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Tail Risk and Hedge Fund Returns

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Abstract

We document large, persistent exposures of hedge funds to downside tail risk. For instance, the hardest hit hedge funds in the 1998 crisis also suffered predictably worse returns than their peers in 2007–2008. Using the conditional tail risk measure derived by Kelly (2012), we find that tail risk is a key driver of hedge fund returns in both the time series and cross-section. A positive one standard deviation shock to tail risk is associated with a contemporaneous decline of 2.88% per year in the value of the aggregate hedge fund portfolio. In the cross-section, funds that lose value during high tail risk episodes earn average annual returns nearly 6% higher than funds that are tail risk-hedged, controlling for commonly used hedge fund factors. These results are consistent with the notion that a significant component of hedge fund returns can be viewed as compensation for selling disaster insurance.

Keywords: Hedge fund, tail risk
JEL Codes: G12, G20

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1 Introduction

Hedge fund managers are often characterized as pursuing strategies that generate small positive returns for a period of time before incurring a substantial loss. For instance, Stulz (2007) argues,

> Hedge funds may have strategies that yield payoffs similar to those of a company selling earthquake insurance; that is, most of the time the insurance company makes no payouts and has a nice profit, but from time to time disaster strikes and the insurance company makes large losses that may exceed its cumulative profits from good times.

Tail events represent states in which investors have extremely high marginal utility, thus investors are willing to pay large sums to insure such states and demand compensation to hold assets that suffer in a tail event. As a result, tail risks have large impacts on asset prices even if crashes are infrequently realized.[1]

If hedge funds are the providers of crash insurance, they earn an attractive insurance premium in normal times but suffer severe losses in a tail event. Adding leverage to this kind of strategy can further enhance a fund's performance, as long as the hazard does not materialize. When a large enough disaster strikes, payouts on the crash insurance that it has written can quickly drive a fund's capital to zero. Moreover, anecdotes such as the collapse of Long-Term Capital Management (LTCM) in 1998, and the liquidation of two Bear Stearns hedge funds in 2007, demonstrate that infrequent but dramatic losses of large hedge funds can exert significant pressures on the stability of the financial system.

[1]For example, Santa Clara and Yan (2010) find investors regularly anticipate crashes in the S&P 500 that are bigger than any realized crashes in their sample. They conclude "These were therefore cases in which the jumps that were feared did not materialize. However, the perceived risks are still likely to have affected the expected return in the stock market at those times.... The compensation for jump risk is on average more than half of the total [S&P 500 equity] premium."

Accordingly, both academics and practitioners have intensified their investigation of the risk and return characteristics of hedge funds.

In this paper, we investigate the exposure of hedge funds to extreme event risk and quantify how tail risk exposure impacts average hedge fund returns both over time and in the cross section. The following research questions guide our analysis:

(1) Do individual hedge funds demonstrate persistent performance across crises?

(2) Do hedge fund returns covary with tail risk? If so, do differences in tail risk betas help explain differences in average fund returns?

(3) Do fund characteristics help explain a fund's tail risk exposure?

We begin by investigating hedge fund performance during two extreme episodes: the 1998 and 2007–2008 financial crises. The 1998 crisis was triggered by the Russian debt default in August 1998 and ultimately led to the demise of the star hedge fund, LTCM, and sent ripples of adverse returns through the hedge fund industry. Similarly, in the recent financial crisis, many hedge funds incurred unprecedented losses over a short period of time resulting from pressure to unwind crowded, high-risk trades (Khandani and Lo (2007)), and exposure to the subprime mortgage market (Hellwig (2009)).

Figure 1 plots monthly returns for the HFRI Fund Weighted Composite Index. Two hedge fund crashes in 1998 and 2008 stand out. The occurrence of these two crises provides an opportunity to ask the question: Did hedge funds that underperformed in the 1998 crisis also perform worse in the recent crisis? We find that a fund's return during the 1998 disaster strongly predicts its performance during the 2007–2008 crisis. In particular, a 1% decline in a fund's return during the 1998 crisis predicts a 0.56% drop in return in the 2007–2008 crisis. The data show many of the worst performers during the 1998 episode were again the worst suffering funds in 2008. This predictability in hedge fund performance across the two crises is statistically significant, and robust to controlling for a variety of hedge fund characteristics. This result indicates that hedge funds have persistent exposure to extreme downside risk. Fahlenbrach, Prilmeier and Stulz (2012) find a similar result for US banks in these two crisis episodes, and conclude that persistent negative crisis performance is evidence that certain banks may operate in a tail risky industry niche, and that this business model deliberately exposes the bank to extreme shocks. A similar view can be taken with respect to hedge funds' business models.

To more deeply investigate the exposures of hedge funds to tail risk, we adopt the factor model approach of Kelly (2012). He argues time-varying tail risk generates differential pricing across assets depending on their crash risk exposure, and also produces predictable time variation in compensation that investors receive for bearing this risk. We use the aggregate tail risk measure from that paper, which is constructed from information in the cross section of extreme events at the firm-level.

We first examine the covariation between aggregate hedge fund portfolio returns and aggregate tail risk. Analyzing over 6,000 hedge funds from the Lipper/TASS database over the 1994–2009 period, we identify a robust link between tail risk and hedge fund returns. A one standard deviation increase in aggregate tail risk is associated with a contemporaneous decline of 2.88% in the value of the aggregate hedge fund portfolio, after controlling for the loadings of hedge fund returns on the widely used Fung and Hsieh (2004) seven factor model. Furthermore, this negative exposure emerges across nine out of ten investment styles, and is statistically significant for six of the ten. The large negative covariation that we document between hedge fund returns and tail risk captures the tendency of the hedge fund industry as a whole to lose value during high tail risk episodes. It also naturally leads us to investigate whether the high average returns enjoyed by hedge funds arise as compensation for taking on tail-risky investments.

To this end, we document substantial heterogeneity in individual hedge fund exposures to tail risk shocks, and test whether differences in tail exposure are associated with differences in average returns across funds. We find funds in the bottom tail exposure quintile (those that are most adversely affected in times of high tail risk) earn average annual returns approximately 6% higher than funds in the top tail exposure quintile (those that serve as relative hedges of tail risk). This large return spread is unattenuated by adjusting for the Fung-Hsieh factors or other performance evaluation models used in the asset pricing literature. These results are consistent with high average returns of some funds being driven by their willingness to bear abnormally high crash risk. Furthermore, these results highlight the need to account for tail risk exposure in evaluating fund manager performance. "Alpha" in excess of standard factors may not represent managerial skill, but merely the willingness of managers to sell "earthquake insurance."

We then relate estimates of funds' tail risk betas to a range of observable fund characteristics. The funds that are most susceptible to tail risk are those that are young, have a "high water mark" provision, have long minimum investment horizons, do not employ leverage, and have managers who do not risk their own capital. These results are consistent with risk taking behavior responses to incentives. For example, our findings support the idea that funds have an incentive to establish a track record of high returns early in their life cycle in order to attract fund flows, and they accomplish this in part by loading up on tail risk. Similarly, when managers do not invest their own capital in the fund, a standard principal-agent problem arises in which the manager is willing to take on extremal risk in order to earn incentive fees and attract more fund inflows.

Our paper joins a growing literature that studies the exposures of hedge funds to systematic risk factors. Asness, Krail, and Liu (2001), Patton (2009), and Bali, Brown, and Caglayan (2011a) provide evidence that, despite the frequent claim that funds are market neutral, they often have significant exposures to market factors. Fung and Hsieh (1997, 2001, 2004), Mitchell and Pulvino (2001), Agarwal and Naik (2004), and Fung, Hsieh, and Ramadorai (2008) emphasize that dynamic trading and arbitrage strategies can lead hedge funds to exhibit option-like returns, and suggest factors to adjust for this pattern. Agarwal, Bakshi, and Huij (2010) examine the exposures of hedge fund returns to volatility, skewness, and kurtosis risks derived from the S&P 500 index options as proxies for higher-order risks. They argue strategies such as Managed Futures, Event Driven, and Long/Short Equity show significant exposure to high-moment risks. Bali, Brown, and Caglayan (2011b) find only market volatility, and not skewness or kurtosis, explains the cross-sectional variation in hedge fund returns. Jurek and Stafford (2012) argue the cost of capital for hedge fund investors is accurately approximated by a portfolio of cash and a short put on the S&P 500 index. Sadka (2010) provides evidence of liquidity risk as a contributing factor for hedge fund returns. We contribute to this literature with evidence that time-varying tail risk is an important determinant of hedge fund returns, even after controlling for previously studied factors and option-based risk measures. By showing common exposures to time-varying tail risk lead to comovement among hedge fund returns in times of distress, we also contribute to what recent studies refer to as hedge fund "contagion." Such studies includes Boyson, Stahel, and Stulz (2008), Chan, Getmansky, Haas, and Lo (2009), Adrian (2007), Dudley and Nimalendran (2011) and Adrian, Brunnermeier, and Nguyen (2011).

The rest of the article is organized as follows: Section 2 introduces our methodology and sample construction, and Section 3 provides evidence of predictability of hedge fund performance across the 1998 and 2007–2008 financial crises. In Section 4, we show tail risk is an important determinant of the time series and cross-section variation in hedge fund returns, and consider a series of robustness checks. Section 5 concludes.

2 Data and Tail Risk Measure

2.1 Hedge Fund Sample

We obtain data on hedge fund returns and characteristics from the Lipper/TASS database for the period 1994–2009. The sample includes both "live" funds that are in operation and "graveyard" funds that no longer report to TASS for reasons such as liquidation, fund merger, and closure to new investments. We include graveyard funds that are available in the post-1994 period.

We use the following standard filters for our sample selection. First, we require that funds report their net-of-fee returns at a monthly frequency. Second, we filter out funds denoted in a currency other than US dollars. To mitigate the effects of backfill bias, we exclude the first 18 months of returns for each fund. Finally, we exclude all funds-of-funds from our sample. This process leaves us with a final sample of 6,252 distinct hedge funds.

