.0013	-0.0015	0.0013	-0.0015	0.0013
Lockup Periods	0.0110	0.0071	0.0103	0.0070	0.0103	0.0070
Redemption Notice Periods	0.0044**	0.0018	0.0045**	0.0018	0.0045**	0.0018
Lagged Fund Age	0.0012	0.0009	0.0011	0.0009	0.0012	0.0009
Open to Public	-0.1328	0.1267	-0.1427	0.1263	-0.1392	0.1264
Leverage	0.1576	0.0966	0.1627*	0.0966	0.1636*	0.0965

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level

Table 3 Polynomial Regression for Each Style

The table shows the results of the pooled regressions for each style category. The dependent variable is style-adjusted returns. Control variables included in the regressions (but not reported for simplicity) are incentive fee, management fee, high-water mark provision dummy, redemption frequency, subscription frequency, redemption notice period, lockup period, lag of fund age, lag of capital flow, open to public dummy, leverage dummy, style dummy and year dummy. The standard errors of the coefficients are clustered by fund and are reported in parentheses.

	Convertible Arbitrage			Emerging Markets			Equity Market Neutral		
Intercept	-199.8935	-1.1891	0.0753	1274.7143***	89.8555**	10.2921***	-10.7919	-0.9730	-3.7828
	(234.6573)	(31.5811)	(3.5801)	(445.4898)	(38.7765)	(3.4824)	(218.6961)	(20.9225)	(2.9411)
Log Lagged Assets	31.7587	0.0746	-0.0601	-200.1144***	-9.1212**	-0.5379***	1.3199	-0.2726	0.0360
	(36.6477)	(3.2245)	(0.1298)	(71.4293)	(4.1536)	0.1775)	(35.2584)	(2.2555)	(0.1050)
Square of Log Lagged Assets	-1.6765	-0.0036		10.4572***	0.2312**		-0.0774	0.0084	
	(1.9001)	(0.0851)		(3.8055)	(0.1109)		(1.8949)	(0.0608)	
Cubic of Log Lagged Assets	0.0293			-0.1819***			0.0015		
	(0.0327)			(0.0674)			(0.0338)		

	Event Driven			Fixed Income Arbitrage			Global Macro		
Intercept	206.3394	7.4761	-4.1030	273.3396	5.0443	-0.7170	804.1910*	-24.8698	-0.3438
	(164.6054)	(14.3383)	(1.3014)	(525.0651)	(33.1428)	(3.4692)	(436.8914)	(36.8693)	(3.2434)
Log Lagged Assets	-32.7565	-1.2021	0.0183	-43.7808	-0.7682	-0.1535	-129.5518*	2.4033	-0.2098
	(25.9170)	(1.4854)	(0.0648)	(84.6083)	(3.5147)	(0.1301)	(69.7906)	(3.9019)	(0.1468)
Square of Log Lagged Assets	1.6931	0.0324		2.3060	0.0164		6.8976*	-0.0692	
	(1.3562)	(0.0388)		(4.5225)	(0.0932)		(3.7025)	(0.1037)	
Cubic of Log Lagged Assets	-0.0290			-0.0405			-0.1221*		
	(0.0236)			(0.0804)			(0.0653)		

	Long/Short Equity Hedge			Managed Futures			Multi-Strategy		
Intercept	331.0199**	0.8601	0.9195	285.4944	3.1230	1.5421	110.0423	-24.6802	0.2866
	(142.0163)	(11.7363)	(1.3594)	(256.2848)	(21.5513)	(2.3478)	(212.4727)	(22.6310)	(2.4110)
Log Lagged Assets	-53.2975**	-0.0556	-0.0621	-45.4425	-0.5866	-0.4184***	-18.8571	2.4176	-0.2536*
	(22.6760)	(1.2605)	(0.0571)	(40.5836)	(2.3057)	(0.1144)	(33.0089)	(2.3858)	(0.1381)
Square of Log Lagged Assets	2.8506**	-0.0002		2.3684	0.0045		1.0445	-0.0708	
	(1.2024)	(0.0339)		(2.1337)	(0.0618)		(1.7028)	(0.0624)	
Cubic of Log Lagged Assets	-0.0507**			-0.0413			-0.0194		
	(0.0212)			(0.0372)			(0.0292)		

