Is there hedge fund contagion?

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Abstract

We examine whether hedge funds are more likely to experience extremely poor returns when equity, fixed income, and currency markets or other hedge funds have extremely poor performance than would be predicted by correlations of hedge fund returns with returns on these markets or with returns of other hedge funds (contagion). First, we consider whether extreme movements in these markets are contagious to Arbitrage, Directional, and Event Driven hedge fund indices. Second, we investigate whether extreme adverse returns in one hedge fund index are contagious to other hedge fund indices. To conduct these examinations, we estimate Poisson regressions using both monthly and daily returns on hedge fund style indices. We find no systematic evidence of contagion from equity, fixed income, and currency markets to hedge fund indices, although the Arbitrage index exhibits evidence of contagion from the equity and currency markets for monthly data. In contrast, we find systematic evidence of contagion across hedge fund styles for both monthly and daily data. Our results provide a new perspective on the systemic risks of hedge funds and suggest that diversification across hedge funds may not help as much as correlations would imply in reducing the probability of very poor returns.

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Assets managed by hedge funds have grown tremendously, with more than $1 trillion in assets under management in the United States alone.[1] This growth has caused regulators concern about the risks that hedge funds might create for the financial system. For example, in June, 2006, the European Central Bank expressed concerns that "hedge funds have created a major global risk for which there are no obvious remedies," citing an increased tendency by funds to mimic strategies followed by others.[2] Hedge funds could cause systemic risk if the probability of concurrent extreme negative returns in hedge funds when financial markets have extreme returns is higher than expected based on simple correlations between hedge funds and financial markets. In this case, extreme negative returns in financial markets could lead to defaults, distressed asset sales, and deleveraging of hedge funds, which could make worse the problems in the financial markets both through the impact of sales on these markets and through the impact of the difficulties of hedge funds on financial institutions.

Paradoxically, however, a major reason cited for the tremendous growth in assets managed by hedge funds is that they offer a valuable source of diversification. For example, in a 2003 survey of institutional pension managers sponsored by State Street Global Advisors, 77% of the respondents cited diversification as an "important" or "extremely important" reason for including hedge funds in a portfolio.[3] Of course, if hedge funds are likely to have extreme negative returns when financial markets also have such returns, the diversification benefit of investing in hedge funds would be least valuable when it is needed most: when financial markets in general perform poorly. In this paper, we investigate whether this is the case.

[1] See Stulz (2007).
[2] See "ECB warns of hedge fund threat to stability," *Financial Times*, June 2, 2006.
[3] Survey was administered by InvestorForce and included 111 large pension sponsors. See full results at: http://www.investorforce.com/images/flonetwork/Hedge_Fund_Survey_2003.pdf.

Studies have shown that hedge fund returns do not follow a normal distribution, that they tend to be heavily skewed, and that their correlations with some risk factors are not stationary.[4] It is well-known that correlation is a poor measure of dependence under such conditions (see, e.g., Embrecht, McNeil, and Straumann, 2002). Consequently, the correlations that play a central role in modern portfolio theory can lead to misleading inferences about the true risk of hedge fund investments and the systemic risks created by the growth of the hedge fund industry.

The most worrisome weakness of correlation, given the properties of hedge fund returns, is that it fails to adequately capture contagion if contagion is present. By contagion, we mean the phenomenon that during bad times assets tend to move together more closely than would be predicted using correlations. Hence, contagion measures a nonlinear effect that is not captured by the linear correlation measure.[5]

The possibility of contagion from traditional asset classes to hedge funds as well as between hedge funds is relevant for investors, for risk managers, and for regulators. If there is a high probability of contagion from traditional asset classes to hedge funds, the diversification benefits of hedge funds do not extend to periods of extremely poor returns in traditional asset classes. If there is a high probability of contagion within the hedge fund sector, diversification across hedge fund styles does not offer protection against extremely poor returns in a specific style. Further, there should be more of a concern of systemic risk from hedge funds if there is contagion between hedge fund styles and from the traditional asset classes to hedge funds, because in bad times a significant number of hedge funds will perform poorly, thereby threatening the health of the financial institutions that are their lenders and their counterparties in trades.

[4] See, for example, Agarwal and Naik (2000), Amin and Kat (2004), Bacmann and Gawron (2004), Brealey and Kaplanis (2001), Brooks and Kat (2002), Chan, Getmansky, Haas, and Lo (2005), Fung and Hsieh (1997, 1999, 2001), Geman and Karoubi (2003), Getmansky, Lo, and Makarov (2004), and Lo (2002).

[5] We understand that there are many definitions of contagion (see Dornbush, Park, and Claessens, 2000). We use this definition because we believe, following Bae, Karolyi, and Stulz (2003), that it corresponds most closely to the meaning of contagion in epidemiology.

Our paper builds on and contributes to a large and growing literature on the exposure of hedge funds to risk factors. A number of studies, including Fung and Hsieh (1997, 1999, 2001), Brown, Goetzmann and Ibbotson (1999), Ackermann, McEnally and Ravenscraft (1999), Liang (1999), and Agarwal and Naik (2000, 2004), have examined the relationship between hedge fund returns and broad market returns. The studies that focus on linear measures of association, such as beta, generally find a weak relationship between market returns and hedge fund returns. However, when studies relax the assumption of linearity, a more complicated relationship is uncovered. For example, Edwards and Caglayan (2001) examine performance in up and down markets, and show that, on average, hedge funds have stronger positive correlations with broad market indices during bear markets, but that three hedge fund styles – Market Neutral, Event Driven, and Global Macro – provide some measure of downside protection during bear markets. Similarly, Schneeweis, Karavas, and Georgiev (2002) estimate unconditional and conditional correlations between hedge funds and stock market indices and find that correlations differ between up and down markets. Mitchell and Pulvino (2001) show that most risk arbitrage hedge funds are positively correlated with market returns in down markets but uncorrelated with the market in up markets. Liang (2004) reports a similar result for a broader range of hedge fund styles. Fung and Hsieh (1997, 2001, 2004), Mitchell and Pulvino (2001), and Agarwal and Naik (2004) show that exposures to risk factors of hedge funds have option-like properties, so that exposures can vary with the performance of broad market indices when these indices are chosen as risk factors.

In contrast to this earlier literature, we focus explicitly on understanding the determinants of extreme returns of hedge funds and allow for the possibility of contagion from the broad markets as well as from other hedge funds. We use a Poisson regression approach to model the incidence of contagion in which the dependent variable is an indicator variable set to 1 if the hedge fund index being tested experiences an extreme bad outcome and 0 otherwise. Similarly, independent variables representing the other indices of interest (e.g., broad market indices) are set to 1 if the index experiences an extremely bad return and 0 otherwise. The Poisson regression framework is suitable to analyze "count data" that is common in event history analysis and other research involving rare events where assumptions of a normally distributed dependent variable do not apply. It is particularly appropriate when the outcome of interest is rare, so that the Poisson approximation to the binomial distribution can be used (Gart, 1978). It has often been used in medical and clinical work; for example, it might be used when the dependent variable is a count of rare events such as the number of cases of lung cancer occurring in a population over a certain period of time.

Previous finance literature has used the logistic model to test for contagion, assuming an underlying binomial or multinomial distribution.[6] However, for rare events such as the contagion events that we model, it can be argued that the Poisson regression framework is more appropriate since the underlying Poisson distribution explicitly assumes that the probability of observing an additional event of a count variable (as in 0 events versus 1 event, or 1 event versus 2 events) is "small."[7] By contrast, the binomial and multinomial distributions are not based on such an assumption and might be less suitable to estimate events with such small probabilities. Hence the primary analysis of this paper uses the Poisson regression framework while robustness tests use the binomial and multinomial distribution models. The Poisson regression has been used occasionally in finance applications; some examples include Hausmann, Hall, and Griliches (1984) who apply Poisson regressions to analyze the relationship between R&D and patent applications, and Hermalin and Weisbach (1988) and Lerner (1995), both of whom use a Poisson regression to model the addition and departure of Board members after CEO turnover.

We use both monthly and daily hedge fund index return data for our analysis. The use of daily data represents an important innovation of our paper since earlier hedge fund research uses monthly data. There are both benefits and costs to using daily data. The main benefit is that using

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[6] See, for example, Eichengreen, Rose, and Wypolz, (1996) and Bae, Karolyi, and Stulz (2003).
[7] We thank Bill Greene for suggesting the use of the Poisson model.

higher frequency data makes our tests more powerful. With the daily data, we focus on 5% tail events. Such events occur less than once every twenty months with monthly data. Since hedge fund index monthly time-series data rarely extends past fifteen years, a study using monthly data and focusing on 5% tail events would be based on a sample with only nine tail events. We therefore use 10% tail events with monthly data. The three main costs of daily data are that the indices that report daily returns include only a subset of hedge funds, namely transparent hedge funds willing to provide daily pricing, that the indices are available for a relatively short period of time, and that there are legitimate concerns about how meaningful daily valuations are for hedge funds that use over-the-counter instruments. Monthly return indices are much less affected by these problems, but the available sample size is smaller with monthly returns than with daily returns.

Both the daily and monthly data are provided by Hedge Fund Research (HFR). The monthly data covers the period January 1990 to June 2006 while the daily data begins on April 1, 2003.[8] We group the HFR data into three aggregate indices: Arbitrage, Directional/Tactical, and Event Driven. These commonly-defined categories are used by a number of academics and practitioners and allow for the estimation of a more parsimonious model than using all the indices provided by HFR. We condition on a number of economic control variables, including broad market indices, interest rates, market volatility, and the asset-based factors proposed by Fung and Hsieh (2001 and 2004). For daily data we also perform analyses using the eight hedge fund sub-indices to further investigate the sources and existence of contagion.