TASS classifies hedge funds into ten style categories: convertible arbitrage, dedicated short bias, emerging markets, equity market neutral, event driven, fixed income arbitrage, global macro, long-short equity, managed futures, and multi-strategy. In terms of the number of funds, long-short equity is the largest strategy category, consisting of 2,342 distinct hedge funds, whereas dedicated short bias is the smallest strategy category, including only 45 distinct hedge funds. In our initial analysis, we group all hedge funds based on their exposures to tail risk. Later, we repeat the analysis for hedge funds within each investment style category.

Panel A of Table I shows the summary statistics of monthly returns in excess of the one-month Treasury bill rate for a single, equal-weighted aggregate portfolio of all individual hedge funds. We also report summary statistics for portfolios of funds formed on the basis of investment style. The equal-weighted portfolio of all individual hedge funds yields an average monthly excess return of 0.63% over the sample period, with a standard deviation of 1.83%. Among the ten style categories, an equal-weighted portfolio of long-short equity funds yields the highest average excess return, 0.84% per month, whereas an equal-weighted portfolio of dedicated short bias hedge funds realizes the lowest performance with an average monthly excess return of -0.05%. In terms of volatility, a portfolio of equity market neutral hedge funds has a standard deviation of only 0.89%, presumably due a strategy of neutralizing exposure to equity market fluctuations. By contrast, emerging market-oriented hedge funds and dedicated short bias funds have monthly return standard deviations of 4.34% and 5.15%, respectively.

2.2 Constructing a Tail Risk Measure

To evaluate individual hedge fund tail risk exposures (Section 4), we use the time-varying tail risk measure introduced in Kelly (2012). He characterizes tail distribution of asset returns according to the following formula:

$$P(R_{i,t} < r \mid R_{i,t} < u_t) \propto \left(\frac{r}{u_t}\right)^{a_i \zeta_t}. \tag{1}$$

Equation 1 states that conditional on exceeding an extreme negative "tail threshold," u_t, the lower tail of an asset's return obeys a power law distribution. $R_{i,t}$ is the return on individual stock i on date t. The tail threshold, u_t, defines where the center portion of the distribution ends and the tail distribution begins. We define u_t as the 5^{th} percentile of the cross-sectional return distribution on date t. The exponent on the right hand side of this proportionality governs the degree of tail risk in a particular stock. a_i is a constant that governs differences in the level of unconditional tail risk across stocks, and ζ_t is a time-varying tail parameter that is common to all stocks. The goal of this specification is to measure the common component in tail risk, ζ_t. A more positive value of the power law exponent ζ_t in Equation 1 stretches the lower tail of the return distribution further left, and is therefore associated with higher tail risk.

The key identifying assumption is that the panel of stock return tails depends on stock fixed effects and time effects, and does not depend stock-time effects. Kelly shows ζ_t can be estimated by applying Hill's (1975) power law estimator to the pooled cross section of extreme daily return observations for all CRSP stocks in a given month t. Thus the estimate of month t tail risk takes the form

$$\frac{1}{\zeta_t^{Hill}} = \frac{1}{K_t} \sum_{k=1}^{K_t} \ln \frac{R_{k,t}}{u_t},$$

where $R_{k,t}$ is a daily return of stock k during month t, and K_t is the number of daily returns that exceed the extremal threshold u_t that month. We conduct all of our analyses use the following standardized measure of tail risk:

$$Tail_t = \frac{\hat{\zeta}_t^{Hill} - \hat{E}\left[\hat{\zeta}_t^{Hill}\right]}{\hat{\sigma}\left(\hat{\zeta}_t^{Hill}\right)},$$

where $\hat{E}$ and $\hat{\sigma}$ denote the full sample time series mean and standard deviation of monthly tail risk estimates.

Panel B of Table I shows the correlation between our tail risk measure and various options-based measures of tail risk over the period 1996–2010. We compare our tail factor with the price of an option portfolio designed to be exposed to fluctuations in tail risk of the S&P 500 index. This portfolio, called the tail put spread, combines a long position in a deep out-of-the-money (delta = −20) S&P 500 put with an offsetting short position in a closer-to-the-money (delta = −25) put.[2] The put spread is constructed to be both

[2]We use options with one year to maturity to capture tail risks investors face over the medium-term. Results are nearly identical using shorter maturities.

delta- and vega-neutral.[3] The motivation for comparing the tail risk measure against a delta- and vega-hedged position is that it nets out the first-order impact of variation in the index price and the volatility level, and thus the remaining value of the position is likely to be more purely exposed to tail risk than the unhedged position. Also, by subtracting the price of the closer-to-the-money option, this portfolio adjusts for non-tail-risk price effects that may be common across strikes.

Our tail risk measure has a correlation of 58% with the cost of this put spread strategy, suggesting our measure is closely associated with tail risks perceived by investors in equity index options. Tail risk has a correlation of 43% with an unhedged version of this strategy. We also calculate the tail put spread for the 100 largest constituents of the S&P 500 each day (again delta- and vega-neutralized). We find the average put spread for individual stocks has a 41% correlation with our measure of tail risk. It has a -10% correlation with risk-neutral skewness (Bakshi, Kapadia and Madan (2003)), suggesting the risk-neutral distribution of the index is more left skewed when tail risk is high. It is less correlated, only 5%, with the variance risk premium (Bollerslev, Tauchen and Zhou (2009)), though this result is perhaps unsurprising given that many factors, such as a fluctuating price of variance risk, are likely to impact variation in this series more directly than tail risk.

Tail risk is moderately countercyclical. It shares a monthly correlation of 44% and −11% with unemployment and the Chicago Fed National Activity Index (CFNAI). It is fairly persistent, with a monthly AR(1) coefficient of 0.864.

[3] An option's delta (vega) is the sensitivity of the option price to small changes in the price (volatility) of the underlying. Neutral portfolios set these derivatives to zero by construction. Because the value of an option position can be influenced by fluctuations in delta and vega, neutrality is an attractive feature when comparing option prices over time. We use Black-Scholes delta and vega when constructing put spread portfolios. The table also reports "unhedged" put spreads, which combine a simple long out-of-money and short near-the-money position without imposing neutrality.

3 Did Funds That Underperformed in 1998 Also Perform Worse in 2007–2008?

The 1994–2009 period witnessed two episodes in which hedge funds suffered large losses that coincided with extreme negative market-wide returns (see Figure 1). The first occurred in 1998 and was triggered by the Russian debt default, and notoriously brought about the downfall of star hedge fund LTCM. The second was the recent financial crisis during which hedge funds incurred unprecedented losses over a short period of time due to the "quant meltdown" in 2007 and the fall of subprime mortgage derivative markets.

Fahlenbrach, Prilmeier and Stulz (2012) argue these two episodes share the following close similarities. At the time each was occurring, they were each considered "the worst financial crisis in the last fifty years" (then Treasury Secretary Robert Rubin referring to the 1998 market downturn). In both cases, investors experienced large losses in securities that were marketed and rated as having minimal risk. These losses induced fire sales and liquidity withdrawals in other asset classes (see Fahlenbrach et al., pp. 2-8).

These two periods provide an opportunity to address research question (1) and investigate whether hedge funds possess persistent exposure to extreme events. Our test adopts an approach used by Fahlenbrach, Prilmeier and Stulz (2012) to evaluate whether a fund's performance in 1998 foreshadows its performance during the arguably similar crisis of 2007–2008.

The data for this test includes 603 hedge funds that survived the 1998 crisis and stayed in operation at the end of June 2007. Figure 2 shows the time series of returns for this sample of funds. It reports equal-weighted average returns for two groups – the top and bottom 20% of funds in terms of their performance during the summer of 1998 (denoted "crisis insensitive" and "crisis sensitive," respectively). The figure shows those funds that performed particularly poorly in 1998 repeated the same underperformance relative to their peers in 2007-2008.

We perform cross-sectional regressions of the cumulative return to individual funds from July 2007 to December 2008 on their performance in the 1998 crisis, which take the form

$$R_{i,2007-2008} = b_0 + b_1 R_{i,1998} + b_2^{'} \text{controls}_i.$$

We measure a fund's performance in the 1998 crisis using two metrics: the cumulative return to the fund from August 1998 to December 1998 and the worst single-month return to the fund in the period from August to December 1998.

Results in Table II provide evidence of persistence in hedge fund performance across crisis episodes. Specifically, Column 1 indicates a 1% decline in fund return during the 1998 crisis (from August to December 1998) predicts a 0.56% drop in fund return in the 2008 crisis. In the cross-section of hedge funds, a one standard deviation lower return during the 1998 crisis is associated with a 10% (0.560×0.187) lower return in the recent financial crisis. This effect is highly statistically significant. Returns in 1998 alone account for 8.8% of the cross-sectional variation in hedge fund returns during the recent crisis.

In Columns 2 and 3, we include a fund's performance in 2006 and its beta on the market excess return as control variables. Performance in 2006 is negatively associated with performance in the recent crisis. This mean-reversion in hedge fund returns could be driven by better-performing funds in 2006 increasing their risk exposures or leverage and subsequently being more exposed to the crisis shock. Funds with high market betas also experience a more negative return during the crisis. The inclusion of a fund's 2006 performance or market beta does not affect our finding of persistence in hedge fund returns across the two crises. The coefficient on the 1998 return declines only slightly from 0.560 to 0.506, and the t-statistic remains above 4.0.

In Columns 4 and 5, we include several additional fund characteristics that previous literature shows relates to hedge fund returns, including fund size (log of total assets under management), fund age, fund return volatility during 2006, percentage fund flow in 2006, manager personal capital, incentive fee, management fee, redemption notice period, lock-up period, leverage, and a high water mark dummy. These fund characteristics are measured at the end of 2006 and their inclusion reduces the sample size to 469 distinct hedge funds. Controlling for fund characteristics and fund return in 2006 slightly attenuates the effect of the 1998 return. The main message from Columns 4 and 5 is that performance in 1998 is a strong predictor of a fund's performance in the recent crisis. The estimate remains economically large, with a slope coefficient of 0.367 that is statistically significant at the 1% level. In Columns 6-10, we use a fund's worst single-month performance in the 1998 crisis as the independent variable. Based on this measure of a fund's 1998 performance, we uncover the same predictive relation with the fund's performance in the recent crisis that we found when predicting with the August to December 1998 return.