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level

Table 4 Compensation-Size Relationship

This table shows the results of pooled regressions for the compensation-size relationship. Panel A shows the results for the whole industry. The dependent variables are the total fee and the incentive fee charged by the fund manager. The total fee, the incentive fee, fund assets and fund family assets are in million dollars. In all regressions, year dummies and style dummies are included but not reported. Panel B shows the results for each style. The dependent variable is managers' total compensation and control variables are the same as in Panel A (not reported for simplicity). The standard errors of the coefficients are clustered by fund and are reported in parentheses.

Panel A.

	Total Fee ($ million)		Incentive Fee ($ million)	
	I	II	III	IV
Intercept	-17.4080***	-17.4014***	-6.1522**	-6.1764**
	(5.3487)	(5.2982)	(2.6381)	(2.5841)
Lagged Fund Assets ($ million)	0.0384***	0.0382***	0.0196***	0.0204***
	(0.0058)	(0.0042)	(0.0054)	(0.0036)
Square of Lagged Fund Assets	0.0000		0.0000	
	(0.0000)		(0.0000)	
Incentive Fee (%)	0.5341***	0.5335***	0.4849***	0.4872***
	(0.0917)	(0.0896)	(0.0779)	(0.0789)
Management Fee (%)	5.8233**	5.8283**	-0.4425	-0.4608
	(2.4739)	(2.5033)	(0.8838)	(0.9125)
High-water Mark	-3.7960***	-3.7919***	-3.2738***	-3.2890***
	(1.0907)	(1.0769)	(0.9897)	(0.9697)
Minimum Investment	0.4537	0.4569	0.5910	0.5793
	(0.6253)	(0.6078)	(0.4248)	(0.4240)
Fund Family Assets ($million)	0.0003	0.0004	0.0007	0.0007
	(0.0007)	(0.0007)	(0.0006)	(0.0006)
Redemption Frequency	0.0065*	0.0066*	0.0061*	0.0061*
	(0.0036)	(0.0037)	(0.0031)	(0.0033)
Subscription Frequency	-0.0310*	-0.0310*	-0.0157	-0.0158
	(0.0181)	(0.0182)	(0.0099)	(0.0100)
Lock-up Period	0.0719	0.0717	0.0631	0.0638
	(0.0513)	(0.0521)	(0.0448)	(0.0467)
Redemption Notice Period	0.0294	0.0295	0.0271	0.0268
	(0.0252)	(0.0254)	(0.0240)	(0.0239)
Fund Age	0.0021	0.0022	-0.0035	-0.0039
	(0.0079)	(0.0086)	(0.0063)	(0.0063)
Open to Public	1.2952	1.2958	0.3583	0.3563
	(1.0270)	(1.0265)	(0.7444)	(0.7394)
Leverage	0.2714	0.2768	0.4548	0.4352
	(0.6325)	(0.6730)	(0.5686)	(0.6188)

Panel B.

	Convertible Arbitrage		Emerging Markets		Equity Market Neutral	
Intercept	2.9351	1.8583	-2.4384	-2.9089	-4.3735***	-3.6657***
	(9.9996)	(9.3064)	(4.3165)	(4.2360)	(1.4455)	(1.3761)
Lagged Fund Assets ($ million)	0.0573***	0.0599***	0.0586***	0.0449***	0.0253***	0.0177***
	(0.0133)	(0.0048)	(0.0138)	(0.0074)	(0.0025)	(0.0009)
Square of Lagged Fund Assets	5.90E-07		-7.29E-06		-4.17E-06***	
	(0.0000)		(0.0000)		(0.0000)	

	Event Driven		Fixed Income Arbitrage		Global Macro	
Intercept	-14.1812**	-11.1468	-4.4694	-1.5928	-10.6258	-21.5685*
	(6.5578)	(7.7798)	(8.2558)	(8.0817)	(8.7964)	(11.0481)
Lagged Fund Assets ($ million)	0.0328***	0.0484***	0.0494***	0.0270***	0.0172	0.0476***
	(0.0041)	(0.0045)	(0.0064)	(0.0048)	(0.0113)	(0.0109)
Square of Lagged Fund Assets	2.11E-06***		-1.58E-05**		1.09E-05**	
	(0.0000)		(0.0000)		(0.0000)	