We begin with the analysis of monthly data, which is performed at the aggregate index level. Out of a possible nine coefficients for contagion of extreme negative market movements, we find

[8] An earlier version of this paper also used hedge fund index data provided by Standard and Poor's. Unfortunately, due to the closure of one of the hedge funds in the Standard & Poor's index and an ongoing legal investigation into this hedge fund, the Standard and Poor's data is not deemed reliable beyond some time in 2005, as one reason for this fund's closure was fraudulent data reporting. As a result of this event, a number of funds in the Standard and Poor's index stopped reporting data to Standard and Poor's, and the index was discontinued in its form in June of 2006.

only three coefficients consistent with contagion. Specifically, among extreme negative returns, equity and currency markets are contagious to the Arbitrage index but bond returns are not, and bond markets are contagious to the Directional index. The Arbitrage index is less likely to have an extreme negative return when the bond market has an extremely poor return and the Directional index is less likely to have an extreme negative return when equity markets have an extremely poor return. While the evidence of contagion from broad markets is weak, there is strong evidence of contagion *between* the three hedge fund indices. Generally speaking, if one index experiences an extreme negative return, there is a significant increase in the likelihood that the other indices will experience an extreme negative return.

Turning to the aggregate index tests for the daily data, we find even weaker evidence of contagion from the broad markets to hedge funds than for the monthly data (the only instance of contagion is from bond markets to the Arbitrage index), but continue to find very strong evidence of contagion between the three hedge fund indices. At the sub-index level, we again find modest evidence of contagion from broad markets to hedge funds that is generally consistent with the monthly data results. More importantly however, consistent with both the monthly and daily aggregate index results, the sub-index analysis provides very strong evidence of contagion across hedge fund styles. This contagion is not concentrated in any particular sub-index, but rather, exists for each of the sub-indices.

The paper is organized as follows. In Section I we describe the data for monthly and daily hedge fund index returns. Section II uses HFR monthly hedge fund indices and examines the relationship between the three hedge fund indices and broad market returns and the relationship across hedge fund returns. Section III performs a similar analysis using HFR daily index data. Section IV performs a more detailed analysis of the eight hedge fund sub-indices, and section V performs robustness checks. We attempt to interpret our results and conclude in Section VI.

I. Data

In our study of contagion, we focus on contagion between hedge funds and three representative markets: the stock markets, the fixed-income markets, and the currency markets, as well as between hedge funds. We use the return of the Russell 3000 index to proxy for the return of the equity market, the return on the Lehman Brothers bond index (LB bond index hereafter) to proxy for the return of the fixed-income markets, and the change in the trade-weighted US dollar exchange index published by the Board of Governors of the US Federal Reserve System (FRB dollar index in the following) to proxy for the return of the currency markets.[9] We therefore also present data on these indices.

I.1. Monthly hedge fund index data from Hedge Fund Research (HFR)

Our initial tests of contagion use monthly data provided by HFR. This data extends from January 1990 to June 2006. The indices are published by HFR and consist of eight single strategy indices: Convertible Arbitrage, Distressed Securities, Equity Hedge, Equity Market Neutral, Event Driven, Macro, Merger Arbitrage, and Relative Value Arbitrage. The monthly indices are aggregates that include over 1,600 funds, with no required minimum track record or asset size. Additionally, the monthly indices are not investible; that is, they include funds that are closed to new investment dollars.[10]

I.2. Daily hedge fund index data from Hedge Fund Research (HFR)

In addition to the monthly HFR indices, we also use HFR daily indices. The daily data covers the same eight categories as the HFR monthly data, but the indices are constructed differently. They are fully investible both directly through HFR and also through a number of indexed products offered by companies such as Citigroup, ABN Amro, and UBS Warburg. The daily data for the indices begins on April 1, 2003. See Appendix B for detail on the HFR daily indices.

[9] The source for these indices is Thomson DataStream.
[10] See Appendix A for further detail on the construction of the HFR monthly indices.

All indices contain only hedge funds that are open to new investment. The individual strategy indices are rebalanced on a quarterly basis and, according to HFR, have been designed to offer daily pricing, consistent fund selection through cluster analysis, stringent risk management, and strict reporting standards. HFR also imposes a minimum asset size of $50 million and a minimum track record of 2 years. There are currently sixty-nine funds in these indices, spread across the 8 styles as appropriate to ensure that the styles are representative of the strategies they represent.

Since the requirements for inclusion in the daily and monthly indices are quite different and we use both sets of indices to test for contagion, we perform simple Pearson correlation tests to determine whether the indices are comparable. The eight correlation coefficients for each of the indices range from 0.85 to 0.94, so we are comfortable that the indices are similar enough for our analysis.

II. Tests of contagion using HFR monthly index data

We begin our analysis with the monthly data, which is available from January 1990 to June 2006 for 197 monthly observations. There is a trade-off between using monthly and daily hedge fund data to perform contagion tests; while the daily data provides more observations (872), it also covers a shorter time period. By contrast, the monthly data provide fewer observations over a longer time period, and in particular encompass a number of market crises including the Asian and Mexican currency crises and the failure of Long Term Capital Management. For the monthly data we use an upper and lower 10% cutoff of the overall distribution of returns to identify "extreme" or "tail" returns, whereas we use a 5% cutoff for the daily data.

II.1. Monthly HFR Indices: Summary statistics

There are eight HFR sub-indices. For our main analysis, we aggregate the HFR indices into three categories – Arbitrage, Directional, and Event Driven – by equally-weighting the corresponding component sub-indices. The categorization is consistent with prior literature (for example, see Agarwal and Naik, 2004) and with other hedge fund index providers such as Standard and Poor's. The aggregate Arbitrage style index includes the sub-indices of Convertible Arbitrage, Relative Value, and Equity Market Neutral. The aggregate Directional style index includes the sub-indices Macro Index and Equity Hedge. Finally, the aggregate Event Driven style index includes the sub-indices of Merger Arbitrage, Distressed Securities, and Event Driven.

Table I.A. provides summary statistics and correlations for the monthly indices and the broad markets. The data in Panel 1 indicate relatively high positive unconditional correlations between hedge fund indices. Additionally, the correlations with the Russell 3000 index are large and positive for all three monthly hedge fund indices. The correlations with the FRB dollar index (the currency index) are low or negative, and correlations with the LB Bond index are all positive, although not large.

The Arbitrage index exhibits first-order autocorrelation as shown in Panel 2, and the Ljung-Box tests reject the hypothesis of no autocorrelation for the first six lags for both the Arbitrage and Event Driven indices. These results are generally consistent with Getmansky, Lo, and Makarov (2004) and other prior literature. Finally, the normality tests as shown in Panel 3 are rejected for all three indices, although the results are significant for the Directional index at only the 10% level.

Table I.B provides a first look at the relationship across hedge fund index returns and market returns during up and down market conditions. Up markets are defined as periods when the conditioning market return is in the top half of all returns for the period, while down markets comprise periods where the conditioning market return is in the bottom half of returns. Our choices of conditioning market returns are the Russell 3000, LB bond index, and the FRB dollar index. Using this simple categorization of up and down markets, the conditional correlations between hedge fund indices and between hedge fund indices and stock, fixed income, and currency indices do not vary much from the unconditional correlations reported in Table I.A.

Though some of the correlations – both between hedge fund indices and between hedge fund indices and market indices – are fairly high, this does not ultimately affect our analysis as our contagion tests investigate the *nonlinear* relationship between hedge fund indices and broad markets and between hedge fund indices. In particular, we control for the linear relationship in our tests by including the returns on the market factors as control variables that act as instruments for the general risk exposures of hedge funds. In addition, our contagion tests include a large number of other control variables, such as volatilities and the asset-based factors (ABS) derived by Fung and Hsieh (2001, 2004) that have been shown to explain the overall returns of hedge funds. Finally we standardize the returns to control for volatility clusters (see below and Section III for details on the standardization) in our tests of contagion. Thus, our approach is carefully constructed to test for contagion over and above the linear relationship implied by these relatively high correlations.

II.2. Testing for contagion

A. Existing approaches

There is a large literature on contagion in emerging markets.[11] A large part of this literature focuses on testing whether correlations increase in troubled periods. This approach has been heavily criticized. We avoid this approach for three reasons. First, as Baig and Goldfajn (2002), Forbes and Rigobon (2002), and others argue, there are statistical difficulties involved in testing changes in correlations across different regimes. Second, using correlations is problematic in this type of test, as correlations are linear measures of association that are not appropriate to investigating behavior during extreme market conditions, while the approach we use specifically focuses on nonlinearities in return distributions. Third, correlations are particularly ill-suited for evaluating contagion for hedge funds because these funds often pursue strategies with non-linear payoffs.

[11] For surveys, see Karolyi (2003), Dungey and Fry (2004), de Bandt and Hartmann (2000), and Pesaran and Pick (2004).

An alternative approach would be to employ extreme value theory (EVT) as in Longin and Solnik (2001). Such an approach is implemented using monthly hedge fund indices by Geman and Kharoubi (2003) and Bacmann and Gawron (2004). Geman and Kharoubi (2003) find that, though above-threshold correlations between hedge fund returns and the S&P 500 index go asymptotically to zero for positive returns as the threshold increases, this is not the case for negative returns. Bacmann and Gawron (2004) find no asymptotic dependence of hedge funds and bonds, but find some dependence of hedge funds and stocks which disappears when August 1998 is removed from the sample. While EVT and the use of copulas, makes it possible to examine tail dependence without resorting to using correlations, it requires the choice of a copula function and can easily give too much weight to extremely rare observations. Further, it does not permit explicit conditioning on additional risk factors and, hence, makes it difficult to explore the determinants of contagion.