In summary, we find hedge funds that suffered poor returns during the 1998 crisis experienced predictably worse performance in the recent crisis as well. This evidence is consistent with the view that the choice of a hedge fund to pursue trading strategies that are vulnerable to extreme events is a persistent attribute of the fund's business model. The same funds that were most exposed to the tail shock in 1998 were again the most exposed to the 2007–2008 tail shock.

4 Tail Risk and Hedge Fund Returns

We next address research question (2) by examining whether funds' exposure to our tail risk measure helps explain time series and cross-sectional variation in hedge fund returns.

4.1 Hedge Fund Tail Risk Exposure

We start with a time series analysis that examines the exposures of hedge funds to AR(1) innovations in the tail risk measure. We compute returns on an equal-weighted portfolio of all hedge funds, as well as equal-weighted portfolios within each style category. We then examine the sensitivities of fund portfolio returns to tail risk shocks, after controlling for their loadings on the Fung and Hsieh seven factors. In another specification, we assess the relevance of tail risk innovations after including three high-moment risk proxies extracted from S&P 500 Index options: the change in the CBOE volatility index (ΔVIX), change in risk-neutral skewness (ΔRNSKEW), and change in risk-neutral kurtosis (ΔRNKURT). Risk-neutral skewness and kurtosis are calculated according to Bakshi, Kapadia and Madan (2003). To facilitate interpretation, we standardize the tail factor and high-moment risk proxies to have means of zero and standard deviations of one. The sample period is from January 1994 to December 2009. For regressions using options data, the sample period is from February 1996 to December 2009.

Table III presents the results. For the aggregate hedge fund portfolio, a one standard deviation increase in tail risk is associated with a decline in hedge fund returns of 0.24% per month, or 2.88% per year. The effect is statistically significant at better than the 1% level based on bootstrap standard errors. When we further include changes in VIX and risk-neutral skewness and kurtosis, we find they are insignificantly related to hedge fund returns. However, the association between innovations in tail risk and hedge fund returns remains economically strong and statistically significant.

We next analyze investment style portfolios, and find the average exposure of hedge funds to tail risk is negative in nine out of ten style categories (the only exception is the managed futures style). The negative exposure is negative for six out of ten styles, including convertible arbitrage, emerging markets, equity market neutral, event driven, long-short equity, and multi-strategy. In terms of magnitudes, returns to hedge funds that invest in emerging markets and those that pursue long-short equity strategy are particularly sensitive to tail risk shocks. For example, a one-standard deviation increase in tail risk is associated with a drop in returns of 0.60% per month for hedge funds investing in emerging markets; and for hedge funds that engage in long-short equity investing, the corresponding number is 0.41% per month.

4.2 Tail Risk in the Cross Section of Hedge Fund Returns

The evidence that returns to a typical hedge fund are sensitive to tail risk suggests tail risk may be an important determinant of average return differences across funds. To evaluate this empirically, we construct hedge fund portfolios that are sorted on the basis of their exposures to tail risk. Specifically, at the end of each month, we run a time series regression of individual fund excess returns on the market return and AR(1) innovations in tail risk, using the most recent two years of data (we require at least 18 months of data in the estimation window). We then sort funds into five quintile portfolios based on their tail risk betas. We track the performance of the quintile portfolios over various holding periods ranging from one month to 12 months, following the scheme of Jegadeesh and Titman (1993). For holding periods beyond one month, our tests use Newey and West (1987) standard error adjustments for serial correlation.

Table IV shows the performance of hedge fund tail beta quintile portfolios as well as a long-short portfolio that is long quintile five and short quintile one. Our results show substantial dispersion in hedge fund returns across tail beta-sorted portfolios.

Hedge funds in quintile one have negative tail betas. When tail risk is high, the returns of these funds tend to be negative; thus the funds in quintile one are especially susceptible to tail risk shocks. These funds may be interpreted as providers of crash insurance. This portfolio earns an average post-formation monthly return of 0.85%, representing large compensation for tail risk exposure. On the other hand, funds in quintile five have high, positive tail betas, and are thus effective tail risk hedges. These funds may be thought of as purchasers of crash insurance, and realize an average return of 0.36% in the post-formation month. The return spread between the two groups of funds is -0.49% per month with a t-statistic of -2.63. After adjusting for funds' differential exposures to the Fung and Hsieh seven factors, the tail risk spread (quintile five minus quintile one) widens slightly to -0.53% per month, with a t-statistic of -2.69.

The difference in performance between tail risk insurers and hedgers persists when we extend the holding period of tail beta quintile portfolios. For example, with a six-month holding horizon, the average return spread between hedge funds with positive exposures to tail risk and those with negative exposures to tail risk is -0.40% per month, with a t-statistic of -3.00. With a 12-month holding period, the average return difference remains as large as -0.33% per month, with a t-statistic of -2.50. As in the one-month holding period case, adjusting for the Fung and Hsieh seven factors renders the difference in performance even larger both in magnitude and statistical significance.

Table IV also reports portfolios' post-formation tail risk betas. Post-formation betas increase from quintiles one to five with the exception of a non-monotonicity at quintile four. The beta spread between high and low tail risk exposure portfolios is 0.53, which is significant at the 1% level. This evidence suggests a high degree of persistence in tail risk betas, and is consistent with the notion that individual funds' tail exposures are fixtures of the trading strategies pursued by their managers.

Figure 3 plots one-month post-formation returns on a tail-risk-hedged portfolio (quintile five minus quintile one). This portfolio shorts funds that are sellers of tail risk insurance and is long funds that purchase tail risk insurance. In extreme market downturns such as the summer of 1998 and multiple episodes during the 2007-2009 crisis, tail risk hedges perform exceedingly well and are negatively correlated with the excess returns on the market. The premium that a hedger pays for tail insurance was realized in February 2000, one-month prior to the burst of the dot-com boom. In this month, the high-minus-low tail beta portfolio experienced its worse return (-12.5%), while the excess market return was positive (2.8%).

4.3 Alternative Performance Evaluation Models

We next explore alternative hedge fund performance evaluation models. In Table V, we estimate alphas for tail beta quintile portfolios after extending the Fama-French and Fung-Hsieh models to include a richer set of risk factors. First, we consider the Carhart (1997) four-factor model, which augments the Fama and French (1993) factors (the market, size, and value factors) with the Jegadeesh and Titman (1993) momentum factor. This model is motivated by the observation that equity-oriented hedge funds dominate our sample, and momentum is one of the most common strategies pursued by equity funds. Next, we consider a five-factor extension of the Carhart model that further includes the Pastor and Stambaugh (2003) traded liquidity risk factor. The third performance evaluation model in Table V comes specifically from the hedge fund literature. It augments the Fung and Hsieh seven factors with two additional option return factors, namely, the return on OTM put options on the S&P 500 Index and the return spread between OTM and ATM put options on the S&P 500 Index, following Agarwal and Naik (2004).

Table V shows the return spread between hedge funds with negative and positive exposures to tail risk remains economically large and statistically significant after adjusting for their loadings on the extended factor models. Controlling for momentum, liquidity, and options strategy returns has little effect on our findings. Alphas on a strategy that is long tail risk beta quintile 5 and short quintile 1 range from -0.33% to -0.53% per month, with t-statistics above 2.5 in absolute value in all cases.

In Table VI, we conduct robustness tests with respect to additional factors that may influence hedge fund returns. Sadka (2010) emphasizes the contribution of liquidity risk to hedge fund performance. This motivates us to examine whether liquidity risk influences the time series association between tail risk and hedge fund returns. We also consider the influence of correlation risk on our results given Buraschi, Kosowski, and Trojani's (2011) result that correlation risk has explanatory power for hedge fund returns. We proxy for correlation risk using the average pairwise correlation among S&P 500 constituent stocks in a 22-day rolling window. The table shows tail risk remains an important determinant of hedge fund returns after controlling for liquidity risk, proxied either by the Pastor and Stambaugh factor (column 1) or the Sadka permanent liquidity factor (column 2). Both liquidity measures have some explanatory power for hedge fund returns, but neither has an influence on the coefficient estimate on tail risk, which remains close to the 0.24 estimate from Table III. Correlation risk (column 3) does not appear to be associated with fund return behavior after controlling for tail risk.

In addition to time series tests of exposures to these alternative factors, we also check whether differences in returns across tail beta-sorted portfolios are robust to bivariate sorts based on exposures to additional risk factors. Table VII presents average excess returns and the Fung and Hsieh seven-factor alpha on 25 hedge fund portfolios from independent sorts on tail risk beta and betas on Pastor and Stambaugh's (2003) liquidity risk factor (Panel A), Sadka's (2006) permanent variable factor (Panel B), or average stock correlation (Panel C). All betas are estimated in bivariate regressions of fund excess returns on the relevant risk measure and the excess return on the aggregate stock market over the previous 24 months.

Overall, the tail risk beta return spread is robust to bivariate sorts. When sorting along with Pastor-Stambaugh liquidity risk betas (Panel A), the five-minus-one tail beta return spread ranges from -0.35% per month to -0.66% per month, and is significant at the 5% level within four out of five liquidity beta quintiles. Results are somewhat stronger in terms of Fung-Hsieh sever-factor alphas, where the tail beta spread is significant across all liquidity beta quintiles. When sorting along with Sadka liquidity betas (Panel B), tail beta return and alpha spreads are slightly attenuated, remaining significant within three out of five liquidity quintiles. The spread is always negative and large in economic magnitude (the least negative spread we find is -0.24% per month). Finally, when sorting along with correlation risk betas (Panel C), tail beta return and alpha spreads are significant within three out of five liquidity quintiles, and the least negative spread across correlation beta quintiles is -0.31% per month.

Our findings are also robust to other traditional measures of performance evaluation such as Sharpe ratios. Hedge funds that behave as sellers of tail risk insurance (quintile 1) earn an average smoothing-adjusted[4] monthly Sharpe ratio of 0.22, twice as large as the 0.10 Sharpe ratio for their peers who hedge tail risk (quintile 5). Similarly, the appraisal ratio for low tail risk beta funds (the average Fung and Hsieh seven-factor monthly alpha divided by its standard deviation) is 0.40, which is three times as large as that for high tail risk beta funds (0.13).