	Long/Short Equity Hedge		Managed Futures		Multi-Strategy	
Intercept	-7.4347***	-8.7750***	-23.0949***	-23.0326***	-2.3060	-3.5547
	(2.2325)	(2.8367)	(8.1905)	(8.6064)	(5.3353)	(5.6516)
Lagged Fund Assets ($ million)	0.0502***	0.0260***	0.0716***	0.0420***	0.0349***	0.0250***
	(0.0049)	(0.0034)	(0.0124)	(0.0100)	(0.0126)	(0.0011)
Square of Lagged Fund Assets	-6.62E-06***		-6.02E-06***		-1.27E-06	
	(0.0000)		(0.0000)		(0.0000)	

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level

Table 5 Summary of Different Fund Sizes

This table summarizes different fund sizes. Column 2 shows the performance-size relationship. Column 3 exhibits the optimal size in terms of fund performance. We use our regression results in Table 3 to calculate the optimal size for each style. We take the first-order derivative and solve for the local maximum. For funds with negative linear relationship between fund performance and fund size, we use "↓" to indicate that smaller funds have better performance. Column 4 shows the performance-size relationship, while Column 5 exhibits the optimal size for managers' compensation. For funds show significant concave relationship, we use the regression results from Table 4 and solve for the maximum. For funds with significant linear relationship between managers' compensation and fund size, we use "↑" to indicate that fund managers prefer more assets under management. The standard deviations of the two optimal sizes are reported in parentheses.[29] The last four columns provide summary statistics of fund assets for each style.

	Performance-size Relationship	Optimal Size for Performance	Compensation-size Relationship	Optimal Size for Compensation	Q1	Median	Q3	Max
Emerging Markets	Cubic	103,160,000 (38,258,000)	Positive Linear	↑	31,300,000	68,400,000	187,532,921	3,424,890,975
Global Macro	Cubic	58,042,000 (20,571,000)	Positive Linear	↑	39,956,996	112,317,516	465,000,000	7,239,000,000
Long/Short Equity Hedge	Cubic	55,205,000 (16,598,000)	Concave	3,792,100,000 (368,360,000)	29,802,260	67,000,000	166,553,883	7,387,486,137
Managed Futures	Negative Linear	↓	Concave	5,949,300,000 (1,034,500,000)	27,000,000	65,700,000	210,600,000	10,085,464,742
Multi-Strategy	Negative Linear	↓	Positive Linear	↑	41,700,000	116,565,347	334,769,459	9,887,465,687

[29] We use delta methods to estimate the standard deviation of the two optimal sizes.

Table 6 Flow-Performance Relationship

This table shows the results of the pooled regression for the flow-performance relationship. The dependent variable is quarterly capital flows. The standard errors of the coefficients are clustered by fund. Style category dummies and year dummies are included but not reported. Panel A shows the regression results for the whole hedge fund industry. Panel B shows the results of the piecewise regression for the flow-performance relationship. Following Sirri and Tufano (1998), we rank fund monthly performance from 0 to 1 and divide them into five groups. The bottom quintile is defined as Performance Rank 1 = min (0.2, performance rank), and the 2nd quintile is defined as Performance Rank 2 = min (0.2, performance rank – rank1), and so on.

Panel A.