A third approach involves allowing explicitly for nonlinearities and for different return distributions in troubled times. Chan, Getmansky, Haas, and Lo (2005) follow this approach in a study of the systemic risk of hedge funds. They use models that include non-linear exposures to various markets such as squared and cubed returns on the S&P 500 index and also apply regime-switching models to hedge fund returns. We allow for nonlinearities in exposures to risk factors as well. However, we do not parameterize the tail dependencies for the same reason that we do not use copulas: our approach makes it less likely that we will give too much weight to few observations.

B. The Poisson regression approach.

We use a Poisson regression model to examine contagion.[12] A Poisson regression model is a generalized linear model with a "log" link function and Poisson distributed errors. This model attributes to a count response variable Y a Poisson distribution whose expected value depends on predictor variables x in the following way: $\log \mathrm{E}[Y_{it} \mid x_{it}] = \beta_i x_{it}$ where x_{it} is a vector of regressors

[12] Much of the following discussion follows Hausman, Hall, and Griliches (1984).

describing the characteristics of an observation unit i (a hedge fund return index in our study) during a given time period t, and Y_{it} is the observed event count (number of extreme returns) for unit i during the time period t.

If Y are independent observations with corresponding values x of the predictor variable, then β can be estimated by maximum likelihood if the number of distinct x values is at least 2. As noted earlier, the Poisson regression is particularly appropriate when analyzing "count" data for rare events that occur during a period of time t. In the monthly (daily) analysis of hedge fund returns, we set the dependent variable to 0 if the index does not have an extreme return in any given month (day), and to 1 if the index does have an extreme return, where an extreme return is defined as a standardized return that is in the highest or lowest 10% of all returns (5% for daily returns) for that index over the entire time period studied. Extreme good and extreme bad events are modeled separately. Because the events or incidents of extreme returns during any given period we are modeling are rare events by construction, the Poisson approach is well-suited for our analysis. Some other benefits of using the Poisson regression are that it handles the integer property of observed event counts directly and works well when the number of possible outcomes is small, both of which apply to our data.

If there is no contagion, a regression model in which the values of risk factors that affect hedge fund returns enter linearly should describe the likelihood that a hedge fund will have an extreme return. By contrast, with contagion from a specific risk factor, the likelihood of an extreme return is greater when that risk factor has an extreme realization than would be predicted by a model in which the risk factors enter only linearly. To account for this nonlinear dependence, we add to the regression model in which risk factors also enter linearly, indicator variables that take the value 1 when certain of the risk factors have extreme realizations and 0 otherwise where the definition of an extreme realization is equivalent to the identification of extreme hedge fund returns. Other hedge fund returns are not used as risk factors in the models of hedge fund returns. These returns are in principle captured by the typical risk factors. However, we allow also for extreme realizations of other hedge fund indices to explain the probability of extreme realizations of a hedge fund index. The coefficients on the other funds' extreme return indicator variables measure contagion among hedge fund indices.

The basic Poisson probability specification is:

$$\Pr\left(Y_{it} = n_{it} \mid x_{it}\right) = \frac{e^{-\exp(\beta_i x_{it})} \exp(\beta_i x_{it})^{n_{it}}}{n_{it}!} \tag{1}$$

In our monthly (daily) analysis, i represents a hedge fund index, t the month (day), and $n_{it} \in \{0,1\}$ whether index i has an extreme outcome (Y_{it} = 1) during month (day) t. The mean value of Y, $\exp(\beta_i x_{it})$, depends on a vector of explanatory variables x_{it}, where the exponential function guarantees non-negativity. Maximum likelihood with a log-likelihood function is used to estimate the model for a sample of T observations for each index as:

$$L(\beta_i) = \sum_{t=1}^{T} [n_{it}! - e^{\beta_i x_{it}} + n_{it}!\, \beta_i x_{it}] \tag{2}$$

Goodness-of-fit is measured using McFadden's (1974) pseudo-R^2 approach, where both unrestricted (full model) likelihood, L_ω, and restricted (constant only model) likelihood, L_Ω, are compared:

$$\text{pseudo } R^2 = 1 - \frac{\log L_\omega}{\log L_\Omega} \tag{3}$$

As noted earlier, we use the Poisson regression approach for the majority of our analyses. In addition, we use the binomial and multinomial logit models for robustness tests.[13]

II.3. Contagion between monthly hedge fund and market indices, and across hedge fund indices

We wish to identify the extent to which hedge fund indices are subject to contagion. Since Fung and Hsieh (1997), it is well-known that hedge funds pursue strategies with highly non-linear

[13] For a detailed description of the logit models used, see Bae, Karolyi, and Stulz (2003).

payoffs. It is therefore important that we do not mistakenly identify contagion for the outcome of strategies with non-linear payoffs. Thus, we use the payoffs of such strategies as explanatory variables to make sure that we are able to separate contagion from normal co-movement.

Hedge fund returns are related to a number of risk factors, including equity, fixed income, and commodity factors as well as non-linear factors such as put options on the S&P 500 index, returns on "lookback straddles", and other factors.[14] To control for shifts in the mean returns with as many risk factors as possible, we include the following factors in our analysis: the return on the Russell 3000 index, the change in the FRB dollar index, the return on the LB bond index, the return on the 3-month Treasury bill, and the negative portion of the S&P index return to proxy for a put option. In addition, because it is likely that the volatility in these indices could be related to extreme returns in our dependent variables, we include a measure of monthly volatility extracted from univariate GARCH(1,1) models for each of the following factors: the return on the Russell 3000, the change in the FRB dollar index, and the return on the LB bond index.

In addition, we follow Fung and Hsieh (2001 and 2004) and control for additional risk factors using asset-based factors that are designed to mimic the returns of certain types of hedge fund strategies. Five of these factors are from Fung and Hsieh (2001). These factors are modeled as "Primitive Trend-Following Strategies" (PFTS), or "lookback straddles." Simply stated, a lookback straddle strategy assumes that an investor owns both a lookback call option, which gives an investor the right to buy an asset at its lowest price over the life of the option and a lookback put option, which gives an investor the right to sell an asset at its highest price over the life of the option. Fung and Hsieh construct lookback straddles on bonds, currencies, commodities, short-term interest rates, and equities.[15]

We also use three additional asset-based factors, as suggested by Fung and Hsieh (2004). These are a size-spread factor, calculated as the Wilshire Small Cap 1750 - Wilshire Large Cap

[14] See, for example, Fung and Hsieh (1997, 2001, 2004), Ackermann, McEnally and Ravenscraft (1999), Liang (1999), Mitchell and Pulvino (2001), and Agarwal and Naik (2000, 2004).
[15] We thank David Hsieh for providing us these returns for the period January, 1990 to June, 2006.

750 monthly return, a bond factor, calculated as the change in the 10-year treasury constant maturity yield from month-end to month-end, and finally, a credit spread factor, calculated as the change in the monthly spread of Moody's Baa yield less the 10-year treasury constant maturity yield from month-end to month-end.[16]

In addition to the above factors, we include indicator variables that represent extreme return events (top or bottom 10%) for each of the stock, bond, and currency markets as well as the other hedge fund indices to test for non-linear contagion effects both from markets to hedge funds and across hedge fund styles. Specifically, for the "negative tail" case, the "same-direction" market (other hedge fund style) indicator variable is set to one if the relevant market (other hedge fund style) has an extreme negative return and zero otherwise. When both the hedge fund index of interest and a market (other hedge fund style) experience extreme negative returns, the coefficient on the market (other hedge fund style) indicator variable will be positive indicating contagion among extreme poor returns.

In contrast, a negative coefficient on the market (or other hedge fund style) indicator variable implies that there is no contagion of extreme poor returns. We interpret this outcome as evidence of a weak form of crash protection being provided by the hedge fund index. Similarly for the "positive tail" case, the same-direction market (other hedge fund style) indicator variable is set to one if the market (other hedge fund style) has an extreme positive return and zero otherwise. When both the hedge fund index and the market (other hedge fund style) index experience extreme positive returns, this indicates contagion among good returns. We are most interested in instances of contagion during down periods as indicated by a positive coefficient on the "negative tail" market indicator variable, and will focus our discussion on the negative tail case.

[16] The data for the size-spread factor are obtained from Wilshire, and the data for the bond and credit spread factors are obtained from the website of the Board of Governors of the Federal Reserve System. See the website of David Hsieh at http://faculty.fuqua.duke.edu/~dah7/HFRFData.htm for links to the Wilshire and Federal Reserve data.

Table II examines contagion between the HFR monthly hedge fund indices and market indices as well as contagion across hedge fund indices. Following McCullagh (1983) and McCullagh and Nelder (1989), we allow for overdispersion to overcome the shortcoming that the mean and variance in the standard Poisson approach must be the same and estimate the parameters and standard errors using a quasi-likelihood function framework. In addition and as mentioned above in the description of the data, we use the standardized residuals from GARCH(1,1) models to control for volatility clustering.

The first two regressions are for the negative and positive tails of the Arbitrage style index. Focusing on the negative tail case, we first examine the results for the continuous variables and ABS factors. There is a negative relationship between extreme negative returns for the index and the Russell 3000 index, indicating that the probability of an extreme negative return in the Arbitrage index declines when the Russell 3000 index performs well. This relationship is similar for the Arbitrage index and the 3-month T-bill rate. By contrast, there is a positive relationship between extremely poor returns for the index and the LB bond index, indicating that the probability of an extreme negative return in the Arbitrage index increases when the LB bond index performs well. This relationship is similar for the negative portion of the S&P 500 index.

