Original Article

The relation between hedge fund size and risk

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ABSTRACT **In their quest for safety, investors have been willing to forego the higher returns that could be achieved with investing in smaller hedge funds for the perceived greater safety of larger funds. Thus, hedge fund investors have flocked to larger hedge funds in the past, and are currently doing so to an even greater extent. This article provides evidence suggesting that large funds may actually be riskier than smaller funds. Specifically, we find that the largest hedge funds are more likely than smaller hedge funds to either cease operations or restrict investor liquidity. Therefore, we believe that investors' current focus on larger hedge funds may be misplaced, and that institutional investors who focus on larger hedge funds may not see the expected portfolio benefits of uncorrelated, absolute returns and a reduction in overall volatility.**

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INTRODUCTION

Existing research provides conflicting opinions regarding the expected change in performance (for example, absolute returns, alpha and Sharpe ratio) as hedge fund size increases. Ammen and Moerth, 2005, 2008) find that performance decreases as hedge fund size increases; Edwards and Caglayan (Edwards and Caglayan, 2001), among others, come to the opposite conclusion; and Gregoriou and Rouah (Gregoriou and

Rouah, 2003), among others, find no relationship between hedge fund performance and fund size. With respect to risk, prior studies are in agreement that risk decreases for large funds, as measured by their lower standard deviations. In this article, we reconcile the various results about the relationship between fund size and performance, and describe a specific risk that *increases* as funds grow very large.

A fundamental risk of investing in hedge funds is that the investment terms are significantly altered, which may include suspension of redemptions or a fund entering into a liquidation process. We will refer to any significant adverse change in investment terms as a fund *closing*. Returns dramatically decline in the 12 months before a fund's closing (Grecu *et al.*, 2006). In addition, because of lock-ups and other restrictions on withdrawals, investors must face delays in recovering their investment. In all likelihood, the liquidation process will generate additional losses to those incurred in the 12 months before closing. Therefore, we focus on the risk that the fund closes. We introduce a model of hedge fund closing, and show that a fund's probability of closing is a function of several factors that we formally define below, including its (i) relative size, (ii) absolute size, (iii) ability to generate alpha, (iv) relationship with equity and hedge fund indices, (v) ability to exploit market volatility, (vi) returns volatility, and (vii) capital raising activities. We find that subsequent to achieving optimal assets under management (AUM), a further increase in AUM increases the probability of closing.

Studying the impact of hedge fund size is complex from both methodological and analytical perspectives. Most alternative investment firms offer related investment vehicles, such as onshore and offshore pairs, leverage options, and different currencies. Despite being subject to a single investment strategy, the related vehicles may have different start dates and varying amounts of AUM. To the extent that investors have a preference for larger funds and that larger funds have different risk and return characteristics compared to smaller funds, the relevant size is the total amount of capital the manager employs in the strategy, rather than the amount of capital in a particular vehicle. Therefore, we aggregate all of a managers' related vehicles into a single composite fund, with the start date being the earliest date for which returns data exist, and the end date being the latest such date. We believe this to be an improvement over the prior studies examining the impact of hedge fund size.

From an analytical perspective, the impact of fund size is difficult to detect because the initial effects of a large increase may be different from the longer-term effects. Specifically, while increased AUM increases a fund's longer-term closing risk, we show that there is a positive correlation between the amount of capital that a fund has raised and contemporaneous returns, and this relationship is actually stronger for larger funds than for smaller funds. Thus, the ultimate negative consequences of raising too much capital are masked in the short term by the temporary performance boost. A plausible explanation of the dynamics between fund-raising, performance and closing risk is as follows. First, the fund generates good returns, which leads to significant fund-raising. Subsequently, the fund generates positive returns while growing its positions by deploying the new capital, because this raises the valuations of the existing positions. A 'resonance' occurs: the strong returns lead to the raising of more capital, which leads to even stronger returns.

Eventually, the cycle ends as new capital is not enough to generate performance, returns moderate and investors recognize that the good run may be over (Ammen and Moerth, 2008).[1] At this point, the fund's assets are overvalued and it has more AUM than it is capable of effectively managing. When this happens, the fund may take excessive risk in an attempt to maintain returns or face disappointed investors and mounting redemptions.

Hedge funds generally do not enjoy the advantages of large investment banks such as permanent investor capital, a sizeable reserve for use during periods when the fund is below its high water mark, the ability to raise additional equity by selling shares at a discount, the ability to tap various lines of credit, or a management succession plan. Thus, there are a number of contingencies that can trigger investor concern about a very large fund, and the resulting redemptions and reduction in AUM may leave the fund unable to support its infrastructure and investment team. In addition, as a large fund's position sizes tend to also be very large, the unwinding of these positions may cause significant price declines in those positions, which may reverse the positive feedback described in the foregoing paragraph. Smaller funds, on the other hand, tend to have (i) smaller position sizes, so it is less costly for them to unwind positions, and (ii) more modest infrastructure and staffing costs, so they are better able to cope with a decline in revenues. Therefore, we believe that very large hedge funds are at greater risk of closing than smaller funds.

Ultimately, we expect that in order to both grow and survive, very large hedge funds will need to transition to either a private-equity model, where the capital is locked-up for long periods of time, or to an investment-bank model with permanent capital and access to public markets for capital. However, the current structure, in which investments are made in very large hedge funds because of the expectation of liquidity, does not appear sustainable. Eventually, fund size will hinder performance and trigger a redemption cycle that has a strong negative feedback.

Berk and Green, 2004 and Chen *et al.*, 2004 come to a similar conclusion for mutual funds; the quality managers attract more capital, which degrades future performance due to increased transaction and market friction costs. We add to the literature by showing that (i) it is hedge fund size rather than hedge fund inflows that degrades future performance, (ii) unlike mutual funds, capital inflows initially have a positive effect on hedge fund performance, and (iii) not only does performance eventually decline with an increase in size, but the probability of closing *increases* as well. Thus, investors in large hedge funds do not enjoy lower risk in exchange for lower expected returns. On the contrary, large hedge funds generate lower alpha and have a higher probability of closing. Moreover, to the extent that larger hedge funds are able to generate 'good' returns, it is likely to be through systematic exposures to equity indices rather than from alpha. This is the least desirable source of returns for hedge fund investors. The conclusion is that if investors seek liquid hedge fund investments that can reasonably be expected to meet their stated liquidity terms and generate absolute returns, they should focus on smaller funds. Unfortunately, most of the new capital currently being invested in hedge funds is being allocated to the very largest funds.

HYPOTHESES

The factors discussed below are related to a fund's likelihood of closing. For most of the factors discussed, we offer specific hypotheses about how they relate to a fund's likelihood of closing, and for the other factors, we review the conflicting arguments without offering specific hypotheses.

1. *Relative size*: The greater the size of a hedge fund relative to that of other hedge funds, the greater its ability to attract and retain skilled investment professionals, enter into favorable prime-brokerage and borrowing arrangements, and source attractively priced new and secondary issues. Therefore, the probability of closing should be negatively related to a fund's relative size.
2. *Absolute size*: Given a fund's relative size, the probability of closing should be positively related to its absolute size. As AUM grows, (i) the impact on the portfolio from individual 'great trades' is diminished, (ii) the portfolio tends to emphasize larger, more liquid investments, which typically are not as profitable as smaller, less liquid investments, (iii) the difficulty of exiting losing and/or stressed positions is increased, and (iv) regulatory scrutiny and oversight increases. Our focus on both absolute and relative measures of size may help reconcile prior contradictory results about size. If (i) relative size is a positive factor for performance, (ii) absolute size is a negative factor for performance and (iii) relative size is not controlled for, then the estimated relationship between absolute size and performance may be positive even if it is, in fact, not the case.
3. *Fund age*: There are two possible effects of a fund's age on its closing probability. On the one hand, a fund is often formed in response to a given market opportunity and to the founding Portfolio Manager (PM) 'edge' in trading the current market environment. Over time, the original market opportunity and the founding PMs' 'edge' may erode, as the market evolves and/or competitors enter the space, and the fund's ability to generate superior performance declines. Thus, the probability of closing should be positively related to a fund's age. Consistent with this argument, Frumkin and Vandergrift (Frumkin and Vandergrift, 2009) find that hedge fund performance is negatively related to the fund's age, and (Gregoriou, 2002) finds that closing rates increase for the oldest funds. On the other hand, the longer the fund has been in business, the better its investing reputation may be, the more patient investors might be in dealing with a period of weak performance, and the greater the opportunity the fund might have to recover from such a period. Therefore, we do not offer any hypothesis.
4. *Alpha generation*: The more a fund's returns are derived from non-systematic exposures, the greater the interest investors will have in the fund. Therefore, the probability of closing should be negatively related to a fund's alpha generation. Consistent with this hypothesis, (Grecu *et al.*, 2006) find that funds that outperform their peers have a lower probability of closing.
5. *Fund beta*: There are two arguments why funds with higher systematic exposure to equity and hedge fund indices should have lower closing risk. First, these funds should have higher returns, on average, and