	Estimate	Std Err	Estimate	Std Err
Intercept	12.6531***	1.8863	7.5209***	1.9707
Fund Performance, t-1	0.3383***	0.0183	0.3004***	0.0187
Fund Performance, t-2			0.2048***	0.0162
Fund Performance, t-3			0.1364***	0.0154
Std Dev of Lagged Fund Performance	-0.2872***	0.0376	-0.1667***	0.0275
Lagged flow	0.3019***	0.0091	0.2637***	0.0096
Log of Lagged Fund Assets	-1.2478***	0.0879	-0.9209***	0.0897
Incentive Fee (%)	0.0270	0.0249	0.0122	0.0264
Management Fee (%)	0.6648***	0.2050	0.3434	0.2178
High-water Mark	1.0073***	0.2634	0.8466***	0.2709
Log of Minimum Investment	0.4710***	0.1011	0.4766***	0.1069
Redemption Frequency	0.0009	0.0011	0.0016	0.0011
Subscription Frequency	-0.0059	0.0037	-0.0014	0.0034
Lockup Periods	0.0078	0.0140	0.0070	0.0149
Redemption Notice Periods	0.0103**	0.0048	0.0086*	0.0051
Open to Public	0.5800*	0.3205	0.5179	0.3343
Leverage	0.3631	0.2407	0.4895*	0.2521

Panel B.

	Estimate	Std Err	Estimate	Std Err
Intercept	7.3470***	1.8594	-1.4106	2.0516
Fund Performance, t-1				
Performance Rank 1	16.1474***	3.2433	11.9367***	3.4221
Performance Rank 2	12.0311***	2.4435	12.8922***	2.5477
Performance Rank 3	6.4311***	2.3680	3.0960	2.4357
Performance Rank 4	12.2689***	2.5132	10.7991***	2.5554
Performance Rank 5	13.5327***	3.4049	12.5908***	3.6857
Fund Performance, t-2				
Performance Rank 1			8.3471**	3.5026
Performance Rank 2			8.4007***	2.6187
Performance Rank 3			6.3388***	2.3835
Performance Rank 4			5.2120**	2.4909
Performance Rank 5			4.7829	3.3245
Fund Performance, t-3				
Performance Rank 1			1.7972	3.5218
Performance Rank 2			5.8755**	2.5402
Performance Rank 3			2.7097	2.4031
Performance Rank 4			3.4483	2.4378
Performance Rank 5			8.3779***	3.0462
Std Dev of Lagged Fund Performance	-0.2574***	0.0379	-0.1163***	0.0374
Lagged flow	0.2972***	0.0091	0.2484***	0.0095
Log of Lagged Fund Assets	-1.2948***	0.0862	-1.0247***	0.0892
Incentive Fee (%)	0.0372	0.0248	0.0324	0.0272
Management Fee (%)	0.5948***	0.2036	0.2159	0.2195
High-water Mark	0.9877***	0.2568	0.8344***	0.2673
Log of Minimum Investment	0.4553***	0.0997	0.4478***	0.1065
Redemption Frequency	0.0003	0.0011	0.0006	0.0010
Subscription Frequency	-0.0059	0.0037	-0.0015	0.0035
Lockup Periods	0.0046	0.0138	0.0025	0.0152
Redemption Notice Periods	0.0083*	0.0048	0.0044	0.0052
Open to Public	0.5965*	0.3165	0.5441	0.3373
Leverage	0.3702	0.2341	0.5063**	0.2478

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level

Table 7 Funds' Closure/Reopening Decisions

We rank funds within the same style category into percentiles based on their performance and their assets under management every quarter. Panel A shows the average percentile ranking of fund performance/fund assets in the quarter of closure/reopening. In Panel B, we first calculate the average percentile ranking in the one year time period after the closure/reopening for each individual fund. Then we calculate the summary statistics of the average ranking for each style category. In both panels, we compare the average percentile ranking of fund performance and fund size to the 50 percentile using a t-test.

Panel A. Percentile Ranking in the Quarter of Closure/Reopening

	Closure Quarter						Reopening Quarter					
	Performance Rank			Size Rank			Performance Rank			Size Rank		
	Mean	Median	Std Dev	Mean	Median	Std Dev	Mean	Median	Std Dev	Mean	Median	Std Dev
Emerging Markets	56.39	53.66	31.68	61.39	70.84	33.32	27.33*	18.53	28.08	44.85	46.61	29.33
Global Macro	75.01***	77.36	18.24	78.13***	76.60	16.05	58.29	63.04	31.70	72.80*	90.38	33.84
Long/Short Equity Hedge	52.05	62.53	32.21	72.20***	78.04	22.89	60.48*	61.63	23.21	55.83	60.66	29.57
Managed Futures	59.08	63.10	19.38	63.96	75.95	30.62	68.67	63.22	13.38	85.05***	85.05	5.75
Multi-Strategy	29.47	29.47	7.28	65.70	65.70	5.00	54.57	54.57	49.62	83.77	83.77	22.96