In addition, volatility is related to extreme negative returns in the Arbitrage index. Specifically, the probability of an extreme negative return in the Arbitrage index is increasing in bond market volatility and decreasing in currency market volatility. For the asset-based (ABS) factors, there are several significant relationships with the Arbitrage index. Extreme negative returns in the Arbitrage index are positively related to the change in the 10-year Treasury note yield, the change in credit spread, and the return on the stock index lookback straddle, and negatively related to the return on the currency lookback straddle and the short-term interest rate lookback straddle. The statistical and economic significance of these results highlight the importance of controlling for both linear and non-linear factors in modeling contagion.

Turning to the contagion variables, we first focus on contagion with broad markets. The positive and significant coefficients on the stock and currency index indicator variables indicate contagion in negative returns between these indices and the Arbitrage index. By contrast, the negative and significant coefficient on the bond index signifies weak-form downside protection being provided by the Arbitrage index. Finally, we examine the other hedge fund style indicator variables. There is strong evidence of contagion between the Directional index and the Arbitrage index for extreme negative returns, and also between the Event Driven index and the Arbitrage index for extreme positive returns.

For the Directional index, there are a number of significant relationships between extreme negative outcomes in the Directional index and the control variables, again highlighting the importance of including these control variables. For the contagion variables, there is evidence of contagion from the Bond index to the Directional index, and evidence of downside protection for the Russell 3000 index. Across hedge funds, there is strong evidence of contagion in extreme negative returns from both the Arbitrage and the Event Driven index to the Directional index and contagion in extreme positive returns from the Event Driven index.

Finally, for the Event Driven index, there are again many cases of significant relationships between the control variables and the indicator variable for extreme negative returns for the index. For the contagion variables, there is no evidence of contagion from broad market indices to hedge funds, but there is evidence of contagion in extreme negative returns from the Directional to the Event Driven index, as well as contagion in extreme positive returns from both the Arbitrage and Directional indices.

Together, these results imply that there is no evidence of systematic contagion in extreme negative returns from broad market indices to hedge funds. While 3 coefficients out of 9 are consistent with contagion, 2 coefficients out of 9 are consistent with crash protection. The picture is more muddled when looking at indices separately because, for the market indicator variables, two coefficients are positive and significant for the Arbitrage index, one is significant for the

Directional index, and none is significant for the Event Driven index. Hence, if one were to be concerned about contagion for specific hedge fund styles, concern would be most warranted for arbitrage funds. In contrast, there is clear evidence of systematic contagion in extreme negative returns across hedge fund indices. In particular, 4 out of 6 coefficients are consistent with contagion and no coefficient is consistent with crash protection. The contagion across hedge fund indices is also strong among extreme positive returns.

The statistically significant evidence showing strong contagion among hedge fund indices is also economically significant. A simple way to see this is to evaluate the regressions at the mean of the explanatory variables and change the indicator variable for a hedge fund index extreme return from 0 to 1. We focus only on the significant contagion coefficients. For the Arbitrage index, we find that the probability of an extreme negative return increases by 5.48% if the indicator variable for the Directional index moves from no extreme negative return to an extreme negative return – the probability of an extreme negative return evaluated at the mean of the explanatory variables increases from a trivial 0.83% to 6.30%. For the Directional index, a move of the Arbitrage index or the Event Driven index from no extreme return to an extreme negative return increases the probability of an extreme negative return by slightly more than 3%. Finally, the Event Driven index probability of an extreme return increases by 1.30% if the Directional index has an extreme return.

III. Hedge fund contagion with daily index returns

The analysis in the previous section uses monthly data to test for contagion, where contagion is defined as coincident poor returns using a 10% cutoff. One weakness of using monthly data is the small number of observations available, requiring a 10% cutoff to have an adequate sample size.[17] Therefore, to further investigate the effects of contagion, we perform a similar analysis

[17] We attempted to re-perform the tests using a 5% cutoff for extreme returns but there were not enough coincident poor returns for all the regressions to converge.

using daily return data, which has over four times as many observations as the monthly data and allows us to define extreme returns using a 5% cutoff. While the daily index data does not cover as long a time period and includes fewer hedge funds, it nonetheless allows us to test for contagion with more precision.

In this section, we investigate hedge fund contagion using daily returns provided by HFR. As with the monthly data, we examine contagion to hedge fund style index returns from two sources: extreme returns in market risk factors and extreme returns in other hedge fund styles. We focus on whether extreme realizations of market risks and hedge fund style returns have a qualitatively different impact on the probability of extreme hedge fund returns than linear/direct realizations of the risk factors.

III.1 Daily HFR Indices: Summary statistics

Like the HFR monthly indices, the HFR daily indices are reported for eight sub-indices which we aggregate into the same three broad indices, calculating equally-weighted average returns within each style. Table III.A reports summary statistics for the HFR combined categories. The data are daily for the period April 2, 2003 through September 15, 2006 for a total of 872 observations. In general, the correlations across hedge fund indices and between markets and hedge fund indices are lower for daily than for monthly data. Specifically, the correlations between the Arbitrage and Directional and Arbitrage and Event Driven indices have dropped dramatically. In addition, in contrast to the monthly results, the correlations between all three hedge fund indices and the FRB dollar index are always negative, and the correlations between all three hedge fund indices and the bond index are very small and sometimes negative. The correlations between the Directional and Event Driven indices and the Russell 3000 index remain large and positive, but the correlation between the Arbitrage and Russell 3000 index is very small and negative.

In Panel 2, the autocorrelation results for daily data also differ from the monthly data in Table I. Specifically, there is no evidence of autocorrelation in the Arbitrage returns, but there is evidence of autocorrelation in both the Directional and Event Driven indices. Further, the tests of normality reported in Panel 3 are strongly rejected. Therefore, the regressions performed in Table IV are based again on GARCH(1,1) standardized residuals. Finally, Table III.B presents the conditional correlations among the combined HFR hedge fund indices and the market indices. The results are not too different from the unconditional correlations performed in Table III.A.

III.2. Contagion between daily hedge fund indices and market indices, and across hedge fund indices

Table IV presents the results of the daily HFR regression analysis. The dependent variables are defined in the same way as for the monthly analysis. We include the same control variables as in the monthly analysis, with the exception of the five "lookback straddle" variables, which cannot be calculated reliably for daily data. As before, we allow for overdispersion to overcome the shortcoming of the standard Poisson approach that the mean and variance must be the same. Also consistent with the monthly analysis, we standardize hedge fund returns using the conditional volatilities from univariate GARCH(1,1) models.

As with the monthly results, we focus our discussion on the negative tail case. The first regression is for the Arbitrage index. In contrast to the monthly results, there is no evidence of contagion from the stock and currency markets, but we do find evidence of contagion from the bond market. For contagion across hedge fund indices, there is evidence of contagion from the Event Driven index.

The second regression is for the Directional index. In contrast to the monthly results, there is no contagion from broad markets to hedge funds, but consistent with the monthly results, we show evidence of contagion from the Event Driven index to the Directional index. Finally, for the Event Driven index, there is again no contagion from broad markets to hedge funds, but there is strong evidence of contagion from both the Arbitrage and Directional indices to the Event Driven index. These results are even more significant than for the monthly results.

Taken together, the results for the daily indices indicate that there is no systematic contagion from broad markets to hedge fund indices. In only 1 of 9 possible cases do we show contagion among extreme negative returns. In contrast, 4 out of 6 possible cases show contagion among hedge fund indices. The evidence for daily returns is therefore roughly consistent with the evidence for the monthly return regressions: weak evidence of contagion from the broad markets but strong evidence of contagion from other hedge fund indices. In addition, the economic significance of the contagion coefficients is such that the probability of an extreme negative return more than doubles for all significant contagion coefficients when a hedge fund index has an extreme negative return.

IV. Sub-index analysis of contagion

While we have documented contagion within the hedge fund industry using broad indices, we have not yet investigated to what extent this phenomenon represents a systematic effect in the sense that it affects many funds in each index. This section performs this analysis focusing on sub-indices using two separate approaches. The first approach (in Table V) slightly modifies the Poisson regression by redefining the dependent variable. The second approach (in Table VI) performs the Poisson analysis directly using the eight sub-indices rather than the three aggregate indices to examine in more detail the contagion effects between each of the indices.

In Table V, we modify the Poisson regressions presented in Table IV by allowing the dependent variable to take on the value of zero if none of the sub-indices in the aggregate index has an extreme return, 1 if one of the sub-indices has an extreme negative return, and 2 if two or more of the sub-indices have an extreme negative return.[18] The properties of the Poisson regression imply that the most likely outcome is a 0, the next most likely outcome a 1, and the least likely outcome a 2. Thus, this is a more detailed analysis of contagion, although the interpretation of the results is similar.

[18] This amounts to allowing Y_{it} in equation (1) to take on values $\{0,1,2\}$.

We compare the contagion results from Table V to those previously discussed in Table IV. With respect to contagion from broad markets to hedge funds, the evidence of contagion from the bond market to the Arbitrage index disappears, and new evidence indicating contagion from the currency index to the Directional index surfaces. These results suggest that the coefficients indicating contagion from broad markets have to be interpreted with caution. In contrast, with respect to contagion across hedge fund indices, the results are not only consistent with evidence presented in Table IV but are even stronger. Specifically, now that contagion at the sub-index level is being considered, there is evidence of contagion from the Arbitrage to the Directional index, so that 5 of the 6 "negative tail" contagion variables show contagion across extreme negative returns.