therefore a greater opportunity to recover after a period of poor performance. Consistent with this argument, Frumkin and Vandergrift (Frumkin and Vandergrift, 2009) find that hedge funds' returns are positively correlated with their betas. Second, to the extent that the fund's investment strategy is understandable and the association of the fund's returns with that of recognized equity and hedge fund indices is high, investors might be more forgiving of poor performance. For example, consider a long-biased fund that specializes in value stocks and whose returns are highly correlated with equity markets. If large losses in the fund occur concurrently with large losses in equity markets, investors may not be as quick to redeem. Arguments why funds with higher systematic exposures should have higher closing risk are that the higher a fund's systematic index exposure, (i) the greater its likelihood of incurring the type of considerable drawdown that leads to significant investor redemptions, and (ii) the more its systematic returns will dominate its alpha returns, the higher the fees investors effectively pay for the alpha returns, and the less favorably investors will view the fund. We do not offer any hypothesis about the relationship between a fund's beta and its probability of closing, although we include fund beta as a control variable in our model of hedge fund closing.

6. *Volatility of returns*: There are conflicting arguments regarding the effect of volatility of returns on the probability of closing. On the one hand, the higher a fund's volatility, the greater its likelihood of incurring a large drawdown. On the other hand, if a fund's strategy is known to produce volatile returns, investors will likely be more accepting of a period of poor performance. We include returns volatility as a control variable but do not offer a hypothesis about the relationship between a fund's returns volatility and its probability of closing.
7. *Short-biased*: Short-biased funds are often judged by different criteria than are other funds, because their role is to reduce portfolio volatility rather than to generate returns. Connolly and Hutchinson (Connolly and Hutchinson, 2010) note that short-biased hedge funds have positive skew, which can help offset the negative skew common to many hedge funds. As a result, a returns profile that would be unacceptable to investors if it were in a typical fund might be acceptable for a short-biased fund. For example, a short-biased fund with a low to even negative Sharpe ratio may still add value to a hedge fund portfolio. Therefore, the probability of closing should be lower for short-biased funds.
8. *Fund-raising*: A greater ability to raise capital may allow a fund to more easily replace capital lost through redemptions and market losses. Having stable or growing capital enables a fund to hire and retain key personnel, acquire and maintain infrastructure, diversify business lines and strategies, and continue purchasing and supporting investments it already owns. Therefore, we expect prior fund-raising to be negatively related to the probability of closing.
9. *Ability to exploit market volatility*: The ability to exploit volatility is a determinant of a hedge fund's success. There are two distinct strategies by which funds can do so: sell overpriced volatility and buy cheap volatility.

Market participants are often willing to pay excessive premiums to hedge risk, as is typically reflected in the volatility-smile. As a result, hedge funds can potentially earn positive expected returns by selling over-valued volatility to risk-averse investors and assuming a short volatility profile. This positioning would be consistent with Agarwal and Naik's (Agarwal and Naik, 2000) finding that hedge fund returns exhibit a short options profile, and with Goetzmann *et al*'s (Goetzmann *et al.*, 2003) finding that managers can maximize their funds' Sharpe ratio with a short options profile. Moreover, as shown by (Fung and Hsieh, 2004), Gupta *et al* (Gupta *et al.*, 2008), and Ammen and Moerth, 2008, hedge fund returns can be modeled by several factors, including a short straddle position.[2] Likewise, a strategy of gaining market exposure through undervalued option-like positions is very appealing for its asymmetric risk-reward profile. Therefore, the greater the extent to which a fund can exploit market volatility with either a long or short volatility profile, the lower its probability of closing.

DATA AND SAMPLE

We use the Hedgefund.net databases of live and dead funds (funds that have ceased reporting), which contain returns data for 7 545 live and 8 916 dead funds, respectively, from 1995 through May 2010. Grecu *et al* (Grecu *et al.*, 2006) present results strongly implying that funds stop reporting returns because of performance reasons rather than because of a diminished need to continue marketing activities. Our analysis of the dead fund database suggests that on the date they stopped reporting returns, many of the dead funds began liquidating, adversely changed the fund's stated liquidity terms, or created large side-pockets. Accordingly, we define a fund as having closed if it is in the dead fund database. The definition of closing and the closing date is applied to the composite fund: the fund is not considered to have closed as long as one of a manager's related vehicles continues to report returns.

We eliminate fund-of-funds (to avoid double-counting) and funds with no data for AUM.[3] These two requirements reduce our sample-size to 4 551 live funds and 6 129 dead funds, with a total of 266 885 and 250 338 monthly observations, respectively.[4] We consolidate all vehicles managed by a manager in a single strategy into a single composite fund, with the start (end) date being the earliest (latest) date for which returns data exist for a particular strategy. This reduces the number of monthly observations for the live and dead funds to 191 399 and 169 815 respectively, as 28 per cent of monthly observations are eliminated through the process of fund consolidation. When we refer to a 'fund', we refer to the consolidated fund that we create from similar vehicles operated by the manager.

Figures 1–4 provide returns data for funds that stop reporting and Figures 5–8 provide fund-raising data for funds that stop reporting. Because the data occur over a 15-year period, which include both strong and weak equity markets and fund-raising environments, we provide results both absolutely and relative to a hedge fund index. We construct the figures as follows. First, we eliminate data from the funds' first 12 months of existence. The rationale is that institutional investors are typically not attracted to funds with very short histories, and funds that close within their first 12 months of existence

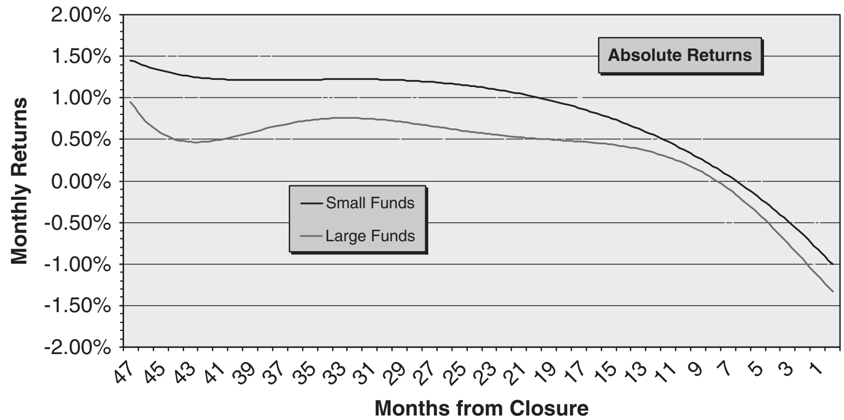

Figure 1: The figure shows the average absolute monthly performance of Large Funds (funds which ranked in the 75th percentile or higher in assets under management at the time of closure) and Small Funds (funds which ranked in the 25th percentile or lower of assets under management at the time of closing) for the 48 months before closing.