Panel B. Average Percentile Ranking One Year after Closure/Reopening

	One Year after Closure						One Year after Reopening					
	Performance Rank			Size Rank			Performance Rank			Size Rank		
	Mean	Median	Std Dev	Mean	Median	Std Dev	Mean	Median	Std Dev	Mean	Median	Std Dev
Emerging Markets	49.91	46.16	20.08	60.93	65.71	32.45	46.85	41.87	15.05	46.75	56.55	29.13
Global Macro	57.17	62.12	17.00	79.20****	76.78	13.85	59.86*	55.90	14.30	82.37***	91.34	21.32
Long/Short Equity Hedge	46.43	45.03	13.98	74.80***	78.99	20.92	62.47**	60.29	16.98	60.23	54.66	26.09
Managed Futures	48.31	50.23	11.78	63.67	77.70	30.15	53.82	58.39	10.76	70.13	84.70	34.25
Multi-Strategy	46.93	46.93	23.20	69.91	69.91	7.76	49.53	49.53	3.58	80.15	80.15	28.08

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level

Table 8 Robustness Test: Different Measures and Cutoff Points

This table shows the results of performance-size relationship using different performance measures and different cutoff points of fund size. Panel A shows the results using different performance measures. Raw return is the net-of-fee return reported by hedge funds. Risk-adjusted return is calculated from Fung and Hsieh's (2004) seven-factor model. We use rolling window to estimate factor loadings. We also calculate an alternative style-adjusted return using asset-based average as the benchmark. Standard errors are clustered by fund and are reported in parentheses. Panel B and C summarizes the performance-size relationship using different performance measures and cutoff points for the hedge fund industry and different investment styles respectively.

Panel A. Polynomial Regression: Different Performance Measures

	Raw Return			Risk-adjusted Return			Style-adjusted Return (asset-based)		
	I	II	III	IV	V	VI	VII	VIII	IX
Intercept	374.3217***	18.8067**	5.7770***	49.1036	-24.5388**	1.6910	328.7172***	10.0675	1.0929
	(88.2506)	(7.7341)	(0.8332)	(116.5648)	(10.3758)	(1.0708)	(82.0613)	(7.1512)	(0.7888)
Log Lagged Assets	-58.3907***	-1.5681*	-0.1697***	-8.9774	2.7154**	-0.0708	-52.0056***	-1.0751	-0.1119***
	(14.0493)	(0.8200)	(0.0374)	(18.3848)	(1.0963)	(0.0512)	(13.0683)	(0.7581)	(0.0351)
Square of Log Lagged Assets	3.0514***	0.0375*		0.5421	-0.0740**		2.7272***	0.0258	
	(0.7430)	(0.0218)		(0.9632)	(0.0288)		(0.6915)	(0.0202)	
Cubic of Log Lagged Assets	-0.0531***			-0.0108			-0.0476***		
	(0.0131)			(0.0168)			(0.0122)		
Log Lagged Family Assets	-0.0096*	-0.0092*	-0.0095*	-0.0113*	-0.0112*	-0.0102	-0.0094**	-0.0090*	-0.0092**
	(0.0050)	(0.0050)	(0.0050)	(0.0067)	(0.0067)	(0.0066)	(0.0046)	(0.0046)	(0.0046)
Lagged Capital Flows	-0.0025	-0.0028	-0.0030	-0.0112***	-0.0112***	-0.0108***	0.0013	0.0011	0.0009
	(0.0021)	(0.0021)	(0.0021)	(0.0032)	(0.0032)	(0.0032)	(0.0019)	(0.0019)	(0.0019)
Incentive Fee	0.0078	0.0077	0.0068	-0.0347**	-0.0347**	-0.0331**	0.0040	0.0039	0.0033
	(0.0119)	(0.0120)	(0.0119)	(0.0155)	(0.0155)	(0.0155)	(0.0106)	(0.0106)	(0.0106)
Management Fee	0.3626***	0.3521***	0.3557***	0.1021	0.0983	0.0860	0.3047***	0.2952***	0.2977***
	(0.1129)	(0.1153)	(0.1136)	(0.1358)	(0.1358)	(0.1388)	(0.1076)	(0.1099)	(0.1087)
High-water Mark	0.1265	0.1276	0.1215	-0.0176	-0.0183	0.0018	0.0212	0.0221	0.0179
	(0.1190)	(0.1198)	(0.1191)	(0.1519)	(0.1521)	(0.1534)	(0.1130)	(0.1135)	(0.1131)