While the results of Table V suggest the importance of examining contagion at the sub-index level, it is difficult to identify the specific contagious effect for each sub-index. Therefore, we perform an additional analysis that models contagion at the sub-index level. This regression approach is identical to that performed in Table IV with the three aggregated hedge fund indices, but it uses all eight individual sub-indices instead. This approach allows us to better identify which of the sub-indices are driving the aggregate contagion results.

The results of this regression are presented in Table VI. For brevity, this table presents only the results from the "negative tail" regressions. We first examine the results for each of the indexes comprising the aggregate Arbitrage index. The first is the Convertible Arbitrage (CA) sub-index. There is weak evidence of contagion from the bond index to the CA sub-index. In addition, there is evidence of contagion from the Relative Value (RV), Equity Market Neutral (EM), and Distressed Securities (DS) sub-indices to the CA index. For second sub-index, the Relative Value (RV) index, there is no contagion from the broad markets, but there is evidence of contagion from the Equity Market Neutral (EM), the Macro Index (MM), and the Event Driven (ED) sub-indices. The final sub-index, the Equity Market Neutral (EM) sub-index, has no contagion from broad markets. However, there is contagion from the Convertible Arbitrage (CA), Relative Value (RV), Equity Hedge (EH), and Distressed Securities (DS) sub-indices.

For the sub-indices comprising the aggregate Directional index, there is contagion from the stock and currency broad market indices to the Macro sub-index (MM). In addition, there is evidence of contagion from the Relative Value (RV), Equity Hedge (EH), and Merger Arbitrage (MA) sub-indices. Turning to the Equity Hedge sub-index (EH), there is contagion from currency markets and from the Equity Market Neutral (EM), Merger Arbitrage (MA), Distressed Securities (DS), and Event Driven (ED) sub-indices.

Finally, for the sub-indices comprising the aggregate Event Driven index, the first is the Merger Arbitrage (MA) sub-index. The MA sub-index shows no contagion from broad market indices, but does have contagion from the Equity Hedge (EH) and Event Driven (ED) sub-indices. The second sub-index, Distressed Securities (DS), has contagion from the broad market bond index. Further, there is evidence of contagion from the Convertible Arbitrage (CA), Equity Market Neutral (EM), and Event Driven (ED) sub-indices. Finally, the Event Driven sub-index has no contagion from broad markets, but does have contagion from the Relative Value (RV), Macro (MM), Equity Hedge (EH), Merger Arbitrage (MA), and Distressed Securities (DS) sub-indices.

The general conclusion from this analysis is that, within the daily data, there is still no systematic evidence of contagion from broad market indices to hedge fund sub-indices. Of the 24 possible occurrences of contagion (eight sub-indices and three market contagion variables for each), there are five instances of contagion which affect four of the eight sub-indices. However, out of the 24 possible coefficients, seven are significantly negative, indicating crash protection, so that there is actually more evidence of crash protection than of contagion.

The results for contagion across hedge funds on the other hand are strong. Of the 56 possible occurrences of contagion (eight sub-indices and seven "other sub-index" contagion variables for each), there are 27 instances of contagion, which affect all 8 of the sub-indices. Each sub-index has at least two and at most five contagious sub-indices, indicating that across-index contagion is not concentrated within one sub-index. There are only two instances of crash protection.

V. Robustness tests

This section performs robustness tests on the monthly and daily data. First, we investigate whether we miss contagion from fixed-income markets because of a flight to safety such as the one that took place in the fall of 1998, in which case extreme positive returns for fixed-income markets could be associated with extreme negative returns for hedge fund indices. We re-estimate our regressions allowing extreme positive returns in fixed-income markets to increase the probability of extreme negative returns for hedge fund indices. Second, we investigate the same possibility of flight-to-quality by omitting the returns from August to October 1998 and re-estimating the monthly regressions. Third, we control for autocorrelation in the preliminary GARCH models for each of the three monthly hedge fund indices by using an AR(1) structure for each mean equation.[19] These robustness tests do not lead us to alter our conclusions.

Next, we repeat all tests using a binomial logit model rather than the Poisson model. The results using the binomial model are largely consistent with the main results presented in the paper. Finally, we perform an additional analysis at the sub-index level. This analysis uses a multinomial specification as follows.

For each day and each aggregate HFR style (Arbitrage, Directional, and Event Driven) we count the number of extreme returns experienced by the sub-indices within each style. As an example, take the case of the aggregate HFR Arbitrage index. The sub-indices for HFR Arbitrage include Convertible Arbitrage, Relative Value, and Equity Market Neutral. We create a variable called *COUNT* which takes the value of zero if none of the sub-indices experiences an extreme return, one if one of the sub-indices experiences an extreme return, and two if two or more of the

[19] The AR(1) structures are selected based on the partial autocorrelation functions; see for example Hamilton (1994).

sub-indices experience extreme returns. *COUNT* is then used as the dependent variable in a multinomial logit regression, where the independent variables include the control variables described in Section II.1a., six (0/1) indicator variables for positive (negative) extreme returns for each of the market indices (Russell 3000, LB bond, and FRB dollar), and the *COUNT* variables for the other two aggregate hedge fund styles (in this example, these would include the HFR Directional and HFR Event Driven indices).

The results from this analysis (not reported) are largely consistent with the results of the analyses performed in Section IV, and provide again evidence of contagion at the sub-index level that does not appear to be driven by any one particular sub-index.

VI. Implications and Conclusions

In this paper, we use a new approach to study contagion in hedge funds. Our approach, which uses a Poisson regression model, avoids many of the issues inherent in tests of correlations. By using the Poisson model, we focus on co-incidences of extreme returns in the broad markets and hedge fund indices. Specifically, we examine the co-incidence of extreme returns (very good and very poor returns) between hedge fund indices and broad markets, and also between hedge fund indices, taking carefully into account the known properties and determinants of hedge fund returns.

We find no systematic evidence of contagion between broad markets and hedge funds after accounting for correlation between market factors and hedge fund returns. The limited evidence of contagion from the broad markets we find is strongest at the monthly aggregate index level and weakest at the aggregate daily index level. In contrast to the weak evidence of contagion from the broad markets, we find extremely strong and consistent evidence of contagion *across* hedge fund styles. Our data is categorized into three aggregate indices representing Arbitrage, Directional, and Event Driven hedge funds, and we find evidence of contagion between all three styles. These contagion effects are strong for extreme poor returns for both daily and monthly indices. Tests using sub-index data find consistent results. Further, they provide additional evidence that contagion across hedge funds is not concentrated in any one index, but rather, is distributed across all eight sub-indices with all of them experiencing some degree of across-style contagion.

Our study is the first to examine contagion across hedge fund returns and also the first to use daily hedge fund data, which only recently became available. Our daily data sub-index finding of only weak contagion from financial markets to hedge funds suggests that perhaps certain hedge fund categories such as Relative Value and Merger Arbitrage can provide diversification benefits against downside performance in broad markets while other categories such as Global Macro may not. These results should be interpreted with caution as they cover only a short time frame and are not completely consistent across daily and monthly returns.

Our consistent findings of significant contagion between hedge fund styles, regardless of whether we use daily, monthly, aggregate index, or sub-index data, indicate that diversifying between hedge funds within a portfolio does not reduce downside risk associated with extremely poor returns. Our results have important implications for regulators and investors. Recent concerns by regulators that hedge funds might be mimicking each others' strategies appear to be borne out in our analysis which indicates strong evidence of contagion across hedge fund styles. Further, investors investing in a diversified portfolio of hedge funds should be aware that diversification across hedge funds is less effective when hedge fund indices experience extremely poor returns.

Our paper raises an important issue, which is why there is such sharp contagion among hedge fund indices. It is well-known that there are many difficulties with hedge fund data. However, these difficulties cannot explain our main result. This result holds both for monthly data and for daily data. In contrast to the indices with monthly returns, the indices with daily returns are investible. The explanation for our result has to be that there are unique risks to hedge fund strategies. Richards (1999) provides some evidence to that effect. He models the idiosyncratic return of an asset as the return on a portfolio that is long in that asset and short in other assets in the same class and shows that idiosyncratic risk is correlated. He conjectures that extreme return outcomes for one long-short hedge fund should tend to occur at the same time as extreme return outcomes for other funds, even those in different asset classes. The collapse of LTCM provides anecdotal evidence of a common factor in hedge fund strategies, namely a common sensitivity to liquidity risk. In the case of LTCM, many uncorrelated strategies became correlated, and through all these strategies LTCM was apparently providing liquidity to the markets. Beyond a common factor like liquidity, it could also be that a more traditional contagion mechanism, highlighted for emerging markets by Kodres and Pritsker (2002), is at work. If a levered fund implements strategies from different styles, a loss in one strategy could force it to sell assets from other styles. As a result, the losses in one style would put pressure on prices for hedge funds specialized in other styles. Further research focused on explaining the channels of contagion would be helpful in understanding the benefits of hedge fund diversification and the systemic risk of hedge funds.

Table I.A: Summary statistics of monthly returns on aggregated HFR indices and market factors: January, 1990 to June, 2006

Summary statistics for monthly data on the HFR monthly hedge fund indexes and the market factors used in the paper are reported below. The statistics include the mean, median, standard deviation, skewness, and kurtosis. The indices include Arbitrage, Directional, and Event Driven and are described more fully in Section I.1 and Appendix A. The market factors are from Datastream and include the return on the Russell 3000 index, the change in the Federal Reserve Bank competitiveness-weighted dollar index (the FRB Dollar Index), and the daily return on the Lehman Brothers U.S. Bond Index. The number of observations is 197. Correlations between the variables and the autocorrelations as well as Jarque-Bera test statistics for normality are reported below the summary statistics. The second row in the autocorrelation table reports t-values in parentheses. Bold and italic bold correlation results indicate significance at the 5% and the 10% level, respectively.