4.3.1 Tail Risk and Fund Returns Conditional on Style

In Table VIII, we examine the association between tail risk exposure and cross-sectional dispersion of hedge fund returns *within* each investment style category. One caveat is that certain strategy styles contain few hedge funds, leaving us without statistical power in

[4]See Getmansky, Lo and Makarov (2004).

these cases. For example, monthly quintile portfolios of funds in convertible arbitrage, dedicated short bias, equity market neutral, fixed income arbitrage, and global macro strategies contain less than 20 funds on average.

Among four of the five styles that have over 20 funds in each quintile portfolio, we find differences in tail risk exposure are significantly associated with differences in average returns. Among the significant styles, tail beta return spreads are -1.00% per month (emerging markets), -0.53% (long/short equity), -0.45% (multi-strategy) and 0.35% (event driven).

4.4 Fund Characteristics and Tail Risk

Our third research question investigates why some funds are more susceptible to tail risk than others. We examine the relationship between funds' tail risk betas and the characteristics of each fund as reported in the TASS/Lipper database. In particular, Table IX reports Fama-MacBeth (1973) cross-sectional regression coefficients of monthly estimated tail risk betas on contemporaneous fund characteristics over the period of December 1995 to November 2009.

We divide available fund characteristics into six groups: size/age, incentive contracts (percentage management fee on assets under management, incentive fee as percentage of fund profits, and an indicator for whether the fund has a high water mark provision), minimum investment horizons[5] (length of lock-up, redemption notice and payout periods), manager "skin in the game" (indicators for whether the manager has personal capital invested in the fund or is an owner of the management company), and an indicator for whether a fund employs leverage. We control for recent performance (fund returns, return

[5] Lock-up period is the length of the window over which newly purchased shares of a fund cannot be sold or redeemed. Redemption notice period is the length of advanced notice that funds require from investors that wish to redeem their shares. Payout period is the time before investors receive cash back once sell orders are processed.

volatility and net flows over the previous 24 months). For ease of interpretation, we cross-sectionally standardize tail risk beta, size, age, fund return, return volatility and fund flow to have means of zero and standard deviations of one. Payout period, redemption notice period, and lock-up period are transformed using the natural log of one plus the number of days. Test statistics are based on Newey-West (1987) standard errors with a 24-month lag. Columns 1 through 5 of Table IX consider various subsets of characteristics, whereas column 6 reports results controlling for all characteristics simultaneously.

Recall that funds with negative tail risk betas are those that are most susceptible to tail risk. When crash risk rises, these funds experience negative returns. Our estimates suggest funds that are the most susceptible to tail risk are young, have a "high water mark" provision, have long minimum investment horizons, do not employ leverage, have managers that do not risk their own capital, and are highly volatile. These characteristics explain as much as 11% of the variation in tail risk betas across funds.

Our results relating fund characteristics with tail risk exposure have intuitive interpretations. Funds have an incentive to establish a track record of high returns early in their life cycle in order to attract fund flows. One way for young funds to establish a track record of "alpha" relative to standard benchmarks is to take on tail-risky investments that carry high risk compensation, leading to the positive age coefficient that we find. Funds that are below their high water mark may similarly reach for alpha by loading up on tail-risky investments, producing the negative coefficient that we find on the high water mark dummy. When funds subject their investors to long lock-ups and redemption periods, they have more flexibility to take on riskier, less liquid positions. Leverage may serve as a disciplining device, because a tail shock to a levered fund can quickly wipe out all of the fund's capital. Rather than jeopardizing a fund's ongoing viability, levered funds may invest less in or even hedge against tail risk, leading to the large positive coefficient that we estimate. Finally, when managers do not invest their own capital in the fund, the standard principal-agent problem becomes exacerbated, and the manager may be more willing to take on extremal risk in order to earn incentive fees and attract more fund inflows, because they can do so without risking their own wealth.

5 Conclusion

We have shown that hedge funds exhibit persistent exposures to extreme downside risk. For instance, the same hedge funds that underperformed in the 1998 crisis suffered predictably lower returns during the 2007–2008 crisis. Using an ex ante measure of conditional tail risk derived by Kelly (2012), we find tail risk is an important determinant of the time series and cross section variation of hedge fund returns. A positive one standard deviation shock to tail risk is associated with a contemporaneous decline of 2.88% per year in the aggregate hedge fund portfolio return. In the cross section, hedge funds that covary negatively with tail risk earn average annual returns more than 6% higher than funds with positive tail risk covariation, controlling for commonly used hedge fund factors. These results are consistent with the notion that a significant component of hedge fund returns can be viewed as compensation for providing insurance against tail risk.

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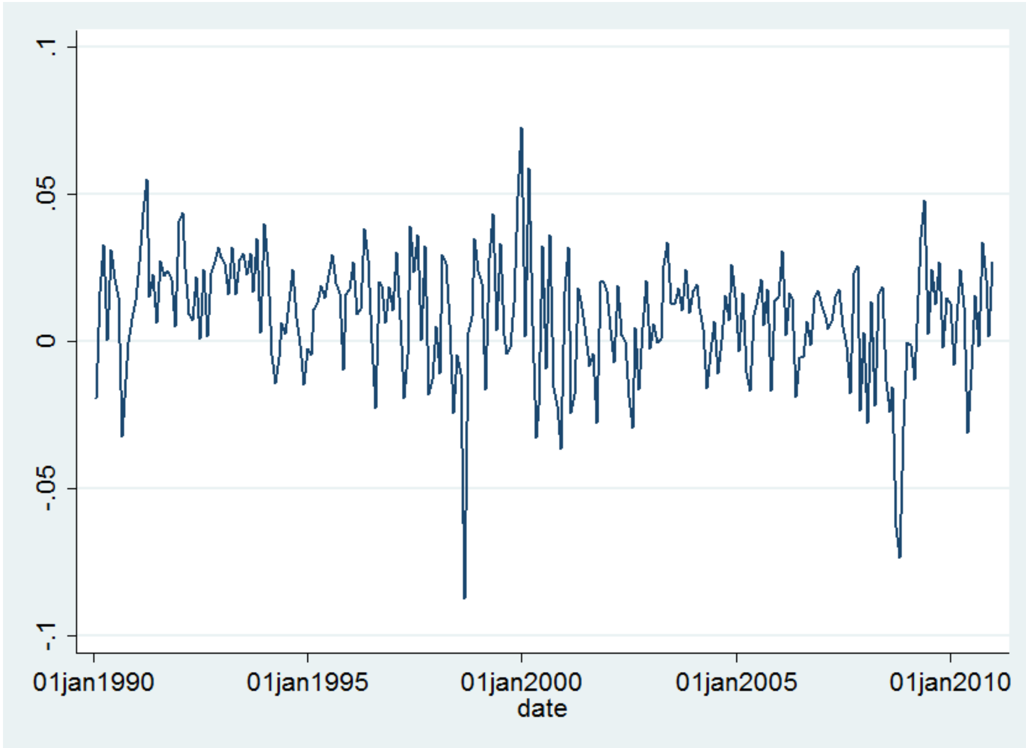

Figure 1. HFRI Fund Weighted Composite Index Return. This figure plots the monthly time series of the HFRI composite index return.

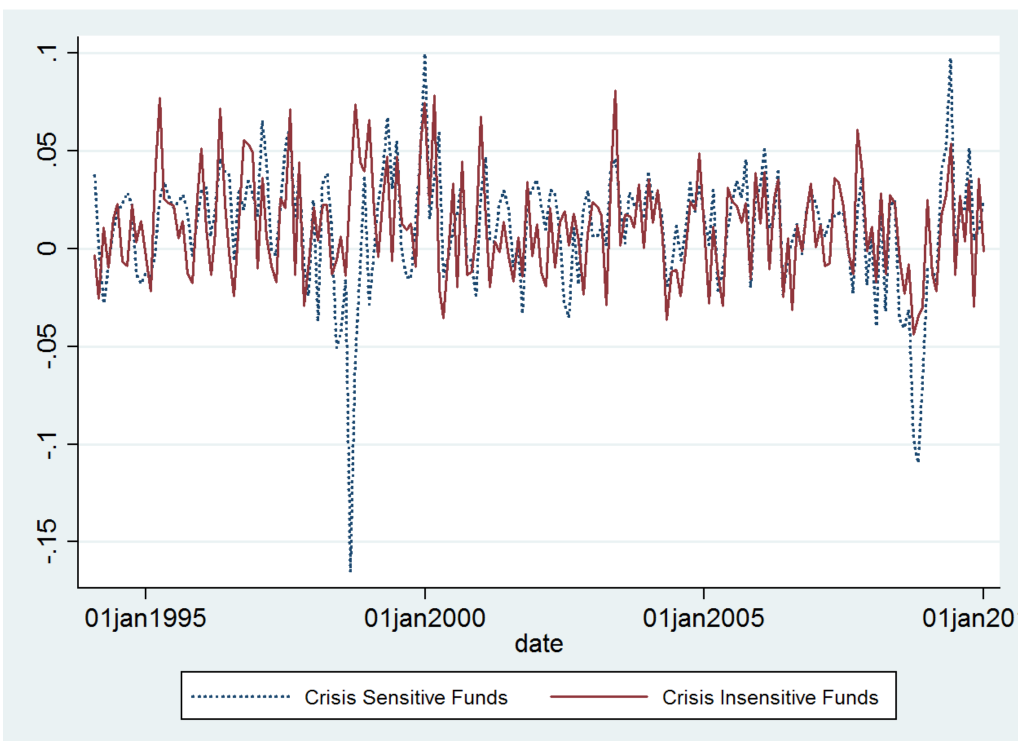

Figure 2. Performance of Crisis-Sensitive and Crisis-Insensitive Funds. This figure plots the time-series of returns on the top 20% (crisis-insensitive) and bottom 20% (crisis-sensitive) of hedge funds by their return performance during the 1998 LTCM crisis.