Log Minimum Investment	0.0635	0.0577	0.0630	0.1882***	0.1869***	0.1757***	0.0634	0.0582	0.0619
	(0.0441)	(0.0442)	(0.0441)	(0.0552)	(0.0551)	(0.0552)	(0.0418)	(0.0420)	(0.0419)
Redemption Frequency	0.0012**	0.0013**	0.0013**	-0.0003	-0.0003	-0.0002	0.0011**	0.0012**	0.0011**
	(0.0005)	(0.0005)	(0.0005)	(0.0006)	(0.0006)	(0.0006)	(0.0005)	(0.0005)	(0.0005)
Subscription Frequency	-0.0015	-0.0018	-0.0018	0.0004	0.0004	0.0003	-0.0013	-0.0016	-0.0015
	(0.0014)	(0.0013)	(0.0013)	(0.0016)	(0.0016)	(0.0016)	(0.0013)	(0.0014)	(0.0013)
Lockup Periods	0.0071	0.0062	0.0063	0.0129	0.0127	0.0122	0.0112	0.0104	0.0104
	(0.0073)	(0.0072)	(0.0072)	(0.0087)	(0.0087)	(0.0086)	(0.0072)	(0.0071)	(0.0071)
Redemption Notice Periods	0.0048**	0.0049**	0.0049**	0.0064**	0.0065**	0.0063**	0.0042**	0.0043**	0.0043**
	(0.0019)	(0.0019)	(0.0019)	(0.0025)	(0.0025)	(0.0025)	(0.0018)	(0.0018)	(0.0018)
Lagged Fund Age	0.0019*	0.0018*	0.0019*	0.0001	0.0001	-0.0002	0.0009	0.0008	0.0008
	(0.0010)	(0.0010)	(0.0010)	(0.0013)	(0.0013)	(0.0013)	(0.0010)	(0.0010)	(0.0010)
Open to Public	-0.0720	-0.0829	-0.0743	0.0155	0.0129	-0.0141	-0.1416	-0.1514	-0.1455
	(0.1342)	(0.1341)	(0.1344)	(0.1820)	(0.1821)	(0.1810)	(0.1280)	(0.1278)	(0.1279)
Leverage	0.0970	0.1026	0.1047	0.2253*	0.2272*	0.2217*	0.1489	0.1539	0.1553
	(0.1026)	(0.1027)	(0.1026)	(0.1320)	(0.1323)	(0.1322)	(0.0970)	(0.0970)	(0.0970)

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level

Panel B.

	5 million	10 million	20 million	50 million
Style-adjusted Return (Equally-weighted)	Cubic	Cubic	Cubic	Negative Linear
Style-adjusted Return (Asset-weighted)	Cubic	Cubic	Cubic	Negative Linear
Raw Returns	Cubic	Cubic	Cubic	Cubic
Risk-adjusted Returns	Cubic	Concave	Concave	Negative Linear

Panel C.