Panel 1: Summary statistics and simple correlations

	Arbitrage	**Directional**	**Event Driven**	**Russell 3000 return**	**Δ in FRB Dollar Index**	**Return on LB bond Index**
Number of observations	197	197	197	197	197	197
Mean	0.834	1.307	1.090	0.968	-0.047	0.586
Median	0.933	1.330	1.160	1.377	0.059	0.720
Standard deviation	0.742	2.174	1.387	4.081	1.860	1.351
Skewness	-1.165	0.237	-1.593	-0.571	0.166	-0.104
Excess kurtosis	5.430	0.643	8.198	1.029	0.322	0.574
Correlations						
Arbitrage	1.000			**0.374**	0.012	**0.208**
Directional	**0.598**	1.000		**0.638**	-0.011	**0.187**
Event Driven	**0.686**	**0.690**	1.000	**0.609**	0.039	0.045

Panel 2: Autocorrelations

Autocorrelations	**Arbitrage**	**Directional**	**Event Driven**
lag 1	**0.44631**	**0.16442**	**0.41061**
	(6.26)	(2.31)	(5.76)
lag 2	**0.27842**	0.06749	0.1266
	(3.30)	(0.92)	(1.54)
lag 3	0.07426	0.00786	0.01847
	(0.84)	(0.11)	(0.22)
lag 4	0.10333	0.02601	-0.00759
	(1.16)	(0.35)	(-0.09)
lag 5	0.1034	0.01896	-0.01997
	(1.15)	(0.26)	(-0.24)
lag 6	**0.22339**	0.06212	-0.05345
	(2.47)	(0.84)	(-0.64)
Ljung-Box test (1-6)	**71.140**	7.340	**37.690**
p-value	0.000	0.291	0.014

Panel 3: Normality test

	Arbitrage	**Directional**	**Event Driven**
Jarque-Bera Test	**271.259**	***4.736***	**602.264**
***p*-value**	0.000	0.094	0.000

Table I.B: Aggregate HFR monthly index correlations conditioned on financial market variables

Conditional correlations for the hedge fund indices and the three market variables are calculated. The conditioning market variables include the return on the Russell 3000 index, the change in the Federal Reserve Bank competitiveness-weighted dollar index, and the return on the Lehman Brothers U.S. bond index. Correlations are conditional upon the market variable being above or below its median for the entire time period studied. Bold and italic bold correlation results indicate significance at the 5% and the 10% level, respectively.

Conditioning variable: Russell 3000 Index

	Conditioning variable above median						**Conditioning variable below median**					
	Arbitrage	Directional	Event Driven	Russell 3000	Δ in FRB Dollar Index	Return on LB bond Index	Arbitrage	Directional	Event Driven	Russell 3000	Δ in FRB Dollar Index	Return on LB bond Index
Arbitrage	1.000			0.129	0.098	**0.228**	1.000			**0.376**	-0.025	***0.183***
Directional	**0.570**	1.000		**0.209**	0.135	0.124	**0.557**	1.000		**0.592**	-0.073	**0.260**
Event Driven	**0.564**	**0.595**	1.000	0.009	0.146	0.006	**0.716**	**0.633**	1.000	**0.688**	0.031	0.042

Conditioning variable: FRB Dollar Index

	Conditioning variable above median						**Conditioning variable below median**					
	Arbitrage	Directional	Event Driven	Russell 3000	Δ in FRB Dollar Index	Return on LB bond Index	Arbitrage	Directional	Event Driven	Russell 3000	Δ in FRB Dollar Index	Return on LB bond Index
Arbitrage	1.000			**0.496**	0.129	0.098	1.000			**0.229**	-0.047	**0.350**
Directional	**0.628**	1.000		**0.684**	0.138	0.056	**0.559**	1.000		**0.597**	**-0.201**	**0.336**
Event Driven	**0.768**	**0.757**	1.000	**0.678**	0.050	-0.037	**0.551**	**0.599**	1.000	**0.548**	-0.001	0.160

Conditioning variable: Lehman Brothers Bond Index

	Conditioning variable above median						**Conditioning variable below median**					
	Arbitrage	Directional	Event Driven	Russell 3000	Δ in FRB Dollar Index	Return on LB bond Index	Arbitrage	Directional	Event Driven	Russell 3000	Δ in FRB Dollar Index	Return on LB bond Index
Arbitrage	1.000			**0.494**	0.069	0.121	1.000			**0.228**	-0.015	**0.276**
Directional	**0.631**	1.000		**0.696**	-0.029	**0.247**	**0.557**	1.000		**0.581**	0.027	***0.183***
Event Driven	**0.761**	**0.705**	1.000	**0.656**	0.041	0.101	**0.608**	**0.689**	1.000	**0.529**	0.029	0.118

Table II: Contagion of extreme events for HFR monthly hedge fund indices

The event of an extreme monthly positive or negative return in each hedge fund style is separately modeled as the outcome of a binary variable and estimated as a Poisson regression. A monthly return is classified as extreme and the dependent variable is set to 1 if it belongs to either the top or bottom 10% of all returns of that style. The control variables are described in Section II.3. The contagion variables are indicator variables set to 1 if the return is classified as an extreme return in the respective aggregate index on the same day. Below the coefficients are the t-values in parentheses. The pseudo R^2 is McFadden's likelihood ratio index. Bold and italic bold coefficients indicate significance at the 5% and the 10% level, respectively.

	HFR Arbitrage		HFR Directional		HFR Event Driven	
	Negative	Positive	Negative	Positive	Negative	Positive
Control Variables						
Market Variables and Volatility Controls						
Constant	**-4.2270**	**-3.9174**	**-3.7346**	**-4.6603**	**-3.5809**	**-4.1225**
	(-9.04)	(-10.24)	(-8.43)	(-11.26)	(-8.44)	(-10.17)
Russell 3000	**-0.5071**	**0.1968**	**-0.6733**	**0.3953**	**-0.3577**	0.1495
	(-4.38)	(2.12)	(-3.24)	(5.40)	(-3.01)	(1.56)
Change in FRB dollar index	0.1524	-0.1296	***-0.1700***	**0.2929**	0.1439	-0.0751
	(1.36)	(-1.11)	(-1.69)	(3.37)	(1.55)	(-0.63)
Return on LB bond index	**0.8897**	0.2962	-0.0534	-0.1102	**-0.6271**	***0.4370***
	(3.53)	(1.24)	(-0.20)	(-0.52)	(-2.48)	(1.86)
3 month T-bill rate	**-11.7963**	2.3786	1.6176	**11.9597**	**-8.3505**	0.1911
	(-3.56)	(0.73)	(0.64)	(4.50)	(-2.80)	(0.06)
-[S&P 500]	**0.6152**	***-0.2696***	0.3029	0.0501	-0.0854	0.0397
	(3.44)	(-1.73)	(1.23)	(0.20)	(-0.44)	(0.16)
S&P volatility	0.0100	0.0100	0.0000	0.0200	0.0000	-0.0600
	(-0.98)	(-0.35)	(-0.08)	(-1.72)	(-0.31)	(-3.83)
FRB dollar index volatility	***-0.0528***	0.0116	0.055	**0.1216**	-0.0271	**0.1157**
	(-1.92)	(-0.35)	(-1.54)	(-2.52)	(-0.80)	(-3.31)
LB bond index volatility	**0.0706**	-0.0231	***-0.0443***	0.0521	0.0291	0.0023
	(1.96)	(-1.05)	(-1.88)	(-1.16)	(-1.00)	(-0.11)
ABS Factors						
Wilshire DJ small cap – large cap	-0.0879	***0.0830***	***-0.1230***	**0.1982**	**-0.2614**	**0.1969**
	(-1.54)	(1.89)	(-1.75)	(4.60)	(-4.42)	(4.20)
Change in 10 year Treasury note yield	**0.4167**	-0.0019	-0.0369	-0.0132	***-0.1040***	0.0554
	(6.37)	(-0.03)	(-0.60)	(-0.29)	(-1.67)	(0.96)
Change in credit spread Baa - Aaa	**0.1425**	0.0145	**-0.0853**	0.0105	0.0387	***-0.0451***
	(4.63)	(0.51)	(-2.47)	(0.46)	(1.26)	(-1.72)
Return on PTFS bond lookback straddle	0.0118	-0.0071	**-0.0223**	0.0046	**-0.0746**	**-0.0442**
	(1.18)	(-0.53)	(-2.23)	(0.42)	(-4.97)	(-3.18)
Return on PTFS currency lookback straddle	**-0.0553**	-0.0160	0.0059	**0.0366**	**0.0260**	**-0.0217**
	(-4.35)	(-1.40)	(0.56)	(4.31)	(2.34)	(-2.24)
Return on PTFS commodity lookback straddle	-0.0200	0.0100	**-0.0500**	***0.0200***	**0.0300**	0.0100
	(-1.62)	(0.81)	(-3.44)	(1.93)	(2.37)	(0.85)
Return on PTFS short-term interest rate	**-0.0345**	-0.0022	**0.0146**	**-0.0658**	**-0.0135**	0.0165
	(-3.22)	(-0.19)	(2.75)	(-4.80)	(-2.37)	(1.49)
Return on PTFS stock index lookback straddle	***0.0170***	***-0.0245***	0.0114	**0.0214**	0.0047	**0.0521**
	(1.95)	(-1.94)	(1.58)	(2.00)	(0.60)	(4.69)
Contagion Variables						
Market Indicator Variables						
Same direction extreme event Russell 3000	**1.4987**	-1.0807	**-1.297**	-0.6875	-0.8995	**-1.3679**
	(2.53)	(-1.52)	(-2.34)	(-1.50)	(-1.50)	(-2.36)
Same direction extreme event Bond index	**-1.4952**	-0.2491	**1.9454**	***0.9677***	-0.9844	-0.8645
	(-2.56)	(-0.44)	(3.22)	(1.94)	(-1.20)	(-1.54)
Same direction extreme event FRB index	**3.0500**	**1.9143**	-23.7079	-0.923	-0.5706	0.9569
	(4.29)	(2.90)	(-0.00)	(-1.38)	(-0.74)	(1.43)
Other Hedge Fund Index Indicator Variables						
Arbitrage			**1.194**	0.4734	0.3791	**0.8169**
			(3.78)	(1.38)	(1.16)	(2.50)
Directional	**2.0901**	0.5013			***0.5368***	**1.0698**
	(5.39)	(1.11)			(1.86)	(2.55)
Event Driven	0.0966	**1.083**	**1.0666**	**0.9011**		
	(0.26)	(2.75)	(3.24)	(2.35)		
McFadden's Pseudo R^2	0.430	0.201	0.471	0.418	0.440	0.366