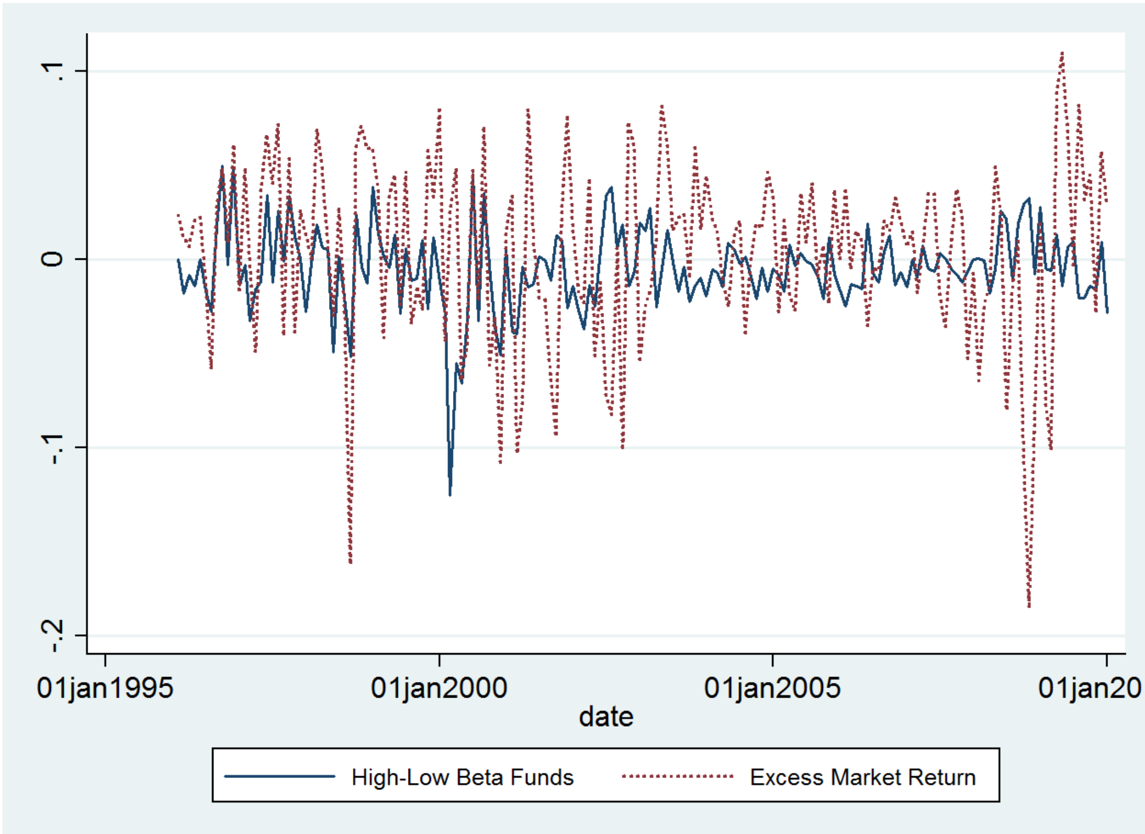

Figure 3. Return Spread between Hedge Funds with High and Low Tail Risk Beta. This figure plots the return time series (solid blue) for a hedge fund portfolio that is long funds in the highest tail risk beta quintile and short funds in the lowest quintile. In each month, we form five tail risk beta portfolios where betas are estimated in a regression of the funds' excess return on the market excess return and tail risk shocks in the past 24 months. Funds with high (low) tail risk betas tend to hedge against (load on) tail risk. We also plot the contemporaneous aggregate stock market return in excess of the risk-free rate (dotted red).

Table I. Descriptive Statistics. This table presents the descriptive statistics for hedge fund returns and risk factors used in our sample. Panel A shows the summary statistics of monthly excess returns on the equal-weighted portfolios of hedge funds in each style category and all hedge funds in our sample January 1994 to December 2009. Returns are in percent per month in excess of the one-month T-bill rate. N is the number of distinct hedge funds in each category. Panel B shows the correlation matrix for the tail risk factor and S&P 500 option-based tail risk measures from 1996-2009.

Panel A Summary Statistics of Monthly Excess Hedge Fund Returns (%)

	N	Mean	Std Dev	Minimum	10th Pctl	25th Pctl	Median	75th Pctl	90th Pctl	Maximum
Convertible Arbitrage	215	0.40	2.12	-16.02	-1.28	-0.26	0.62	1.24	1.83	7.46
Dedicated Short Bias	45	-0.05	5.15	-11.53	-6.02	-3.06	-0.63	2.84	6.60	22.96
Emerging Markets	701	0.81	4.34	-21.84	-4.36	-2.04	1.51	3.46	5.46	13.66
Equity Market Neutral	404	0.48	0.89	-3.24	-0.45	0.07	0.48	0.94	1.53	3.05
Event Driven	619	0.58	1.59	-7.86	-1.23	-0.18	0.86	1.50	2.26	4.13
Fixed Income Arbitrage	247	0.39	1.23	-7.59	-0.63	0.01	0.49	1.00	1.63	3.30
Global Macro	470	0.50	1.78	-4.20	-1.49	-0.66	0.46	1.29	2.82	7.10
Long/Short Equity	2342	0.84	2.77	-9.24	-2.40	-0.86	0.87	2.32	4.02	10.47
Managed Futures	670	0.49	2.90	-5.46	-3.07	-1.59	0.36	2.32	4.33	9.80
Multi-Strategy	539	0.53	1.42	-5.60	-1.28	-0.34	0.70	1.50	1.99	3.79
All Hedge Funds	6252	0.63	1.83	-5.83	-1.66	-0.53	0.68	1.67	2.71	6.22

		(1)	(2)	(3)	(4)	(5)	(6)
Tail	(1)	1.00					
S&P 500 Tail Put Spread	(2)	0.58	1.00				
S&P 500 Spread (Unhedged)	(3)	0.44	0.76	1.00			
Indiv. Tail Put Spread	(4)	0.39	0.50	0.53	1.00		
R.N. Skew	(5)	-0.10	0.02	0.47	-0.13	1.00	
Var. Risk Prem.	(6)	0.05	-0.04	-0.45	-0.09	-0.47	1.00

Table II. Did Hedge Funds with Lower Performance in the 1998 Crisis Also Perform Worse in the Recent Crisis? This table analyzes the performance in the 2007-2008 financial crisis for 603 hedge funds that survived the 1998 crisis through the end of June 2007. We use the cumulative hedge fund return from August 1998 to December 1998, or the worst single month return in this period, to predict funds' cumulative return from July 2007 to December 2008. We control for funds' return in 2006 and a range of fund characteristics including Fund Beta on the market, Size (in million dollars), Age (years since their inception), Return Volatility and Fund Flow in 2006, Personal Capital, Incentive Fee, Management Fee, Redemption Notice Period, Lockup Period, High Water Mark, and a Leverage indicator. These fund characteristics are measured at the end of 2006 and their inclusion leaves us with 469 hedge funds. We estimate individual hedge fund beta by summing up the betas in regressions of excess hedge fund returns on contemporaneous excess market returns and lagged excess market returns in the past three months with data from January 2005 to December 2006. The *t*-statistics are based on bootstrapped standard errors.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Ret1998	0.560	0.506	0.525	0.367	0.331					
	(6.02)	(4.48)	(4.13)	(3.42)	(3.08)					
Worst Month Return 1998						0.586	0.453	0.407	0.474	0.354
						(4.75)	(3.28)	(2.84)	(3.36)	(3.19)
Ret2006		-0.251		-0.332			-0.278		-0.359	
		(-2.13)		(-1.86)			(-1.58)		(-2.09)	
Fund Beta			-0.0508		-0.142			-0.0461		-0.143
			(-3.23)		(-7.56)			(-2.25)		(-6.29)
Size				-0.0206	-0.0206				-0.0239	-0.0239
				(-2.03)	(-2.50)				(-2.45)	(-2.40)
Age				0.00833	0.00729				0.00852	0.00746
				(1.81)	(1.96)				(2.12)	(2.21)
Return Volatility				0.810	5.028				1.446	5.509
				(0.65)	(3.91)				(1.24)	(4.11)
Flow				-0.00436	-0.00688				-0.00548	-0.00781
				(-0.15)	(-0.36)				(-0.21)	(-0.37)
Personal Capital				-0.00374	0.0106				-0.000424	0.0125
				(-0.13)	(0.34)				(-0.01)	(0.52)
Incentive Fee				0.0107	0.0103				0.0114	0.0112
				(2.76)	(2.21)				(2.80)	(3.46)
Management Fee				0.0435	0.0381				0.0440	0.0390
				(1.61)	(1.77)				(1.77)	(1.60)
Redemption Notice Period				-0.00101	-0.00118				-0.00141	-0.00159
				(-1.71)	(-2.29)				(-2.87)	(-3.53)
Lockup Period				-0.00259	-0.00213				-0.00266	-0.00234
				(-1.20)	(-1.29)				(-1.40)	(-1.16)
High Water Mark				0.0397	0.0609				0.0443	0.0650
				(1.06)	(2.23)				(1.39)	(2.19)
Leverage				0.0519	0.0717				0.0655	0.0851
				(1.91)	(2.78)				(2.21)	(3.57)
Constant	-0.0908	-0.0578	-0.0391	-0.0671	-0.0861	-0.0271	-0.00386	0.00282	0.0154	-0.0133
	(-7.27)	(-2.97)	(-2.37)	(-0.32)	(-0.55)	(-1.34)	(-0.17)	(0.15)	(0.08)	(-0.07)
Observations	603	603	603	469	469	603	603	603	469	469
Adj. R-squared	0.0881	0.110	0.112	0.192	0.279	0.0309	0.0568	0.0477	0.180	0.263

Table III. Exposure of Hedge Funds to Tail Risk Factor. This table presents results of time series regressions of hedge fund portfolio returns on the Fung and Hsieh seven factors and the tail risk shocks. We group hedge funds into 10 portfolios based on their investment styles and compute their monthly returns in excess of the one-month Treasury-bill rate. In another specification, we include three high-moment risk proxies extracted from S&P 500 Index options: change in the CBOE volatility index (ΔVIX), change in skewness (ΔRNSKEW), and change in the kurtosis (ΔRNKURT). The tail factor and high-moment risk proxies are standardized to have a mean of zero and standard deviation of one. Our sample period is from January 1994 to December 2009. For the regressions using the option data, the sample period is from February 1996 to December 2009. With the exception of loadings on MKTRF and SMB, coefficients are multiplied by 100 for presentation purposes. *t*-statistics are shown in parentheses.