		5 million	10 million	20 million	50 million
Emerging Markets	Style-adjusted Return (Equally-weighted)	Negative Linear	Cubic	Cubic	Negative Linear
	Style-adjusted Return (Asset-weighted)	Negative Linear	Cubic	Cubic	Negative Linear
	Raw Return		Cubic	Cubic	Negative Linear
	Risk-adjusted Return				
Global Macro	Style-adjusted Return (Equally-weighted)	Cubic	Cubic	Concave	
	Style-adjusted Return (Asset-weighted)	Cubic	Cubic	Concave	
	Raw Return	Cubic	Cubic	Concave	Negative Linear
	Risk-adjusted Return	Concave	Concave	Concave	Negative Linear
Long/Short Equity Hedge	Style-adjusted Return (Equally-weighted)	Cubic	Cubic	Cubic	Negative Linear
	Style-adjusted Return (Asset-weighted)	Cubic	Cubic	Cubic	Negative Linear
	Raw Return	Cubic	Cubic	Cubic	Negative Linear
	Risk-adjusted Return	Cubic	Concave	Concave	Negative Linear
Managed Futures	Style-adjusted Return (Equally-weighted)	Negative Linear	Negative Linear	Negative Linear	Negative Linear
	Style-adjusted Return (Asset-weighted)	Negative Linear	Negative Linear	Negative Linear	Negative Linear
	Raw Return	Negative Linear	Negative Linear	Negative Linear	Negative Linear
	Risk-adjusted Return	Negative Linear	Negative Linear		Negative Linear
Multi-Strategy	Style-adjusted Return (Equally-weighted)	Cubic	Negative Linear	Negative Linear	
	Style-adjusted Return (Asset-weighted)	Cubic			
	Raw Return	Cubic	Concave	Negative Linear	Negative Linear
	Risk-adjusted Return	Concave	Concave	Negative Linear	Concave

Table 9 Robustness Test: Sub-periods

This table shows the performance-size relationship for different sub-periods. Following the literature, we pick three events as the break points: the bankruptcy of LTCM in September 1998; the peak of the tech bubble in March 2000; and the beginning of the subprime crisis in June 2007 (the bankruptcy of two hedge funds of Bear Stearns). Sub-period between October 1998 and March 2000 is too short and the regression may not have enough power. Therefore, we skip this sub-period in our robustness test.

		5 million	10 million	20 million	50 million
Sub-period 1 Jan 1994 ~ Sep 1998[30]	Style-adjusted Return (Equally-weighted)		Convex		
	Style-adjusted Return (Asset-weighted)		Convex		
	Raw Return	Convex		Cubic	
	Risk-adjusted Return				
Sub-period 3 Apr 2000 ~ May 2007	Style-adjusted Return (Equally-weighted)	Cubic	Cubic	Cubic	Negative Linear
	Style-adjusted Return (Asset-weighted)	Cubic	Cubic	Cubic	Negative Linear
	Raw Return	Cubic	Cubic	Cubic	Negative Linear
	Risk-adjusted Return	Cubic	Concave	Concave	
Sub-period 4 Jun 2007 ~ Dec 2009	Style-adjusted Return (Equally-weighted)	Cubic	Cubic	Negative Linear	Negative Linear
	Style-adjusted Return (Asset-weighted)	Cubic	Cubic	Negative Linear	Negative Linear
	Raw Return	Cubic	Cubic	Cubic	Negative Linear
	Risk-adjusted Return	Negative Linear	Negative Linear	Negative Linear	Negative Linear

[30] The starting date for risk-adjusted returns is January 1997, since we use a three-year rolling window to estimate the alpha.

Table 10 Piecewise Regression

This table shows the results of the piecewise regression. The dependent variable is style-adjusted returns. We rank funds from 0 to 1 based on their lagged fund assets and divide funds into five groups. The bottom quintile is defined as Size Rank1 = min (0.2, size rank), and the 2nd quintile is defined as Size Rank2 = min (0.2, size rank – rank1), and so on. We also put the middle three quintiles together and define Size Rank 2~4 as min (0.6, size rank – rank1). Panel A presents the results for the hedge fund industry. In both regressions, style category dummies and year dummies are included but not reported for simplicity. Panel B shows the results for each style category. In all the regressions, control variables and year dummies are included but not reported for simplicity.

Panel A.