Table III.A: Summary statistics of daily returns on aggregated HFR indices and market factors: April 2, 2003 to September 15, 2006

Summary statistics for daily data on the HFR hedge fund indices and the market factors used in the paper are reported below. The statistics include the mean, median, standard deviation, skewness, and kurtosis. The indices include Arbitrage, Directional, and Event Driven and are described more fully in Section I.2 and Appendix B. The market factors are from Datastream and include the return on the Russell 3000 index, the change in the Federal Reserve Bank competitiveness-weighted dollar index (the FRB Dollar Index), and the daily return on the Lehman Brothers U.S. Bond Index. The number of observations is 872. Correlations between the variables and the autocorrelations as well as Jarque-Bera test statistics for normality are reported below the summary statistics. The second row in the autocorrelation table reports t-values in parentheses. Bold and italic bold correlation results indicate significance at the 5% and the 10% level, respectively.

Panel 1: Summary statistics and simple correlations

	Arbitrage	Directional	Event Driven	Russell 3000 return	Δ in FRB Dollar Index	Return on LB bond Index
Number of observations	872	872	872	872	872	872
Mean	0.006	0.022	0.029	0.064	-0.018	0.009
Median	0.010	0.038	0.036	0.089	-0.012	0.054
Standard deviation	0.118	0.270	0.142	0.752	0.474	0.403
Skewness	0.023	-0.602	-0.462	0.056	0.132	-2.464
Excess kurtosis	1.807	1.700	1.390	0.184	0.064	14.489
Correlations						
Arbitrage	1.000			-0.041	**-0.130**	0.034
Directional	**0.161**	1.000		**0.500**	**-0.334**	-0.050
Event Driven	**0.186**	**0.556**	1.000	**0.588**	**-0.075**	***-0.057***

Panel 2: Autocorrelations

Autocorrelations	**Arbitrage**	**Directional**	**Event Driven**
lag 1	-0.05411	**0.23069**	**0.1321**
	(-1.60)	(6.81)	(3.90)
lag 2	-0.01365	**0.07096**	**0.10664**
	(-0.40)	(1.99)	(3.10)
lag 3	**0.07018**	**0.09246**	0.05894
	(2.07)	(2.58)	(1.69)
lag 4	0.00724	-0.00017	0.01151
	(0.21)	(-0.00)	(0.33)
lag 5	0.05021	0.05173	**0.14932**
	(1.47)	(1.43)	(4.27)
lag 6	0.02822	-0.03085	**0.07012**
	(0.82)	(-0.85)	(1.97)
Ljung-Box test (1-6)	10.010	**61.670**	**52.320**
p-value	0.124	0.000	0.000

Panel 3: Normality test

	Arbitrage	**Directional**	**Event Driven**
Jarque-Bera Test	**116.498**	**155.463**	**99.586**
***p*-value**	0.000	0.000	0.000

Table III.B: Aggregate HFR monthly index correlations conditioned on financial market variables

Conditional correlations for the hedge fund indices and the three market variables are calculated. The conditioning market variables include the return on the Russell 3000 index, the change in the Federal Reserve Bank competitiveness-weighted dollar index, and the return on the Lehman Brothers U.S. bond index. Correlations are conditional upon the market variable being above or below its median for the entire time period studied. Bold and italic bold correlation results indicate significance at the 5% and the 10% level, respectively.

Conditioning variable: Russell 3000 Index

	Conditioning variable above median						**Conditioning variable below median**					
	Arbitrage	Directional	Event Driven	Russell 3000	Δ in FRB Dollar Index	Return on LB bond Index	Arbitrage	Directional	Event Driven	Russell 3000	Δ in FRB Dollar Index	Return on LB bond Index
Arbitrage	1.000			-0.072	-0.035	-0.025	1.000			0.076	**-0.227**	**0.104**
Directional	0.067	1.000		**0.299**	**-0.348**	-0.034	**0.318**	1.000		**0.408**	**-0.363**	-0.030
Event Driven	**0.148**	**0.425**	1.000	**0.431**	-0.053	-0.060	**0.307**	**0.504**	1.000	**0.452**	**-0.097**	-0.015

Conditioning variable: FRB Dollar Index

	Conditioning variable above median						**Conditioning variable below median**					
	Arbitrage	Directional	Event Driven	Russell 3000	Δ in FRB Dollar Index	Return on LB bond Index	Arbitrage	Directional	Event Driven	Russell 3000	Δ in FRB Dollar Index	Return on LB bond Index
Arbitrage	1.000			-0.049	**-0.114**	***0.080***	1.000			-0.027	**-0.126**	-0.062
Directional	**0.153**	1.000		**0.517**	**-0.319**	0.051	**0.170**	1.000		**0.486**	**-0.355**	**-0.132**
Event Driven	**0.233**	**0.608**	1.000	**0.591**	-0.075	-0.019	**0.141**	**0.501**	1.000	**0.587**	***-0.090***	-0.063

Conditioning variable: Lehman Brothers Bond Index

	Conditioning variable above median						**Conditioning variable below median**					
	Arbitrage	Directional	Event Driven	Russell 3000	Δ in FRB Dollar Index	Return on LB bond Index	Arbitrage	Directional	Event Driven	Russell 3000	Δ in FRB Dollar Index	Return on LB bond Index
Arbitrage	1.000			0.034	***-0.086***	-0.025	1.000			**-0.118**	**-0.104**	***0.083***
Directional	**0.209**	1.000		**0.500**	**-0.280**	**-0.110**	0.067	1.000		**0.541**	**-0.210**	-0.064
Event Driven	**0.239**	**0.541**	1.000	**0.563**	**-0.144**	**-0.107**	**0.124**	**0.587**	1.000	**0.613**	-0.002	-0.014

Table IV: Contagion of extreme events for aggregated HFR daily hedge fund indices

The event of an extreme daily positive or negative return in each hedge fund style is separately modeled as the outcome of a binary (0,1) variable and estimated using a Poisson regression. A monthly return is classified as extreme and the dependent variable is set to 1 if it belongs to either the top or bottom 5% of all returns of that style. The control and other variables are described in Section II.3. The other hedge fund index indicator variables are set to 1 if the return is classified as an extreme return in the respective aggregate index on the same day. Below the coefficients are the t-values in parentheses. The pseudo R^2 is McFadden's likelihood ratio index. Bold and italic bold coefficients indicate significance at the 5% and the 10% level, respectively.