	TAIL	ΔVIX	ΔRNSKEW	ΔRNSKURT	MKTRF	SMB	ΔTERM	ΔCREDIT	PTFSBD	PTFSFX	PTFSCOM	Intercept	Adj-R2
All Hedge Funds	-0.24				0.28	0.12	-0.95	-1.82	-0.35	0.85	1.60	0.48	0.702
	(-2.74)				(14.34)	(5.86)	(-3)	(-4.16)	(-0.65)	(2.01)	(2.74)	(6.36)	
	-0.27	0.20	0.10	-0.22	0.29	0.12	-0.90	-1.55	-0.36	0.76	1.56	0.48	0.731
	(-2.94)	(1.59)	(0.75)	(-1.44)	(11.05)	(5.50)	(-2.57)	(-3.05)	(-0.59)	(1.54)	(2.54)	(5.95)	
Emerging Markets	-0.6				0.55	0.20	-0.78	-3.71	-2.68	-0.08	0.92	0.50	0.516
	(-2.33)				(9.37)	(3.16)	(-0.81)	(-2.8)	(-1.67)	(-0.06)	(0.52)	(2.21)	
	-0.72	0.08	0.62	-0.49	0.48	0.17	-0.83	-2.95	-3.68	1.01	0.76	0.58	0.596
	(-2.76)	(0.22)	(1.63)	(-1.11)	(6.64)	(2.74)	(-0.84)	(-2.06)	(-2.13)	(0.72)	(0.44)	(2.54)	
Long/Short Equity	-0.37				0.47	0.25	-0.41	-0.45	-0.23	0.26	1.54	0.58	0.774
	(-3.23)				(18.55)	(8.87)	(-0.99)	(-0.78)	(-0.32)	(0.47)	(2)	(5.87)	
	-0.41	0.21	0.17	-0.23	0.47	0.24	-0.33	-0.25	0.08	0.17	1.64	0.58	0.781
	(-3.24)	(1.22)	(0.93)	(-1.08)	(13.25)	(7.99)	(-0.69)	(-0.37)	(0.1)	(0.25)	(1.95)	(5.2)	
Convertible Arbitrage	-0.29				0.13	0.03	-2.43	-6.46	-1.04	-0.68	-0.77	0.48	0.631
	(-2.60)				(5.23)	(1.20)	(-5.97)	(-11.44)	(-1.52)	(-1.25)	(-1.03)	(6.37)	
	-0.31	0.08	-0.22	-0.45	0.13	0.02	-2.16	-5.87	-1.07	-0.83	-0.83	0.35	0.661
	(-2.56)	(0.49)	(-1.23)	(-2.21)	(3.86)	(0.80)	(-4.7)	(-8.85)	(-1.33)	(-1.28)	(-1.03)	(3.26)	

	TAIL	ΔVIX	ΔRNSKEW	ΔRNSKURT	MKTRF	SMB	ΔTERM	ΔCREDIT	PTFSBD	PTFSFX	PTFSCOM	Intercept	Adj-R2
Event Driven	-0.25				0.20	0.09	-0.41	-2.49	-1.75	0.18	-0.07	0.46	0.725
	(-3.50)				(12.12)	(5.17)	(-1.56)	(-6.81)	(-3.95)	(0.52)	(-0.15)	(7.34)	
	-0.26	0.28	-0.06	-0.38	0.21	0.08	-0.28	-2.19	-2.22	0.37	0.02	0.42	0.771
	(-3.43)	(2.75)	(-0.54)	(-3.01)	(10.15)	(4.73)	(-1.01)	(-5.37)	(-4.53)	(0.94)	(0.05)	(6.52)	
Multi-Strategy	-0.19				0.21	0.06	-0.54	-1.34	-0.31	0.09	0.53	0.42	0.612
	(-2.46)				(12.16)	(3.17)	(-1.95)	(-3.46)	(-0.67)	(0.23)	(1.02)	(6.37)	
	-0.18	0.13	-0.01	-0.20	0.21	0.05	-0.24	-1.05	-0.18	0.09	0.44	0.47	0.666
	(-2.28)	(1.19)	(-0.05)	(-1.54)	(9.73)	(2.94)	(-0.82)	(-2.48)	(-0.36)	(0.22)	(0.85)	(6.92)	
Equity Market Neutral	-0.14				0.08	0.01	-0.32	-0.62	-0.40	0.16	0.32	0.44	0.197
	(-2.10)				(4.91)	(0.65)	(-1.25)	(-1.77)	(-0.93)	(0.46)	(0.69)	(7.34)	
	-0.11	0.17	-0.04	-0.10	0.09	0.01	-0.25	-0.66	-0.67	0.26	0.40	0.37	0.227
	(-1.49)	(1.78)	(-0.37)	(-0.86)	(4.32)	(0.63)	(-0.95)	(-1.71)	(-1.44)	(0.69)	(0.84)	(6.03)	
Fixed Income Arbitrage	-0.12				0.03	0.01	-1.80	-3.61	-1.44	-0.87	0.51	0.36	0.475
	(-1.51)				(1.59)	(0.62)	(-6.36)	(-9.22)	(-3.03)	(-2.3)	(0.97)	(5.33)	
	-0.04	0.42	-0.08	-0.18	0.06	0.00	-1.51	-3.81	-1.25	-0.71	0.76	0.34	0.543
	(-0.50)	(3.98)	(-0.75)	(-1.38)	(3.03)	(0.27)	(-5.18)	(-9.09)	(-2.46)	(-1.73)	(1.48)	(5.12)	
Global Macro	-0.09				0.14	0.06	-1.94	-1.66	-1.32	3.14	1.64	0.39	0.371
	(-0.78)				(5.27)	(1.92)	(-4.34)	(-2.68)	(-1.75)	(5.23)	(1.99)	(3.67)	
	-0.09	0.47	-0.17	-0.36	0.20	0.06	-1.95	-1.49	-0.54	2.26	1.70	0.39	0.385
	(-0.74)	(2.81)	(-0.93)	(-1.74)	(5.70)	(1.94)	(-4.21)	(-2.23)	(-0.66)	(3.44)	(2.08)	(3.65)	
Dedicated Short Bias	-0.02				-0.93	-0.44	-1.03	-3.12	0.26	0.41	0.18	0.45	0.844
	(-0.10)				(-23.67)	(-10.11)	(-1.61)	(-3.5)	(0.24)	(0.47)	(0.15)	(2.95)	
	0.01	0.04	-0.09	0.06	-0.91	-0.42	-1.18	-3.12	-0.25	0.14	0.34	0.37	0.852
	(0.04)	(0.15)	(-0.31)	(0.19)	(-16.87)	(-9.29)	(-1.61)	(-2.95)	(-0.19)	(0.14)	(0.26)	(2.16)	
Managed Futures	0.19				-0.01	0.00	-2.50	-0.65	2.93	4.04	5.54	0.53	0.344
	(0.96)				(-0.32)	(0.09)	(-3.36)	(-0.63)	(2.34)	(4.04)	(4.02)	(3.00)	
	0.15	0.07	0.29	0.25	0.00	0.02	-2.67	-0.98	3.30	4.19	5.33	0.52	0.349
	(0.65)	(0.22)	(0.90)	(0.66)	(-0.07)	(0.31)	(-3.14)	(-0.80)	(2.24)	(3.50)	(3.59)	(2.67)	

Table IV. Tail Risk in the Cross-Section of Hedge Fund Returns. This table presents the average excess returns and alphas for hedge fund portfolios formed on the basis of their exposures to the tail risk shocks. In each month, we form five portfolios based on funds' tail risk beta over the past 24 months. We vary the holding periods of these portfolios for *K* months, with *K* ranging from 1 to 12. We also present the post-ranking tail risk beta for the hedge fund portfolios with one month holding period. The Newey-West (1987) *t*-statistics are reported in parentheses. *, **, and *** denote significance at the 10%, 5% and 1% levels.

	Low Tail Beta	2	3	4	High Tail Beta	High - Low
Post Ranking Tail Risk Beta	-0.33	-0.04	0.03	0.01	0.20	0.53
						(2.88)
	Holding Period: One Month					
Average Excess Return	0.85	0.53	0.46	0.39	0.36	-0.49***
	(3.47)	(3.47)	(3.85)	(2.71)	(1.55)	(-2.63)
Fung-Hsieh 7-Factor α	0.78	0.46	0.41	0.31	0.25	-0.53***
	(4.71)	(5.36)	(5.97)	(3.42)	(1.53)	(-2.69)
	Holding Period: Three Months (Overlapping)					
Average Excess Return	0.82	0.53	0.44	0.39	0.39	-0.43***
	(3.23)	(3.21)	(3.18)	(2.47)	(1.57)	(-2.72)
Fung-Hsieh 7-Factor α	0.75	0.47	0.39	0.31	0.28	-0.47***
	(5.07)	(5.39)	(5.06)	(3.60)	(1.83)	(-2.82)
	Holding Period: Six Months (Overlapping)					
Average Excess Return	0.80	0.52	0.44	0.40	0.40	-0.40***
	(3.17)	(3.02)	(3.04)	(2.38)	(1.54)	(-3)
Fung-Hsieh 7-Factor α	0.73	0.45	0.39	0.32	0.29	-0.44***
	(5.36)	(5.21)	(4.72)	(3.57)	(1.89)	(-3.2)
	Holding Period: Nine Months (Overlapping)					
Average Excess Return	0.79	0.51	0.45	0.41	0.40	-0.39***
	(3.21)	(2.98)	(2.95)	(2.37)	(1.49)	(-3.15)
Fung-Hsieh 7-Factor α	0.71	0.44	0.39	0.34	0.29	-0.42***
	(5.44)	(5.06)	(4.48)	(3.53)	(1.93)	(-3.54)
	Holding Period: Twelve Months (Overlapping)					
Average Excess Return	0.75	0.50	0.44	0.42	0.43	-0.33**
	(3.18)	(2.99)	(2.81)	(2.42)	(1.65)	(-2.5)
Fung-Hsieh 7-Factor α	0.67	0.43	0.38	0.35	0.33	-0.35***
	(5.22)	(5.01)	(4.09)	(3.58)	(2.25)	(-3.05)

Table V. Alternative Performance Evaluation Models. This table presents the average excess returns and alphas for hedge fund portfolios formed on the basis of their exposures to tail risk shocks using three alternative performance evaluation models: a four-factor model that augments the Fama and French (1993) three factors with a momentum factor; a five-factor model that further includes the Pastor and Stambaugh (2003) factor; and a nine-factor model that augments the Fung and Hsieh seven factors with returns to OTM put options on the S&P500 Index and returns to a long-short strategy that buys OTM and shorts ATM put options on the S&P500 Index. In each month, we form five portfolios based on the funds' tail risk beta over the past 24 months. We vary the holding periods of these portfolios for *K* months, with *K* ranging from one to 12. We also present the post-ranking tail risk beta for the hedge fund portfolios with one-month holding period. The Newey-West (1987) *t*-statistics are reported in parentheses. *, **, and *** denote significance at the 10%, 5% and 1% levels.