Parameter	Estimate	Std Err	Estimate	Std Err
Intercept	-0.8368	0.6145	-0.8429	0.6140
Size Rank 1	-5.4906***	1.2799	-5.4645***	1.1172
Size Rank 2	0.4803	0.9793		
Size Rank 3	1.1202	0.9866		
Size Rank 4	-0.0505	0.9417		
Size Rank 2~4			0.6063**	0.2637
Size Rank 5	-2.4139**	1.0829	-2.8451***	0.9466
Log Lagged Family Assets	-0.0090*	0.0046	-0.0091**	0.0046
Lagged Capital Flows	0.0016	0.0019	0.0016	0.0019
Incentive Fee	0.0062	0.0102	0.0061	0.0102
Management Fee	0.3070***	0.1058	0.3074***	0.1058
High-water Mark	0.0083	0.1113	0.0081	0.1114
Log Minimum Investment	0.0651	0.0408	0.0653	0.0408
Redemption Frequency	0.0010**	0.0005	0.0010**	0.0005
Subscription Frequency	-0.0014	0.0013	-0.0014	0.0013
Lockup Periods	0.0105	0.0070	0.0105	0.0071
Redemption Notice Periods	0.0043**	0.0018	0.0043*	0.0018
Lagged Fund Age	0.0011	0.0009	0.0011	0.0009
Open to Public	-0.1384	0.1259	-0.1390	0.1260
Leverage	0.1539	0.0962	0.1536	0.0962

Panel B.

	Convertible Arbitrage		Emerging Markets		Equity Market Neutral	
Size Rank 1	4.8312	4.0753	-15.0761***	-17.8086***	-1.2099	0.0924
	(3.8667)	(3.7780)	(5.4519)	(4.7018)	(3.0603)	(2.5231)
Size Rank 2	-2.1495		-4.2549		1.8378	
	(2.8814)		(4.2851)		(2.1884)	
Size Rank 3	-0.1336		4.0003		-0.9172	
	(2.7295)		(4.4283)		(2.1197)	
Size Rank 4	-1.2830		-1.5599		-0.4402	
	(2.6669)		(4.0985)		(2.1853)	
Size Rank 2~4		-1.0197		0.0938		0.0104
		(0.8174)		(1.1964)		(0.7457)
Size Rank 5	1.2372	1.2431	-5.3538	-5.8103	1.9355	1.2187
	(4.0145)	(3.5231)	(5.1557)	(4.6572)	(3.3598)	(3.0245)

	Event Driven		Fixed Income Arbitrage		Global Macro	
Size Rank 1	-4.3018	-4.3768	0.4363	-2.1591	-13.9444**	-12.1439**
	(3.0040)	(2.7266)	(4.8209)	(4.3827)	(6.5765)	(5.6542)
Size Rank 2	0.3296		-4.0625		5.1752	
	(1.9155)		(3.4750)		(4.7856)	
Size Rank 3	2.4723		3.1657		-0.4353	
	(1.8828)		(3.6241)		(4.4279)	
Size Rank 4	-0.9742		-1.3574		3.5344	
	(1.8374)		(3.9957)		(4.4316)	
Size Rank 2~4		0.8771		-0.1265		2.2913*
		(0.5020)		(1.1807)		(1.3169)
Size Rank 5	0.1710	-1.0354	-3.1361	-3.2448	-15.4584**	-15.0717***
	(2.2359)	(1.8893)	(5.6416)	(4.4894)	(6.2164)	(5.6448)

	Long/Short Equity Hedge		Managed Futures		Multi-Strategy	
Size Rank 1	-4.2972**	-4.7365***	-5.4997	-5.6016	-1.8090	-1.7300
	(2.1155)	(1.8140)	(5.5570)	(4.5210)	(4.2061)	(3.8990)
Size Rank 2	-0.1975		-1.3307		-0.0088	
	(1.6741)		(4.6581)		(3.5376)	
Size Rank 3	2.4306		0.1721		0.0486	
	(1.5764)		(4.4223)		(2.6875)	
Size Rank 4	-0.6584		-2.0844		-0.3034	
	(1.5971)		(3.1728)		(3.7652)	
Size Rank 2~4		0.8052*		-0.8919		-0.0641
		(0.4238)		(1.0160)		(0.9655)
Size Rank 5	-2.2167	-3.0479*	-5.5919	-6.3670*	-7.7408*	-7.9134**
	(1.8900)	(1.6049)	(4.0995)	(3.8079)	(4.5038)	(3.9945)

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level