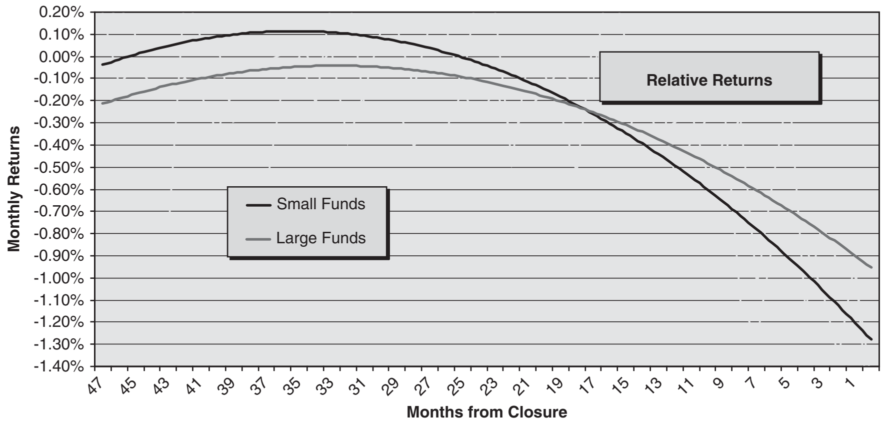

Figure 2: The figure shows the average relative monthly performance of Large and Small funds for the 48 months before closing.

were never really 'open'. Second, we define a fund as being small if its AUM was below the 25th percentile for AUM in month minus 48 relative to the closing month, and we define a fund as being large if its AUM was above the 75th percentile for AUM in month minus 48 relative to the closing month. If the fund does not have 48 months of data, then we define it as being small or large based on AUM in its first available month of data. Third, for each month, we construct Small and Large Hedge Fund samples, consisting of all funds whose AUM was below the 25th percentile and above the 75th percentile, respectively, for that month. The relative return for a Small (Large) hedge fund is defined as that fund's return minus the average return for the Small (Large) Hedge Fund sample, and the relative fund-raising for a Small (Large)

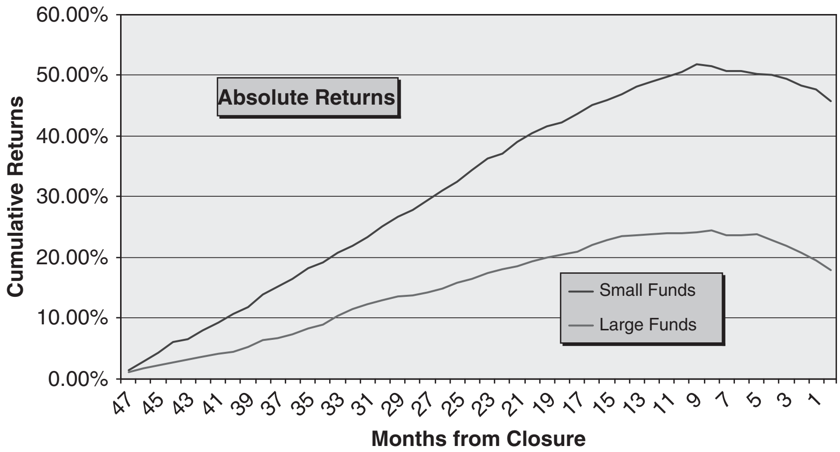

Figure 3: The figure shows the average cumulative absolute return of Large and Small funds during the 48 months before closing.

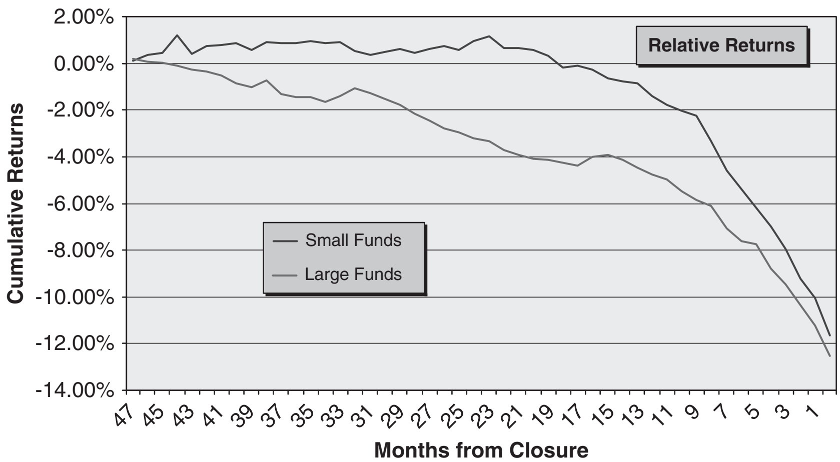

Figure 4: The figure shows the average cumulative relative return of Large and Small funds during the 48 months before closing.

hedge fund is defined as that fund's fund-raising minus the average fund-raising for the Small (Large) Hedge Fund sample.

Because we rank hedge funds by size every month and hedge funds have grown over time, there is a wide historical distribution of values that represent Small and Large Hedge Funds. Across the sample history for the 75th percentile of AUM, the median AUM value is \$142 million and the highest value is \$262 million. Likewise, across the sample history for the 25th percentile of AUM, the median value is \$9.5 million and the highest value is \$17.9 million. The median AUM value for the 90th percentile of AUM is \$434 million, implying that the database does contain a number of investable funds, although most hedge funds are relatively small and only a small percentage are 'investable' to large institutions.

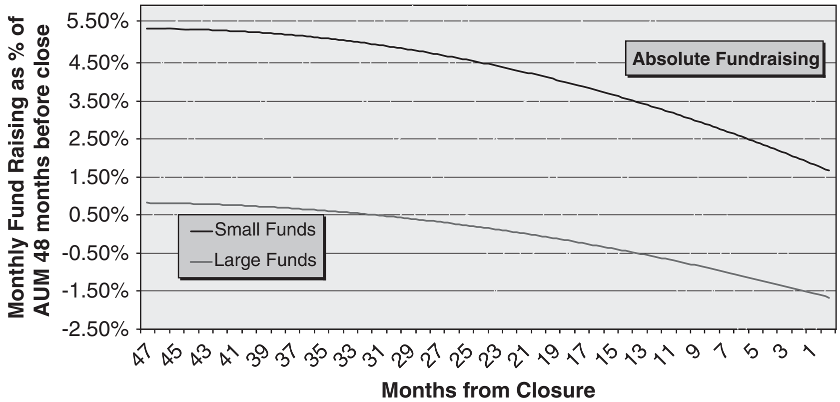

Figure 5: The figure shows the average monthly absolute fund-raising, for Large and Small funds, as a percentage of AUM 48 months before closing.

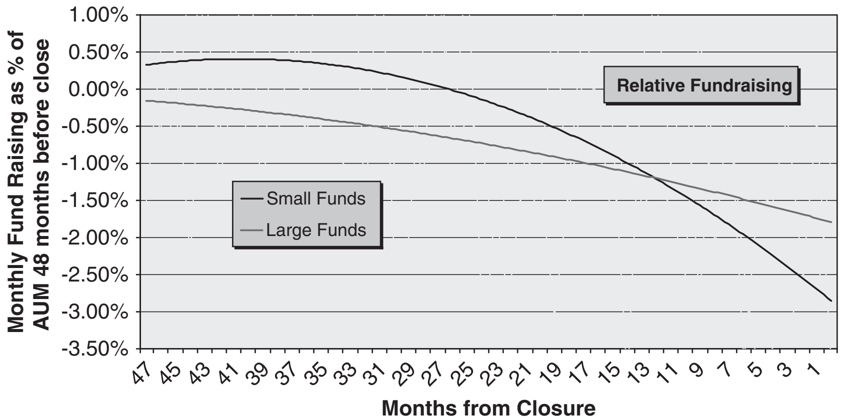

Figure 6: The figure shows the average monthly fund-raising of Large and Small funds, relative to their peers as measured 48 months before closing.

Figure 1 shows that in the months before closing, *absolute* monthly returns are greater for small funds than for large funds. Figure 2 shows that in the months before closing, *relative* monthly returns are initially greater for small funds than for large funds, but that pattern reverses near closing. Figure 3 shows that for small funds, cumulative absolute returns are strong through month minus 12 – with a roughly 50 per cent cumulative return from month minus 48 through month minus 12, while for large funds there is only a roughly 23 per cent cumulative return from month minus 48 through month minus 12. Moreover, this difference in cumulative absolute returns persists until the date of closing. Figure 4 shows that cumulative *relative* returns are initially higher for smaller funds than for larger funds, but the two returns converge by the time of closing.