	Low Tail Beta	2	3	4	High Tail Beta	High - Low
Post Ranking Tail Risk Beta	-0.33	-0.04	0.03	0.01	0.2	0.53
						(2.88)
Holding Period: One Month						
4-Factor α	0.6	0.36	0.32	0.24	0.17	-0.42***
	(3.85)	(3.97)	(4.72)	(3.05)	(1.22)	(-2.61)
5-Factor α	0.55	0.32	0.3	0.22	0.2	-0.35**
	(3.48)	(3.56)	(4.28)	(2.82)	(1.36)	(-2.14)
9-Factor (Option) α	0.82	0.47	0.41	0.29	0.32	-0.50**
	(4.48)	(4.35)	(4.55)	(2.35)	(1.56)	(-1.98)
Holding Period: Three Months (Overlapping)						
4-Factor α	0.58	0.36	0.3	0.24	0.2	-0.38***
	(3.95)	(3.88)	(3.73)	(2.88)	(1.37)	(-2.65)
5-Factor α	0.54	0.33	0.28	0.22	0.22	-0.32**
	(3.66)	(3.51)	(3.31)	(2.62)	(1.44)	(-2.26)
9-Factor (Option) α	0.81	0.48	0.4	0.29	0.34	-0.46**
	(4.81)	(4.40)	(3.91)	(2.43)	(1.73)	(-2.08)
Holding Period: Six Months (Overlapping)						
4-Factor α	0.57	0.35	0.31	0.25	0.21	-0.36***
	(3.78)	(3.62)	(3.59)	(2.85)	(1.44)	(-2.91)
5-Factor α	0.53	0.31	0.29	0.23	0.22	-0.31**
	(3.62)	(3.20)	(3.11)	(2.46)	(1.45)	(-2.53)
9-Factor (Option) α	0.81	0.46	0.4	0.32	0.31	-0.51***
	(5.14)	(4.20)	(3.75)	(2.69)	(1.66)	(-2.7)

	Low Tail Beta	2	3	4	High Tail Beta	High - Low
Holding Period: Nine Months (Overlapping)						
4-Factor α	0.56	0.34	0.31	0.26	0.2	-0.36***
	(3.83)	(3.69)	(3.59)	(3.07)	(1.45)	(-3.42)
5-Factor α	0.52	0.31	0.29	0.24	0.21	-0.31***
	(3.66)	(3.14)	(2.99)	(2.56)	(1.40)	(-2.95)
9-Factor (Option) α	0.81	0.46	0.41	0.33	0.29	-0.52***
	(5.28)	(4.18)	(3.52)	(2.75)	(1.69)	(-3.34)
Holding Period: Twelve Months (Overlapping)						
4-Factor α	0.53	0.34	0.29	0.27	0.22	-0.31***
	(3.71)	(3.78)	(3.36)	(3.28)	(1.80)	(-3.17)
5-Factor α	0.49	0.31	0.27	0.25	0.23	-0.26***
	(3.55)	(3.16)	(2.70)	(2.70)	(1.71)	(-2.68)
9-Factor (Option) α	0.76	0.46	0.39	0.36	0.32	-0.44***
	(5.15)	(4.21)	(3.17)	(2.95)	(1.99)	(-2.99)

Table VI. Hedge Fund Exposures to Tail Risk Controlling for Additional Factors.
This table presents the results of time-series regressions of hedge fund portfolio returns on tail risk shocks and the Fung and Hsieh seven factors after controlling for liquidity risk factors (the Pastor and Stambaugh (2003) liquidity risk factor and the Sadka (2006) permanent variable factor) or a correlation risk factor. We compute monthly returns on an equal-weight portfolio of all individual hedge funds in our sample in excess of the one-month Treasury-bill rate. The tail risk, liquidity risk, and correlation risk variables are standardized to have a mean of zero and standard deviation of one. Except for the loadings on MKTRF and SMB, all estimates are multiplied by 100 for presentation purposes. Our sample period is from January 1994 to December 2009.

	(1)	(2)	(3)
Tail	-0.24	-0.23	-0.22
	(-2.84)	(-2.66)	(-2.48)
Pastor-Stambaugh	0.18		
	(2.42)		
Sadka PV		0.13	
		(1.63)	
Correlation Risk			-0.08
			(-0.97)
VRP			
MKTRF	0.269	0.278	0.278
	(13.77)	(14.41)	(14.32)
SMB	0.128	0.123	0.124
	(6.09)	(5.80)	(5.84)
ΔTERM	-0.98	-0.85	-0.90
	(-3.14)	(-2.63)	(-2.80)
ΔCREDIT	-1.78	-1.61	-1.71
	(-4.11)	(-3.52)	(-3.78)
PTFSBD	-0.35	-0.39	-0.31
	(-0.67)	(-0.73)	(-0.59)
PTFSFX	0.85	0.89	0.83
	(2.04)	(2.10)	(1.94)
PTFSCOM	1.68	1.62	1.58
	(2.91)	(2.78)	(2.70)
Intercept	0.48	0.48	0.48
	(6.49)	(6.39)	(6.37)
Observations	192	192	192
Adj R-squared	0.711	0.713	0.703

Table VII. Portfolio Double Sorts on Tail Risk and Additional Factors. This table presents average excess returns and the Fung and Hsieh seven-factor alpha on 25 hedge fund portfolios from independent sorts on tail risk beta and Pastor and Stambaugh's (2003) liquidity risk beta (Panel A), Sadka's (2006) permanent variable factor (Panel B), or a correlation risk factor (Panel C). All betas are estimated in bivariate regressions of fund excess returns on the relevant risk measure and the excess return on the aggregate stock market over the previous 24 months. *, **, and *** denote significance at the 10%, 5% and 1% levels.

	Average Excess Return						Fung and Hsieh 7-Factor α					
Panel A: PS Liquidity Risk Beta												
Tail Risk Beta	Low				High	High-Low	Low				High	High-Low
Low	0.99	0.83	0.84	0.82	0.72	-0.27	1.00	0.76	0.76	0.73	0.59	-0.42
	(4.52)	(4.88)	(3.96)	(3.92)	(2.06)	(-0.7)	(4.30)	(4.80)	(4.09)	(4.84)	(2.69)	(-1.44)
	0.59	0.54	0.50	0.54	0.53	-0.06	0.56	0.50	0.45	0.44	0.38	-0.19
	(4.26)	(6.23)	(4.63)	(3.11)	(1.65)	(-0.19)	(3.90)	(6.56)	(5.56)	(4.13)	(2.25)	(-0.94)
	0.63	0.40	0.39	0.46	0.62	-0.01	0.61	0.36	0.35	0.38	0.46	-0.16
	(4.09)	(5.54)	(4.24)	(2.88)	(2.02)	(-0.04)	(3.95)	(5.91)	(5.26)	(3.97)	(2.86)	(-0.7)
	0.44	0.36	0.42	0.41	0.43	-0.01	0.41	0.34	0.35	0.30	0.25	-0.16
	(2.97)	(3.80)	(3.43)	(2.31)	(1.34)	(-0.05)	(2.81)	(4.02)	(4.09)	(2.47)	(1.53)	(-0.74)
High	0.38	0.40	0.17	0.30	0.37	-0.01	0.37	0.32	0.10	0.16	0.18	-0.19
	(1.43)	(1.95)	(0.88)	(1.25)	(0.97)	(-0.03)	(1.47)	(1.88)	(0.62)	(0.91)	(0.78)	(-0.61)
High-Low	-0.60**	-0.43**	-0.66***	-0.52***	-0.35*		-0.63**	-0.43**	-0.66***	-0.57***	-0.41**	
	(-2.28)	(-1.98)	(-3.27)	(-2.73)	(-1.79)		(-2.44)	(-1.99)	(-3.06)	(-2.82)	(-2.10)	