Figure 5 shows that in the months before closing, smaller funds raise much more new capital, as a percentage of their beginning capital,

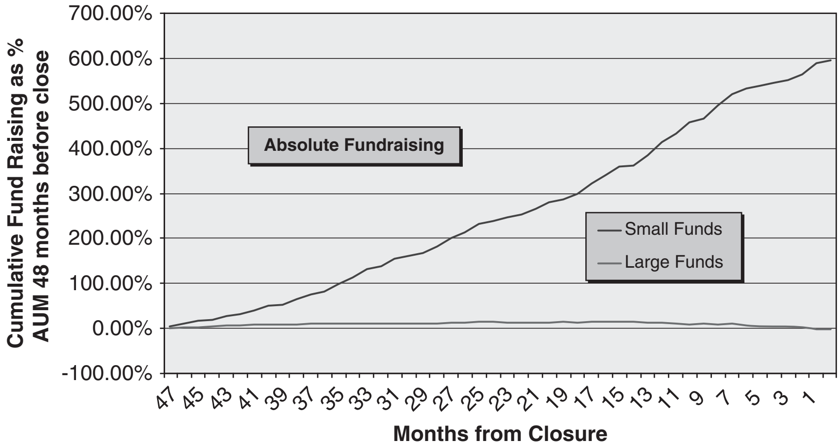

Figure 7: The figure shows the average cumulative absolute fund-raising of Large and Small funds as a percentage of AUM measured 48 months before closing.

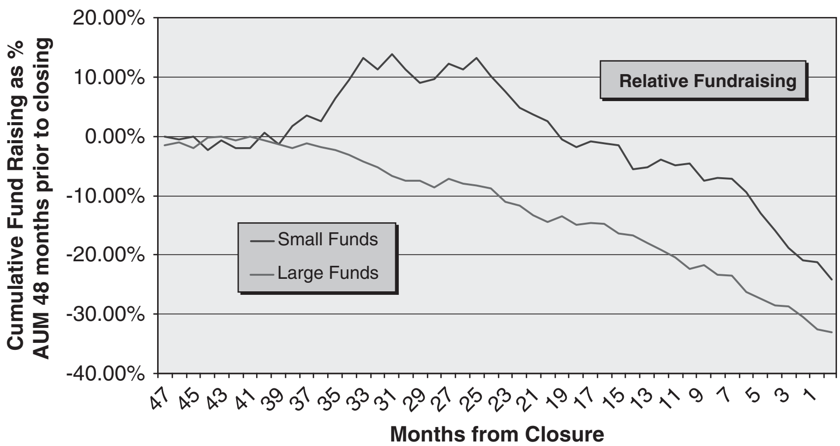

Figure 8: The figure shows the average cumulative fund-raising of Large and Small funds relative to their AUM measured 48 months before closing.

than do larger funds. Figure 6 shows that in the months before closing, *relative* monthly fund-raising is initially greater for small funds than for large funds, but that pattern reverses near closing. Figure 7 shows that for small funds, the cumulative amount of capital raised from month 48 before closing until closing averages about 5 × the fund's initial capital, while for large funds that amount averages less than 0.5× the fund's initial capital. Figure 8 shows that the higher cumulative relative fund-raising for small funds persists through the time of closing.

Notable observations from the pattern leading up to small funds' closing are (i) the rather abrupt nature of the performance decline – absolute performance only weakens about 12–18 months before the fund's closing, and that (ii) absolute fund-raising continues to be positive up until closing. Because of the speed with which weaker performance leads to closing for smaller funds, smaller funds may face a 'no-win' situation with respect to risk-raking. On the one hand, they need to take risk so that they can generate the types of returns that will attract investors to the fund. On the other hand, they cannot afford to take risk, because a bad risk-taking outcome may lead investors to quickly redeem before the fund can recover and demonstrate its investing skill. Therefore, closing rates are much higher in a fund's earlier years Grecu *et al.*, 2006. Notable observations from the pattern leading up to large funds' closing are (i) the prolonged period of weak performance – large fund's underperform their peer group for more than 3 years before closing and (ii) absolute fund-raising turns negative around 18 months before closing.

There are several inferences we draw from the comparison of larger and smaller hedge funds that close. First, it would appear that larger funds have the ability to sustain poor performance before closing for a longer period of time than do smaller funds. Our rationale includes: (i) larger funds may have stricter redemption terms, so their process of closing is more prolonged, (ii) the investor base in larger funds may be more institutional and employ more formal decision-making processes, and they may evaluate hedge fund performance less frequently and based on longer time-series than do investors in smaller funds, (iii) from an operational, investing and behavioral point of view, larger funds may be better capitalized and organized than smaller funds, and therefore better able to withstand longer periods of weak performance, and (iv) larger funds may have a longer track-record of strong performance and a more developed reputation as being savvy investors, and investors are therefore more patient with them. Second, it would appear that for larger funds, the decline in fund-raising *precedes* the decline in performance, while for smaller funds, the decline in fund-raising *follows* the decline in performance. This emphasizes the importance of fund-raising to the continued success of larger hedge funds. Third, judging by performance in the periods before closing, the costs of closing appear to be greater for larger funds than for smaller funds. A possible explanation is that liquidation costs are greater for larger funds, because of their larger average position sizes. Finally, the fact that performance deteriorates sharply in the months before closing is consistent with Grecu *et al*'s (Grecu *et al.*, 2006) conclusion that funds stop reporting returns because of performance reasons rather than because of a diminished need to continue reporting returns.

VARIABLE DEFINITIONS

1. *Relative size*: At each month end, we calculate the percentile rank of a fund's AUM against the entire hedge fund universe. We denote this measure of relative size as AUM_Rank.
2. *Absolute size*: Absolute size is defined as the log of the composite AUM, and denoted by LAUM. LAUM is calculated every month for every fund.
3. *Age*: A fund's age is defined as the log of the number of months for which returns have already been reported to the database, and denoted by LAGE. LAGE is calculated every month for every fund.
4. *Hedge fund returns model*. We define the following variables:
   - H_t is the weighted average (by AUM) of month t's hedge fund returns,

- F_t is the composite fund return for month t,
- S_t is the S&P500 return for month t,
- R_t is the risk-free rate for month t (the three-month T-bill rate).

  We estimate Models (1) and (2) for every fund and every month, using 36 months of data:

$$\ln(1 + F_t - R_t) = A_{s1} + b_{1,S} * \ln(1 + S_t - R_t) + b_{2,S} * \ln(1 + S_{t-1} - R_{t-1})$$

$$\ln(1 + F_t - R_t) = A_h + b_{1,h} * \ln(1 + H_t - R_t)$$

  We include the lag term on the S&P500 index in Model (1) due to possible smoothing of returns on the part of the fund's managers and to the lag with which illiquid securities adjust to index moves (Asness *et al.*, 2001; Lo, 2001; Getmansky *et al.*, 2004).

5. *Fund beta*: Fund beta is defined using Models (1) and (2). Beta to the S&P500 is defined as $b_{1,S} + b_{2,S}$, and beta to the hedge fund index is defined as $b_{1,h}$. Betas are calculated every month for every fund.
6. *Volatility of returns*: Volatility of a fund's returns is defined as the standard deviation of H, over the prior 36 months, and is denoted by V_H. V_H is calculated every month for every fund.
7. *Fund-raising*: We define a fund's fund-raising (FR) for a given month t as: $FR_t = \mathrm{LN}\ \{1 + \mathrm{AUM}_t/\mathrm{AUM}_{t-1} - F_t/0.8\}$ FR_{36} is the average value for FR_t over the prior 36 months. It is calculated every month for every fund. The implicit assumptions in the definition of FR are that (i) all incentive fees earned by the fund's managers are reinvested in the fund, and (ii) the incentive fee is 20 per cent.[5]
8. *Short-biased*: We define a hedge fund as being short-biased if $b_{1,S} + b_{2,S} < -0.1$. The reason we use -0.1 rather than -0 in the definition is to reduce the number of funds spuriously defined as short-biased due to randomness in the estimation of $b_{1,S} + b_{2,S}$. Short_biased is calculated every month for every fund. Short_biased is a $0-1$ variable, with a value of 1 if $B_{sp500} < -0.1$ and a value of 0 otherwise. 13.6 per cent of the sample is classified as short-biased.[6]
9. *Exploitation of volatility*: We estimate Model (3) for every fund at every time t, using 36 months of data.
10.

$$\begin{aligned}\ln(1 + F_t - R_t) &= A_{s2} + b_{11,S} * \ln(1 + S_t - R_t) \\ &+ b_{21,S} * \ln(1 + S_{t-1} - R_{t-1} \\ &+ b_{31,S} * \{\ln(1 + S_t - R_t)\}^2 \\ &+ b_{41,S} * \{\ln(1 + S_{t-1} - R_{t-1})\}^2 \qquad (3)\end{aligned}$$

We define a fund as having negative convexity to the S&P500 if <u>*one*</u> of the following holds:

(A) $b_{1,S} + b_{2,S} > 0$ and $b_{11,S} + b_{21,S} > 0$ and $b_{31,S} + b_{41,S} < 0$
(B) $b_{1,S} + b_{2,S} < 0$ and $b_{11,S} + b_{21,S} < 0$ and $b_{31,S} + b_{41,S} < 0$

When a fund has negative convexity relative to the S&P500 that fund's exposure to equity markets decreases (increases) as the equity market rises (declines). If $b_{1,S} + b_{2,S} > 0$ and $b_{11,S} + b_{21,S} > 0$, then we are confident that the fund has positive exposure to equity markets, and if $b_{1,S} + b_{2,S} < 0$ and $b_{11,S} + b_{21,S} < 0$ then we are confident that the fund has negative exposure to equity markets. However, if $b_{1,S}+b_{2,S}$ and $b_{11,S}+b_{21,S}$ have opposite signs, we cannot determine the fund's exposure to equity markets and what its volatility profile might be.

We define Negconvexity_Prem as max $(0, A_{s2}-A_{s1})$, where A_{s2} is defined as in Model (3) and A_{s1} is defined as in Model (1). Negconvexity_Prem represents the amount of premium the fund generates by being short volatility, and we interpret $b_{31,S}+b_{41,S}$ in Model (3) as the exposure the fund accepts in exchange for the premium of Negconvexity_Prem. Whether this exposure is beneficial to the fund depends on whether the premiums received are greater than the *ex-post* cost of the short volatility position.[7]

We define a fund as having positive convexity to the S&P500 if *one* of the following holds:

(A) $b_{1,S}+b_{2,S}>0$ and $b_{11,S}+b_{21,S}>0$ and $b_{31,S}+b_{41,S}>0$
(B) $b_{1,S}+b_{2,S}<0$ and $b_{11,S}+b_{21,S}<0$ and $b_{31,S}+b_{41,S}>0$

When a fund has positive convexity relative to the S&P500 that fund's exposure to the equity market increases (decreases) as the equity market rises (declines). The logic of the definition is as provided above for the definition of negative convexity. We define Posconvexity_Prem as $\mathrm{Max}(0, A_{s1}-A_{s2})$, where A_{s2} is defined as in Model (3) and A_{s1} is defined as in Model (1). Posconvexity_Prem represents the average premium the fund spends on its long volatility positions. For positively convex funds, basic computations of alpha (for example, A_{s1}) may be overstated by Posconvexity_Prem because they do not capture non-linear exposures such as volatility. ALPHA is defined as A_{s1} if the fund has negative convexity, as A_{s2} if the fund has positive convexity, and as A_{s1} if the fund has neither positive nor negative convexity.[8]

Because the estimation of Models (1) through (3) requires 36 months of data, funds that close within their first 36 months of existence are, by definition, excluded.[9] Models (1)-(3) are estimated each month of the estimation period, which starts in January 1995 and ends 36 months before the last month of data on the data set (May 2010).

Hedge fund convexity, ALPHA and systematic exposure

Convexity

Results for Models (1)–(3) are summarized as follows. More hedge funds have a negatively convex profile (52 per cent) than a positively convex profile (31 per cent).[10] For positively convex funds, the mean estimate for Posconvexity_Prem is 43 bps per month and the mean estimate for ALPHA is 14 bps per month. Thus, for funds that are long volatility, much of what appears to be alpha may be the result of long volatility positions that are not captured by simple linear models. On the other hand, for negatively convex funds, the mean estimate for Negconvexity_Prem A_{s1} is 59 bps per month and the mean estimate for ALPHA is 51 bps per month.

Fund size is not significantly related to whether the fund has a positively or negatively convex profile, but it is related to the magnitude of the fund's exposures.[11] Specifically, among the subsample of positively convex funds, $b_{31,S}+b_{41,S}$ is significantly negatively correlated with fund size – implying that larger funds are less positively convex than smaller funds, and among the subsample of negatively convex funds, $b_{31,S}+b_{41,S}$ is significantly positively correlated with fund size – implying that larger funds are less negatively convex than smaller funds. Likewise, among positively (negatively) convex funds, Posconvexity_Prem (Negconvexity_Prem) is significantly negatively correlated with fund size, implying that larger funds have less long exposure to volatility (generate less premiums from being short) than smaller funds.

To further demonstrate the relationship between the exploitation of volatility, fund size and fund-raising activities, we estimate the following multivariate models, using a pooled time-series and cross-sectional approach. Model (4) is only estimated for funds with positive convexity and Model (5) is only estimated for funds with negative convexity:

$$\begin{aligned}\text{Posconvexity\_Prem} = {} & A + b_1 * \text{AUM\_Rank} \\ & + b_2 * \text{LAUM} \\ & + b_3 * \text{FR}_{36}\end{aligned}$$

$$\begin{aligned}\text{Negconvexity\_Prem} = {} & A + b_1 * \text{AUM\_Rank} \\ & + b_2 * \text{LAUM} \\ & + b_3 * \text{FR}_{36}\end{aligned}$$

Table 1: Ability to exploit volatility and size

Variable	*Parameter*	
	Estimate	*T-Value*
Panel A – Model (4) – Dependent variable: Posconvexity_Prem n=30 714		
Intercept	0.550	81.58
AUM_Rank	0.009	19.61
LAUM	−0.192	−25.17
FR_{36}	−0.008	−17.02
Panel B – Model (5)- Dependent variable: Negconvexity_Prem n=51 745		
Intercept	0.634	87.84
AUM_Rank	0.018	35.22
LAUM	−0.307	−38.37
FR_{36}	−0.009	−16.72

Posconvexity_Prem is the average premium the fund spends on its long volatility positions; Negconvexity_Prem is the amount of premium the fund generates by being short volatility; AUM_RANK is the rank of the fund's AUM; LAUM is the natural log of the fund's AUM; FR_{36} is the average monthly amount of capital the fund raises.

The results[12] presented in Table 1 show that the estimated coefficient b_1 is significantly positive and the estimated coefficient b_2 is significantly negative for both Models (4) and (5). The implications are that while a fund's *relative size* is positively related to one's ability to exploit volatility, a fund's *absolute* size is negatively related to the exploitation of volatility. Our explanations for why volatility exploitation decreases as a fund grows are as follows. First, as a fund grows and its position sizes increase, it becomes increasingly difficult to reduce short volatility positions if and when it becomes necessary to do so (for example, in sharply declining markets). Second, volatility strategies are capacity constrained, and as a fund grows, its ability to buy cheap volatility and sell expensive volatility declines. The negative coefficient for b_3 in both Models (4) and (5) implies that the greater the amount of new capital that a fund has raised in a given time period, the lower its exposure to volatility during that time period, consistent with the notion that volatility strategies are capacity constrained. In summary, the results presented above show that one's ability to exploit volatility is a major source of hedge fund returns, and that ability to exploit volatility decreases as a fund's AUM grows.

ALPHA generation

The average ALPHA across the positively and negatively convex funds is approximately 43 bps per month (a weighted average of the average monthly ALPHA of 14 bps for positively convex funds and 51 bps for negatively convex funds). However, because we forecast fund closing over the 36 months following our estimation period, our estimation period ends 36 months before the end of our data set, and it omits the 2007–2008 period, which was extremely challenging for hedge funds. If we extend the estimation period through 2009, the average estimated ALPHA declines by roughly 5 bps per month, to 38 bps per month.

By definition, the data used to estimate ALPHA contain survivorship bias, because it excludes funds that closed within 36 months of opening, and it excludes funds that closed within 36 months of the estimation date.[13] Ibbotson and Chen, 2006 estimate a 6 per cent bias in reported hedge fund returns.[14] If 2/3 of the bias in reported returns is assumed to be in estimated alpha returns and 1/3 in estimated beta returns, our adjusted estimate for ALPHA is in the range of 0.5 per cent per annum (12×38 bps$-2/3 \times 6$ per cent). Thus, we conclude that over their history, hedge funds have, *in the aggregate*, produced relatively little alpha for their investors. Thus, hedge fund manager selection is even more crucial than investors already recognize, and capturing hedge fund alpha requires investors to minimize the probability of hedge fund closing.