	Average Excess Return						Fung and Hsieh 7-Factor α					
Panel B: Sadka Liquidity Risk Beta												
Tail Risk Beta	Low				High	High-Low	Low				High	High-Low
Low	0.65	0.78	0.71	0.78	1.10	0.45**	0.56	0.68	0.63	0.70	1.04	0.48**
	(2.57)	(4.27)	(3.89)	(3.65)	(4.20)	(2.05)	(2.83)	(4.71)	(4.44)	(4.15)	(4.87)	(2.04)
	0.57	0.52	0.45	0.55	0.70	0.13	0.49	0.47	0.39	0.47	0.65	0.16
	(3.12)	(4.47)	(3.91)	(4.06)	(3.42)	(0.72)	(3.62)	(5.63)	(4.48)	(5.11)	(3.84)	(0.74)
	0.59	0.35	0.38	0.48	0.79	0.20	0.53	0.32	0.34	0.39	0.74	0.22
	(4.00)	(3.62)	(4.28)	(3.57)	(3.98)	(1.23)	(4.49)	(4.20)	(5.82)	(3.80)	(4.63)	(1.26)
	0.25	0.22	0.44	0.50	0.64	0.39**	0.13	0.15	0.35	0.42	0.57	0.44**
	(1.50)	(1.71)	(3.48)	(3.23)	(2.93)	(2.20)	(0.93)	(1.40)	(3.60)	(4.27)	(3.65)	(2.12)
High	0.27	0.21	0.25	0.54	0.48	0.21	0.15	0.07	0.14	0.46	0.38	0.23
	(1.08)	(0.97)	(1.12)	(2.19)	(1.53)	(0.82)	(0.69)	(0.42)	(0.80)	(2.34)	(1.53)	(0.78)
High-Low	-0.38	-0.58***	-0.46**	-0.24	-0.62***		-0.42	-0.62***	-0.49**	-0.24	-0.66***	
	(-1.48)	(-3.12)	(-2.59)	(-1.12)	(-3.19)		(-1.62)	(-3.24)	(-2.55)	(-1.06)	(-3.4)	
Panel C: Correlation Risk Beta												
Tail Risk Beta	Low				High	High-Low	Low				High	High-Low
Low	1.04	0.75	0.65	0.64	0.75	-0.28	0.96	0.71	0.56	0.57	0.67	-0.29
	(3.89)	(3.86)	(3.18)	(3.14)	(2.81)	(-1.18)	(4.48)	(4.46)	(4.01)	(3.69)	(3.03)	(-1.2)
	0.78	0.54	0.46	0.43	0.51	-0.26	0.66	0.49	0.41	0.37	0.44	-0.22
	(4.01)	(4.16)	(4.09)	(3.06)	(2.53)	(-1.59)	(4.49)	(5.33)	(5.39)	(3.99)	(3.14)	(-1.24)
	0.86	0.51	0.35	0.38	0.59	-0.27	0.80	0.45	0.31	0.31	0.54	-0.25
	(4.69)	(4.09)	(3.77)	(3.49)	(3.25)	(-1.49)	(5.26)	(5.24)	(4.88)	(3.70)	(3.86)	(-1.27)
	0.87	0.37	0.36	0.33	0.31	-0.56***	0.77	0.28	0.28	0.26	0.22	-0.56***
	(4.08)	(2.44)	(2.82)	(2.60)	(1.87)	(-3.52)	(4.89)	(2.63)	(2.65)	(2.45)	(1.82)	(-3.38)
High	0.29	0.33	0.28	0.34	0.42	0.13	0.16	0.22	0.17	0.21	0.35	0.19
	(0.97)	(1.45)	(1.19)	(1.57)	(1.75)	(0.55)	(0.73)	(1.50)	(0.90)	(1.25)	(1.83)	(0.78)
High-Low	-0.75***	-0.42**	-0.36*	-0.31	-0.33		-0.80***	-0.49***	-0.39*	-0.36*	-0.32	
	(-3.27)	(-2.48)	(-1.86)	(-1.58)	(-1.38)		(-3.56)	(-2.67)	(-1.85)	(-1.74)	(-1.34)	

Table VIII. Tail Risk in the Cross-Section of Hedge Fund Returns for Each Style.

This table presents the average excess returns and alphas for hedge fund portfolios formed on the basis of their exposures to the tail risk factor for each investment style. In each month, for each of the 10 styles, we form five portfolios based on the funds' loadings on the tail risk factor in a regression of the funds' excess return on the market excess return and the tail factor in the past 24 months. We rebalance the portfolios each month and compute the monthly average returns for each portfolio. The Newey-West (1987) *t*-statistics are reported in parentheses. *, **, and *** denote significance at the 10%, 5% and 1% levels.

	Low Tail Beta	2	3	4	High Tail Beta	High - Low
			Emerging Markets			
# of Funds	33	34	34	34	33	
Average Excess Return	1.52	0.6	0.56	0.72	0.52	-1.00***
	(2.63)	(1.58)	(1.68)	(2.05)	(0.93)	(-2.75)
Fung-Hsieh 7-Factor α	1.3	0.43	0.41	0.51	0.18	-1.12***
	(3.10)	(1.64)	(1.69)	(1.86)	(0.36)	(-2.91)
			Long/Short Equity			
# of Funds	132	132	132	132	132	
Average Excess Return	0.95	0.81	0.62	0.43	0.42	-0.53**
	(3.12)	(3.87)	(3.15)	(1.86)	(1.23)	(-2.17)
Fung-Hsieh 7-Factor α	0.87	0.73	0.54	0.34	0.3	-0.56**
	(4.26)	(5.62)	(5.08)	(2.63)	(1.55)	(-2.21)
			Multi-Strategy			
# of Funds	24	24	24	24	24	
Average Excess Return	0.77	0.45	0.39	0.39	0.31	-0.45**
	(3.35)	(3.23)	(3.31)	(3.41)	(1.71)	(-2.54)
Fung-Hsieh 7-Factor α	0.67	0.42	0.35	0.37	0.19	-0.48**
	(4.03)	(4.89)	(4.10)	(4.18)	(1.19)	(-2.3)
			Event Driven			
# of Funds	40	40	40	40	40	
Average Excess Return	0.76	0.48	0.43	0.31	0.42	-0.35**
	(3.02)	(3.19)	(3.03)	(2.53)	(2.36)	(-2.18)
Fung-Hsieh 7-Factor α	0.65	0.43	0.36	0.26	0.35	-0.29**
	(4.53)	(4.84)	(4.07)	(3.24)	(3.08)	(-2.09)
			Convertible Arbitrage			
# of Funds	14	14	14	14	14	
Average Excess Return	0.57	0.32	0.22	0.37	0.31	-0.25
	(1.60)	(1.49)	(1.11)	(1.98)	(1.32)	(-1.08)
Fung-Hsieh 7-Factor α	0.53	0.28	0.19	0.34	0.24	-0.29
	(2.40)	(2.07)	(1.30)	(2.81)	(1.40)	(-1.28)

	Low Tail Beta	2	3	4	High Tail Beta	High - Low
			Dedicated Short Bias			
# of Funds	2	3	3	3	3	
Average Excess Return	-0.3	0.15	-0.18	-0.22	-0.49	-0.19
	(-0.44)	(0.29)	(-0.41)	(-0.51)	(-0.86)	(-0.34)
Fung-Hsieh 7-Factor α	0.03	0.4	-0.05	-0.06	-0.3	-0.33
	(0.05)	(1.25)	(-0.21)	(-0.22)	(-0.76)	(-0.56)
			Managed Futures			
# of Funds	36	37	37	37	36	
Average Excess Return	0.64	0.53	0.41	0.41	0.52	-0.12
	(2.51)	(2.58)	(2.04)	(1.63)	(1.37)	(-0.4)
Fung-Hsieh 7-Factor α	0.64	0.53	0.39	0.41	0.55	-0.08
	(2.73)	(2.78)	(2.33)	(1.80)	(1.65)	(-0.29)
			Equity Market Neutral			
# of Funds	18	18	18	18	18	
Average Excess Return	0.45	0.32	0.29	0.24	0.41	-0.04
	(3.08)	(3.74)	(2.83)	(2.65)	(3.57)	(-0.25)
Fung-Hsieh 7-Factor α	0.43	0.29	0.26	0.2	0.4	-0.03
	(2.99)	(3.55)	(2.37)	(2.34)	(3.52)	(-0.16)
			Global Macro			
# of Funds	17	17	17	17	17	
Average Excess Return	0.29	0.33	0.22	0.45	0.47	0.18
	(1.36)	(2.09)	(1.54)	(3.02)	(2.21)	(0.82)
Fung-Hsieh 7-Factor α	0.11	0.27	0.13	0.39	0.36	0.25
	(0.59)	(2.00)	(1.04)	(3.13)	(1.88)	(1.18)
			Fixed Income Arbitrage			
# of Funds	13	14	14	14	14	
Average Excess Return	0.14	0.43	0.34	0.22	0.37	0.23
	(0.57)	(3.44)	(4.19)	(2.04)	(2.09)	(1.18)
Fung-Hsieh 7-Factor α	0.06	0.42	0.35	0.2	0.36	0.29*
	(0.37)	(4.38)	(5.09)	(1.93)	(2.47)	(1.66)

Table IX. Tail Risk Betas and Hedge Fund Characteristics. This table reports Fama-MacBeth (1973) cross-sectional regression coefficients of monthly estimated tail risk beta on contemporaneous fund characteristics over the period December 1995 to November 2009. For ease of interpretation, we cross-sectionally standardize tail risk beta, size, age, fund return, return volatility and fund flow to have means of zero and standard deviations of one. The payout period, redemption notice period, and lockup period are transformed using the natural log of one plus the number of days. Variable descriptions are provided in the text. Test statistics are based on Newey-West (1987) standard errors with a 24-month lag. *, **, and *** denote significance at the 10%, 5% and 1% levels.

	(1)	(2)	(3)	(4)	(5)	(6)
Size	-0.012	0.034	0.047**	-0.013	-0.011	0.01
	(-0.58)	(1.56)	(2.33)	(-0.61)	(-0.47)	(0.47)
Age	0.032***	0.019**	0.01	0.025**	0.033***	0.013
	(2.64)	(1.99)	(1.56)	(1.99)	(2.68)	(1.31)
Management Fee		5.812				2.543
		(1.65)				(0.98)
Incentive Fee		0.602				0.58
		(1.39)				(1.45)
High Water Mark		-0.113***				-0.092***
		(-3.82)				(-2.74)
Log Payout Period			-0.004			0.002
			(-0.58)			(0.27)
Log Redemption Period			-0.088**			-0.086**
			(-2.25)			(-2.50)
Log Lock-up Period			-0.005			-0.001
			(-0.68)			(-0.16)
Personal Capital				0.097***		0.097***
				(2.88)		(3.24)
Manager Ownership				0.009		0.061
				(0.09)		(0.66)
Leverage					0.071**	0.046
					(2.40)	(1.59)
Ret24	-0.038	-0.043	-0.039	-0.042	-0.04	-0.051*
	(-1.34)	(-1.56)	(-1.50)	(-1.49)	(-1.45)	(-1.97)
Flow24	0.018	0.016	0.009	0.019	0.020*	0.013
	(1.51)	(1.42)	(0.91)	(1.61)	(1.68)	(1.34)
Volatility	-0.137***	-0.136***	-0.147***	-0.140***	-0.138***	-0.150***
	(-4.41)	(-4.01)	(-3.96)	(-4.61)	(-4.38)	(-4.00)
Adj. R^2	0.078	0.093	0.100	0.083	0.079	0.112