Table 2: Systemic exposure and size

Variable	*Parameter*	
	Estimate	*T-Value*
Panel A – Model (6) – Dependent variable: B_{sp500}; n=99 242		
Intercept	0.534	111.79
AUM_Rank	−0.010	−28.56
LAUM	0.121	22.43
FR_{36}	−0.004	−11.66
Panel B – Model (7) – Dependent variable: B_{hf} ; n=99 242		
Intercept	0.945	121.99
AUM_Rank	−0.031	−52.59
LAUM	0.434	47.54
FR_{36}	−0.006	−10.56

B_{sp500} is the fund's beta to the S&P500; B_{hf} is the fund's beta to a hedge fund index; AUM_RANK is the rank of the fund's AUM; LAUM is the natural log of the fund's AUM; FR_{36} is the average monthly amount of capital the fund raises.

Systematic exposure

Models (6) and (7) examine the relationship between systematic exposure, fund size and fund-raising activities, using a pooled time-series and cross-sectional approach:

$$b_{1,S} + b_{2,S} = A + b_1 * \text{AUM\_Rank} + b_2 * \text{LAUM} + b_3 * \text{FR}_{36}$$

$$b_{1,h} = A + b_1 * \text{AUM\_Rank} + b_2 * \text{LAUM} + b_3 * \text{FR}_{36}$$

The results of Models (6) and (7), presented in Table 2, show that the estimated coefficient b_1 is significantly negative and the estimated coefficient b_2 is significantly positive for both Models (6) and (7). The implications are that while a fund's *relative size* is negatively related to its systematic exposures, a fund's *absolute* size is positively related to its systemic exposure. Our explanation for these results is as follows. At any given point in time, the largest hedge funds have an advantage in sourcing investments with idiosyncratic returns profiles. However, the larger the fund is in absolute terms, the lower the overall impact on the portfolio these idiosyncratic investments will have and the more systematic exposures the fund will need to rely on to generate its returns. The negative coefficients for b_3 in both Models (6) and (7) imply that the greater the amount of new capital that a fund has raised in a given time period, the lower its overall systematic exposures will be during that period.

Table 3: ALPHA and size

Variable	*Parameter*	
	Estimate	*T − Value*
Panel A: Model (8) - Dependent variable: ALPHA; n=99 242		
Intercept	0.585	77.65
AUM_Rank	−0.001	−1.08
LAUM	−0.049	−5.85
FR_{36}	0.008	15.42
Panel B: Model (8a) - Dependent variable: ALPHA; n=99 242		
Intercept	0.594	7778.73
AUM_Rank	−0.001	−2.06
LAUM	−0.042	−4.95
FR_{36}	−0.005	−5.07
FR_{36}★LAUM	0.004	16.21

ALPHA is the fund's average amount of alpha generation; AUM_RANK is the rank of the fund's AUM; LAUM is the natural log of the fund's AUM; FR_{36} is the average monthly amount of capital the fund raises and FR_{36}★LAUM is a multiplicative interaction term with LAUM and FR_{36}.

ALPHA and fund size

We use the following model to examine how ALPHA generation is related to a fund's size and fund-raising activities, using a pooled time-series and cross-sectional approach:

$$\text{ALPHA} = A + b_1 * \text{AUM\_Rank} + b_2 * \text{LAUM} + b_3 * FR_{36}$$

The results presented in Panel A of Table 3 show that the estimated coefficient b_1 is insignificant and the estimated coefficient b_2 is significantly negative. These results imply that while *relative size* may not be disadvantageous with respect to sourcing alpha, *absolute* size is very disadvantageous with respect to sourcing alpha. That is, even if there are scale benefits in operating hedge funds, after some optimal size is reached, size becomes a hindrance rather than an aid to alpha generation. The positive coefficient for b_3 implies that the greater the amount of new capital that a fund has raised in a given time period, the greater the amount of alpha the fund generates during that period. A possible explanation of a causal relationship between FR and ALPHA (that is, higher fund-raising leads to greater alpha generation) is that as the fund deploys its new capital, it supports the value of the securities it owns by continuing to buy those securities and/or by making capital available to the company issuing those securities.

Next, we estimate model (8a), using a pooled time-series and cross-sectional approach, to investigate whether the impact of fund-raising on alpha generation is stronger for larger funds than for smaller funds. For a given amount of FR_{36}, the dollar amount that the fund raises and is therefore available to support existing investments is an increasing function of fund size. Therefore, we expect that the contemporaneous relationship between fund-raising and ALPHA is stronger for larger funds than for smaller funds.

$$ALPHA = A + b_1 * \text{AUM\_Rank} + b_2 * \text{LAUM} + b_3 * FR_{36} + b_4 * (FR_{36} * LAUM)$$

The results presented in Panel B of Table 3 show that the estimated coefficient b_4 is significantly positive. This implies that the contemporaneous relationship between fund-raising and ALPHA generation is stronger for larger funds than for smaller funds. While it cannot be directly determined from Model (8) whether the relation between FR and ALPHA is causal or associative (that is, funds that generate greater alpha tend to raise more capital from investors), there is indirect evidence of a causal relationship. First, if the positive coefficient for b_3 in Model (8) is associative rather than causal, then b_3 should also be positive in both Models (4) and (5), because higher Posconvexity_Prem or Negconvexity_Prem typically leads to higher hedge fund returns. However, the estimates for b_3 are negative in both Models (4) and (5). This suggests the causality interpretation: a sharp increase in AUM makes it more difficult for the fund to exploit volatility but the concentrated deployment of the new capital helps generate alpha. Second, if the positive coefficient for b_3 in Model (8) is associative, rather than causal, then the contemporaneous relationship between fund-raising and ALPHA should be the same for larger and smaller funds and b_4 in Model (8a) should not be significantly greater than zero.

In summary, the results show that alpha is an important source of hedge fund returns, and that alpha decreases as AUM grows. Thus, the larger a fund's AUM, the higher its systematic exposure and the lower its alpha generation and ability to exploit volatility, and the worse it is likely to perform in a poor environment for equities and hedge funds. What appears to mislead investors into believing otherwise is that significant fund-raising by larger hedge funds leads to stronger performance in the near-term, and this performance may serve to validate the fund's claim that it can continue generating strong performance even at much higher AUM levels. However, the fund-raising effect will not persist indefinitely. Therefore, we conclude that if the mandate of investing in hedge funds is that the investment should provide absolute returns that can be sustained even in weak equity markets and when other hedge funds struggle, very large hedge funds would appear increasingly unlikely to be able to fulfill that mandate.

Fund closing model

CLOSE_{36} has a value of 1 if the fund stops reporting returns at some point over the next 36 months and a value of 0 otherwise. We estimate the following Logistic Regression (LOGIT) model, again using a pooled time-series and cross-sectional approach.[15]

$$\begin{aligned}\text{CLOSE}_{36} = a &+ b_1 * \text{AUM\_Rank} \\ &+ b_2 * \text{LAUM} + b_3 * \text{LAGE} \\ &+ b_4 * \text{ALPHA} + b_5 * \text{B}_{\text{sp500}} \\ &+ b_6 * \text{B}_\text{h} + b_7 * \text{V}_\text{h} + b_8 * \text{FR}_{36} \\ &+ b_9 * \text{Short\_biased} \\ &+ b_{10} * \text{Posconvexity\_Prem} \\ &+ b_{11} * \text{Negconvexity\_Prem}\end{aligned}$$

The odds ratio is an important concept in understanding logistic regression.[16] If an event occurs with probability P, the odd-ratio for that event is given as P/(1−P). Thus, even though the probability of an event is bounded by 0 and 1, the odds ratio can be infinitely large, and it can increase or decrease by large multiples regardless of how large or small P is. With logistic regression, the estimated coefficient for a given predictor variable is interpreted as the log of the *ratio* of odds ratios, with the denominator representing the odds ratio with no change in the predictor variable and the numerator representing the odds ratio with a one unit increase in the predictor variable. When the estimated coefficient is exponentiated, the value is interpreted as the percentage change in the odds ratio for a one unit increase in the predictor variable. For example, if the exponentiated coefficient value is 1.15, the implication is that for each 1 unit increase in the underlying variable, the odds ratio of failure increases by 15 per cent. Likewise, if the exponentiated coefficient value is 0.93, the implication is that for each 1 unit increase in the underlying variable, the odds ratio of failure decreases by 7 per cent. We will focus on the exponentiated coefficient values in the discussion below and in the presentation of Table 4, which provides results for Model (9). The percentage of concordant pairs is a relatively good 68.4 per cent.[17] Individual parameter estimates, and their economic significance, are discussed below:

1. *Relative size*: The significantly negative value for b_1 implies that the probability of closing is negatively related to a fund's relative size. An odds ratio estimate of 0.936 for b_1 implies that if the fund's percentile rank increases by 1 per cent, the odds ratio of closing decreases by 6.4 per cent.

Table 4: Model (9) odds ratio estimates

Odds ratio estimates	*Point Estimate*
Effect	
AUM_Rank	0.936
LAUM	2.21*
LAGE	0.677*
ALPHA	0.822*
B_{sp500}	0.893*
B_{hf}	0.998
V_h	0.994**
FR_{36}	0.987*
Short_biased	0.686*
Posconvexity_Prem	0.827*
Negconvexity_Prem	0.954*

*Significant at the 0.01 level.

**Significant at the 0.05 level.

AUM_RANK is the rank of the fund's AUM; LAUM is the natural log of the fund's AUM; LAGE is the natural log of the fund's age in months; ALPHA is the fund's average amount of alpha generation; B_{sp500} is the fund's beta to the S&P500; B_{hf} is the fund's beta to a hedge fund index; V_h is the volatility of the fund's returns; FR_{36} is the average monthly amount of capital the fund raises; Short-Biased is a 0-1 variable with a value of 1 if the fund is short-biased and a value of 0 otherwise; Posconvexity_Prem is the average premium the fund spends on its long volatility positions; Negconvexity_Prem is the amount of premium the fund generates by being short volatility.

2. *Absolute size*: The significantly positive value for b_2 implies that the probability of closing is positively related to a fund's absolute size. An odds ratio estimate of 2.21 for b_2 implies that if the fund's AUM doubles, the odds ratio of closing increases by roughly 84 per cent ($LN(2) \times 1.21 = 0.84$).
3. *Age*: The significant negative value for b_3 implies that a fund's age is negatively related to the probability of closing. An odds ratio estimate of 0.677 for b_3 implies that if the fund's age doubles, the odds ratio of closing decreases by roughly 22 per cent ($LN(2) \times 0.323 = 0.84$).
4. *ALPHA generation*: The significantly negative value for b_4 implies that the probability of closing is negatively related to a fund's alpha generation. An odds ratio estimate of 0.822 for b_4 implies that if alpha generation increases by 1 per cent per month, the odds ratio of closing decreases by roughly 18 per cent.
5. *Systematic exposures*: The significantly negative value for b_5 implies that the probability of closing is negatively related to a fund's beta to the S&P500. On the other hand, the fund's beta to a hedge fund index does not appear to be related to its probability of closing. An odds ratio estimate of 0.893 for b_5 implies that if beta to the S&P 500 increases by 0.1, the odds ratio of closing decreases by roughly 1 per cent (0.107×0.1). Whereas, the odds ratio estimate of 0.998 for b_6 implies that if beta to the hedge fund index increase by 0.1, the odds ratio of closing decreases by approximately 0.02 per cent (0.002×0.1)
6. *Volatility of returns*: The marginally significantly negative value for b_7 suggests that the probability of closing is negatively related to a fund's returns volatility. However, the effect of volatility on closing risk is economically trivial. An odds ratio estimate of 0.994 for b_7 implies that if monthly volatility increases by 1 per cent, the odds ratio of closing decreases by roughly 0.6 per cent.
7. *Fund-raising*: The significantly negative value for b_8 implies that the probability of closing

is negatively related to the amount of assets that the fund raised over the past period. An odds ratio estimate of 0.987 for b_8 implies that if average fund-raising increases by an amount equal to 1 per cent of capital, the odds ratio of closing decreases by roughly 1.3 per cent.

8. *Short-biased*: The significantly negative value for b_9 implies that short-biased funds have a lower probability of closing, and the odds ratio estimate of 0.686 for b_9 implies that being short-biased reduces a fund's odds ratio of closing by 31.2 per cent.
9. *Exploitation of volatility*: The significantly negative value for b_{10} implies that the probability of closing is negatively related to the alpha generated by acquiring cheap volatility. An odds ratio estimate of 0.827 for b_{10} implies that if the average premium the fund pays to be long volatility increases by 1 per cent per month, the odds ratio of closing decreases by 17.3 per cent. The significantly negative value for b_{11} implies that the probability of closing is negatively related to the alpha generated by selling overpriced volatility. An odds ratio estimate of 0.954 for b_{11} implies that if the average premium the fund receives for being short volatility increases by 1 per cent per month, the odds ratio of closing decreases by 4.6 per cent.

The results show that larger funds have factors tending to both lower and increase their closing risk. The primary factors increasing closing risk for larger funds are absolute size, lower exposure to volatility and lower alpha generation, and the primary factors reducing closing risk for larger funds are relative size, age, fund-raising and systematic exposures. Over time, absolute size will continue to grow while volatility exploitation and alpha generation will likely continue to decline, so the factors increasing closing risk are likely to strengthen for very large funds. Offsetting this, only fund age will increase; fund-raising is likely to decline and market exposure will likely level off, so in the aggregate, closing risk is likely to increase as large funds grow still larger.

Seemingly contrary to our conclusion, the probability of closing is, on average, lower for larger funds than for smaller funds, as evidenced by the negative correlation between the estimated closing probability using Model (9) and size. One explanation for this is that while AUM itself is positively related to closing risk, large funds have other factors, such as age and equity market exposure, that are negatively related to closing risk. A second explanation is that closing risk is not linear in size, and size only increases closing risk after a certain size threshold. As evidence, Figure 9, which illustrates how estimated closing probabilities vary with AUM_Rank, shows that closing probabilities are decreasing in size from the 10th percentile of AUM until roughly the 85th percentile of AUM, flat from the 85th percentile of AUM until roughly the 93rd percentile of AUM, and increasing in size from the 93rd percentile of AUM.[18]

Large funds grew large through fund-raising and good performance, and the process of fund-raising itself as well as the strong performance that led to the strong fund-raising, reduces closing risk *for the time-being*. The positive fund-raising that results from strong performance may itself help generate further strong performance, and this virtuous cycle can continue for some time. Moreover, it is rational for large hedge funds to continue growing their AUM because

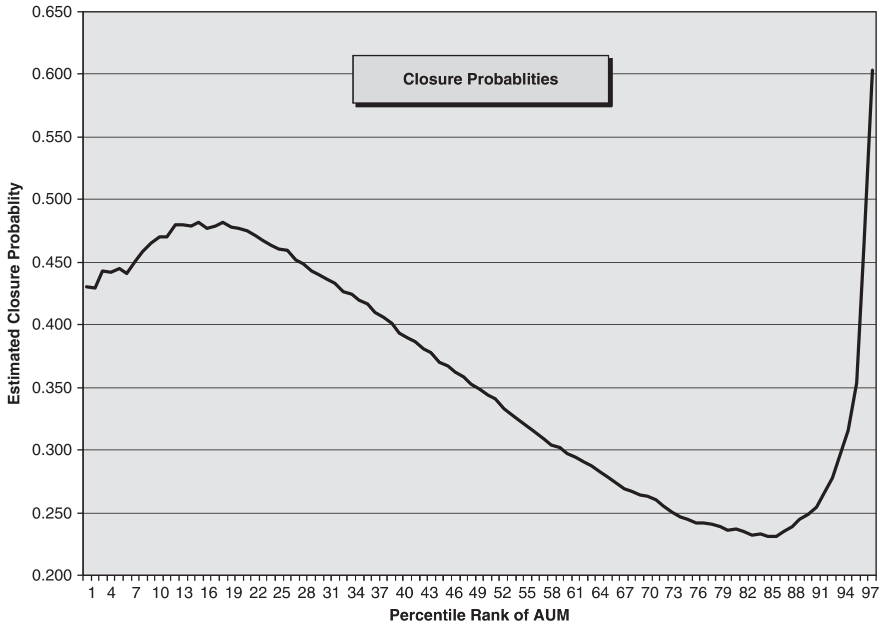

Figure 9: Estimated closing probabilities of funds according to their AUM rank within the hedge fund universe.

AUM growth helps underpin their performance. However, as alpha-generation and the ability to exploit volatility eventually begin to decline due to size and investors perceive the fund to be too large to perform strongly, funding flows may reverse, whereupon the risk of closing will increase.

This analysis also suggests why chasing returns is an ineffective strategy and hedge fund performance does not strongly persist over time (Brown *et al.*, 1999; Agarwal and Naik, 2000; Herzberg and Mozes, 2003). Managers who generate high alpha are likely to receive large capital inflows (Berk and Green, 2004). For a period of time, the inflows themselves may help support performance, as shown above in the positive relationship between alpha generation and contemporaneous fund-raising. However, as fund-raising slows and performance weakens, the negative effects of size begin to dominate – the ability to exploit volatility and generate alpha decline, fund-raising becomes negative, and so on – that is, the seeds of the future decline in performance are embedded in the current strong performance.[19]

LIMITATIONS

The following are possible limitations to our study.

1. There may be a significant number of large, successful hedge funds who *never* reported their returns to the database. Thus, by failing to consider these funds, we may be overstating the case against larger hedge funds.
2. There may be a significant number of large, successful hedge funds who stop reporting their returns to the database either because they are closed to new investors due to capacity constraints or because they no longer

wish to publicize their returns data. Thus, by treating these funds as having experienced negative closing events, we may be overstating the case against larger hedge funds. While there are surely some large funds for whom the decision to stop reporting results is not performance-related, the fact that, in the aggregate, large funds' performance before closing is so poor suggests that these types of closings are the exception rather than the rule.

3. The omission of funds that closed within 36 months of opening may make large funds appear riskier than smaller funds, because funds that close within 36 months of opening are likely smaller funds. In response, we would qualify the article's principal result as follows: among funds that have at least 36 months of history, larger funds have greater closing risk.
4. The returns of funds that report to hedgefund.net may be different from the hedge fund universe. However, the fact that our alpha estimates are consistent with those of past research suggests this is not the case.
5. It is possible that if the estimation period were extended to include the 2008–2009 period, where hedge funds' performance was very weak, results might differ from those reported above. We tested this by replacing $CLOSE_{36}$ with $CLOSE_{12}$ and $CLOSE_{24}$ in Model (9), thus extending the test period. Virtually all the results reported above for Model (9) were the same in the alternative tests, with the exception of the result for b_1 and b_{11}. In the alternative tests, the probability of closing is not significantly related to either the fund's beta to the S&P500 or to the premium generated by selling overpriced volatility. These results are intuitive, because the 2008–2009 was very costly for funds that either had a short volatility profile or a significant long exposure to equity indices.

SUMMARY AND CONCLUSION

Our basic finding is that larger hedge funds are at greater risk of closing than other funds, primarily because of the difficulty in sustaining performance after the fund grows very large and funding inflows moderate and then reverse. Unlike publicly traded investment banks, hedge funds do not generally have permanent investor capital, a sizeable reserve for use during periods when the fund is below its high-water mark, the ability to raise additional equity by selling shares at a discount, the ability to tap various credit lines available to banks, or a credible succession plan for when the managing member leaves that role. Thus, there are a number of contingencies that can trigger investor concern or dissatisfaction with a very large fund, and the resulting redemptions and reduction in AUM may leave the fund unable to support its infrastructure and investment team. In addition, as a large fund's position sizes tend to be very large, the unwinding of these positions in order to generate liquidity for redeeming investors may cause significant price declines in those positions, which may trigger further investor redemptions, which may further exacerbate the fund's liquidity problems, and so on. On the other hand, smaller funds tend to have smaller position sizes that are less costly to unwind, and they tend to have more modest infrastructure and staffing costs and are therefore better able to operationally cope with a decline in revenues.

Within the universe of large hedge funds, funds with weak AUM growth are at greatest risk, because their performance tends to be weakest. In contrast, large hedge funds experiencing AUM growth are less risky than other large funds, because their AUM growth helps underpin performance. Thus, as a normative recommendation, one need not immediately reduce exposure to the largest hedge funds when they first become very large. Rather, one can continue holding investments in these funds until their AUM growth slows.

Our analysis also suggests why chasing returns is an ineffective strategy and why hedge fund performance does not strongly persist over time. Managers who generate high alpha are likely to receive large capital inflows, which may lead to further alpha generation in the near term. However, the increased capital often leads to an eventual decrease in performance and a reversal of those capital flows.

Therefore, we conclude that if investors seek liquid hedge fund investments that can be reasonably expected to meet their stated liquidity terms and to generate significant absolute returns, these investors should avoid the largest funds. Ultimately, in order to both grow and survive, very large hedge funds will need to transition to either a private-equity type model, where capital is locked-up for very long periods of time, or to an investment-bank model, where the capital is permanent and it is relatively easy to access public markets for capital. However, the current structure, in which investors invest in very large hedge funds because of their expectation that the liquidity will be available to them on a reasonably frequent periodic basis, and fund managers offer such liquidity because they are confident they can maintain good performance and forestall investors from redeeming, does not appear sustainable. Larger funds tend to generate less alpha and to have greater systematic equity exposure. Moreover, fund size may eventually hinder performance enough to trigger a redemption cycle that has a strong negative feedback loop.

NOTES

1. Consistent with the argument, Ammen and Moerth (2008) find that hedge fund performance is negatively related to the amount of assets raised in the prior period.
2. In addition, a basic hedge fund strategy is to buy attractively priced risky assets, which is essentially short risk premiums and volatility.
3. Funds appear to be very consistent with how they report AUM data; they typically either always report it or they never report it. Thus, the histories of funds with AUM data should represent complete returns histories.
4. The reason why there are more monthly observations for the live fund sample than for the dead fund sample, despite the fact that there are more dead funds than live funds, is that on average, live funds are in existence longer than dead funds.
5. We note that results are virtually unchanged if FR_t is defined as LN $\{1+AUM_t/AUM_{t-1}\,F_t\}$.
6. A given fund may be defined as being short-biased in some months but not in others.
7. The maximum return from the short volatility position is Negconvexity_Prem.
8. ALPHA can be generated either by security selection or market timing. We do not distinguish between the two.
9. Key results are substantially unchanged if we estimate Models (1)-(3) using only 24 months of past data. Doing so increases the sample

size and reduces potential survivorship bias from requiring funds to be alive for at least 36 months. Nevertheless, we use a 36-month estimation period because it provides better fits for Models (1)-(3).

10. In addition, the median estimated value for $b_{31,S} + b_{41,S}$ is -0.29 for all hedge funds and -0.59 for funds whose estimated B_{sp500} is greater than zero.
11. Specifically, we find that (i) the average AUM_Rank is not significantly different for funds that do and do not have positive convexity, and (ii) the average AUM_Rank is not significantly different for funds that do and do not have negative convexity.
12. Because we are examining returns over the past 36 months in models (4)-(7), we measure AUM_Rank and LAUM at the beginning of the 36-month estimation period.
13. Because we are examining returns over the past 36 months in models (4)-(7), we measure AUM_Rank and LAUM at the beginning of the 36-month estimation period.
14. We further note that these estimates of survivorship bias are likely understated, because they only consider the dead funds' results up to when they stop reporting. In reality, those funds continue performing very poorly during their liquidation period, after they stop reporting.
15. We note that results are substantively the same if the dependent variable in Model (9) is $Close_{24}$, where $Close_{24}$ has a value of 1 if the fund stops reporting returns over the next 24 months and a value of 0 otherwise.
16. In model (9), we measure AUM_Rank and LAUM as of the *end* of the current 36 month estimation period.
17. All possible pairwise combinations are created using one fund that experiences closing and one fund that does not. A pair is concordant if the estimated closing probability is higher for the fund that closes than for the fund that does not close.
18. We also note that within the universe of funds whose size rank is above the 50th percentile, the probability of closing is greater for funds with higher AUM.
19. As evidence of how the persistence of alpha may be related to fund-raising activity, we find that the negative serial correlation in hedge fund returns is related to fund raising. For the subsample where FR_{36} was positive in the first period, the Spearman correlation is -0.08 (P-value <0.0001), but for the subsample where FR_{36} is negative in the first period the Spearman correlation is -0.02 (P-value$\,=\,0.02$).

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