	HFR Arbitrage		HFR Directional		HFR Event Driven	
	Negative	Positive	Negative	Positive	Negative	Positive
Control Variables						
Market Variables and Volatility Controls						
Constant	**-3.5341**	**-2.8897**	**-3.9405**	**-3.9774**	**-3.9249**	**-3.7952**
	(-22.63)	(-20.44)	(-24.58)	(-24.13)	(-23.35)	(-23.00)
Russell 3000	0.3284	**-1.7525**	**-1.1178**	**1.6484**	**-1.8937**	**1.274**
	(1.62)	(-4.37)	(-2.69)	(7.67)	(-3.08)	(5.41)
Change in FRB dollar index	**0.4997**	0.3003	**1.4666**	**-1.1714**	-0.0105	-0.2337
	(2.46)	(1.44)	(10.28)	(-6.85)	(-0.06)	(-1.23)
Return on LB bond index	**1.1617**	-0.3343	***0.7481***	***-0.3762***	0.039	0.0129
	(3.00)	(-1.61)	(1.75)	(-1.79)	(0.10)	(0.06)
3 month T-bill rate	-13.2398	3.8069	***15.7153***	-3.3594	-13.5965	12.2131
	(-1.12)	(0.30)	(1.65)	(-0.31)	(-1.18)	(1.05)
-[S&P 500]	**-1.0781**	**2.0368**	0.7740	0.7150	0.9805	-0.4694
	(-2.64)	(3.97)	(1.40)	(1.05)	(1.36)	(-0.94)
S&P volatility	-0.0300	***0.0400***	**0.0300**	**0.0600**	**0.0800**	***0.0300***
	(-1.37)	(-1.69)	-(2.13)	(-2.69)	(-5.22)	(-1.69)
FRB dollar index volatility	0.1344	-0.1573	**-0.2974**	-0.1687	**0.2038**	**0.3662**
	(-1.49)	(-1.30)	(-2.94)	(-1.50)	(-2.49)	(-4.78)
LB bond index volatility	-0.0727	-0.068	-0.0205	-0.042	-0.0604	**0.4554**
	(-1.57)	(-1.40)	(-0.25)	(-1.01)	(-1.02)	(-3.78)
ABS Factors						
Wilshire DJ small cap – large cap	***-0.3713***	**1.1594**	**-1.4264**	**0.9751**	**-0.5158**	**0.6245**
	(-1.87)	(5.53)	(-7.86)	(4.94)	(-2.51)	(3.18)
Change in 10 year Treasury note yield	**0.3120**	**-0.3757**	0.1093	**-0.4294**	0.0369	***-0.1681***
	(3.49)	(-4.01)	(1.07)	(-4.85)	(0.37)	(-1.89)
Change in credit spread Baa - Aaa	0.0536	0.0087	**0.1926**	**-0.2207**	***0.1506***	**-0.1652**
	(0.61)	(0.10)	(2.72)	(-3.49)	(1.92)	(-2.16)
Contagion Variables						
Market Indicator Variables						
Same direction extreme event Russell 3000	-0.6722	**2.4629**	0.0232	**-2.3474**	**-0.6963**	-0.1914
	(-1.51)	(3.84)	(0.10)	(-6.02)	(-2.82)	(-0.60)
Same direction extreme event Bond index	**1.1769**	0.4569	-22.3198	***-0.6853***	0.0827	-0.2139
	(2.48)	(1.47)	(-0.00)	(-1.89)	(0.13)	(-0.54)
Same direction extreme event FRB index	0.4878	**0.8814**	0.5898	-21.9023	0.1095	-0.3627
	(1.10)	(2.67)	(1.27)	(-0.00)	(0.33)	(-0.67)
Other Hedge Fund Index Indicator Variables						
Arbitrage			-0.1652	**0.6623**	**0.8678**	0.1384
			(-0.65)	(2.31)	(4.39)	(0.38)
Directional	-0.5759	0.5438			**1.2367**	**0.863**
	(-1.47)	(1.59)			(7.28)	(4.25)
Event Driven	**1.2007**	-0.0156	**1.0651**	**0.7757**		
	(4.10)	(-0.04)	(7.30)	(4.41)		
McFadden's Pseudo R^2	0.049	0.073	0.333	0.236	0.292	0.156

Table V: Pervasiveness of contagion of extreme events for aggregated HFR daily hedge fund indices

The event of an extreme daily positive or negative return in each hedge fund style is separately modeled as the outcome of a count variable (0,1,2) and estimated using a Poisson regression. The count variable is set to 0 if none of the sub-indices within the broad hedge fund index experience an extreme return, to 1 if 1 of the sub-indices within the broad index experience an extreme return, and to 2 if 2 or more of the sub-indices within the aggregated index experience an extreme return. A monthly return is classified as extreme if it belongs to either the top or bottom 5% of all returns of that style. The control and other variables are described in Section II.3. The other hedge fund broad index indicator variables are set to 1 if the return is classified as an extreme return in the respective aggregate index on the same day. Below the coefficients are the t-values in parentheses. The pseudo R^2 is McFadden's likelihood ratio index. Bold and italic bold coefficients indicate significance at the 5% and the 10% level, respectively.

	HFR Arbitrage		**HFR Directional**		**HFR Event Driven**	
	Negative	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
<u>Control Variables</u>						
Market Variables and Volatility Controls						
Constant	**-2.2773**	**-1.9033**	**-3.4639**	**-3.3695**	**-2.4819**	**-2.4539**
	(-18.84)	(-16.18)	(-24.29)	(-23.05)	(-19.48)	(-18.85)
Russell 3000	**0.492**	**-0.7454**	0.2894	**1.4337**	-0.2404	**1.0378**
	(3.22)	(-2.66)	(1.59)	(7.35)	(-0.96)	(5.26)
Change in FRB dollar index	**0.3673**	0.063	**1.1277**	**-0.9229**	-0.0573	**-0.3159**
	(2.26)	(0.36)	(7.73)	(-5.73)	(-0.38)	(-1.98)
Return on LB bond index	0.2787	0.0358	0.1038	**-0.4643**	**0.9824**	**0.4812**
	(0.92)	(0.15)	(0.30)	(-2.79)	(2.93)	(2.01)
3 month T-bill rate	12.9688	13.4234	***14.6031***	-11.1175	3.0567	5.5727
	(1.43)	(1.32)	(1.78)	(-1.17)	(0.31)	(0.55)
-[S&P 500]	**-0.7482**	***0.6351***	**-1.2291**	**-1.071**	-0.4296	-0.2712
	(-2.22)	(1.69)	(-3.58)	(-2.87)	(-1.16)	(-0.74)
S&P volatility	-0.0200	0.0100	-0.0400	0.0500	0.0700	0.0700
	(-0.98)	(-0.33)	(-2.79)	(-2.53)	(-4.23)	(-3.99)
FRB dollar index volatility	-0.0456	-0.1396	0.0525	***-0.2023***	-0.0893	**0.1701**
	(-0.50)	(-1.38)	-0.76	(-1.91)	(-0.95)	(-2.08)
LB bond index volatility	0.0097	-0.0587	**-0.1128**	0.0085	0.0617	**0.2462**
	(-0.15)	(-1.48)	(-4.06)	(-0.14)	(-0.70)	(-2.35)
ABS Factors						
Wilshire DJ small cap – large cap	-0.2383	**0.7683**	**-1.4961**	**0.994**	**-0.3867**	0.2097
	(-1.43)	(4.49)	(-9.43)	(5.75)	(-2.41)	(1.29)
Change in 10 year Treasury note yield	**0.1953**	-0.1288	0.1176	**-0.3452**	**0.1897**	-0.0125
	(2.65)	(-1.62)	(1.41)	(-4.51)	(2.38)	(-0.16)
Change in credit spread Baa - Aaa	0.0228	-0.0466	**0.203**	**-0.1864**	0.0948	***-0.1147***
	(0.31)	(-0.61)	(3.12)	(-3.04)	(1.40)	(-1.65)
<u>Contagion Variables</u>						
Market Indicator Variables						
Same direction extreme event Russell 3000	-0.5743	**1.0233**	0.1884	**-0.769**	**-0.5594**	-0.2307
	(-1.35)	(2.26)	(0.74)	(-2.82)	(-2.22)	(-0.77)
Same direction extreme event Bond index	0.4178	0.2411	0.0305	0.0716	0.6817	0.0195
	(1.07)	(0.83)	(0.07)	(0.25)	(1.42)	(0.06)
Same direction extreme event FRB index	-0.715	**0.6403**	**1.3274**	-0.2068	***-0.7471***	0.0495
	(-1.26)	(2.13)	(3.87)	(-0.33)	(-1.91)	(0.13)
Other Hedge Fund Index Indicator Variables						
Arbitrage			**0.2742**	-0.1094	**0.2572**	**0.4118**
			(2.10)	(-0.60)	(2.09)	(2.78)
Directional	0.2305	-0.3273			**0.6438**	**0.6947**
	(1.31)	(-1.30)			(5.42)	(5.14)
Event Driven	**0.4715**	**0.3252**	**0.628**	**0.464**		
	(3.27)	(2.14)	(6.75)	(4.56)		
McFadden's Pseudo R^2	0.052	0.033	0.272	0.202	0.181	0.109

Table VI: Contagion of extreme events for eight individual HFR daily sub-indices
Extreme negative returns only

The event of an extreme monthly positive or negative return in each individual hedge fund style is separately modeled as the outcome of a binary variable (0,1) and estimated as a Poisson regression. A monthly return is classified as extreme and the dependent variable is set to 1 if it belongs to either the top or bottom 5% of all returns of that style. The control and other variables are described in Section II.3. The other hedge fund index indicator variables are set to 1 if the return is classified as an extreme return in the respective sub-index on the same day. Below the coefficients are the t-values in parentheses. The pseudo R^2 is McFadden's likelihood ratio index. Bold and italic bold coefficients indicate significance at the 5% and the 10% level, respectively.

	ARBITRAGE			DIRECTIONAL		EVENT DRIVEN		
	CA	RV	EM	MM	EH	MA	DS	ED
Control Variables								
Market Variables and Volatility Controls								
Constant	**-3.8071**	**-3.3727**	**-3.5804**	**-3.8555**	**-6.0204**	**-3.2669**	**-3.4991**	**-4.6682**
	(-24.28)	(-21.83)	(-23.97)	(-23.62)	(-27.92)	(-20.89)	(-23.39)	(-25.66)
Russell 3000	0.2863	-0.1802	**0.792**	0.1558	0.0396	**-1.3687**	-0.0382	**-1.6296**
	(1.43)	(-0.76)	(5.36)	(0.78)	(0.11)	(-3.16)	(-0.15)	(-2.70)
Change in FRB dollar index	**0.4756**	**0.6418**	0.198	**1.9961**	**0.6157**	-0.1304	0.2071	**-0.3566**
	(2.36)	(3.24)	(1.01)	(11.25)	(4.26)	(-0.67)	(1.04)	(-2.30)
Return on LB bond index	**1.1582**	**-0.7439**	0.5916	**0.8399**	**2.2051**	**1.2354**	**1.0137**	**-0.9233**
	(2.82)	(-2.52)	(1.56)	(2.19)	(6.02)	(2.88)	(2.39)	(-2.18)
3 month T-bill rate	-6.46	***20.2411***	-1.6633	14.9728	**-19.2007**	**34.949**	1.0053	**-33.3119**
	(-0.66)	(1.76)	(-0.14)	(1.61)	(-2.14)	(3.14)	(0.08)	(-3.55)
-[S&P 500]	**-1.5021**	-0.5467	-0.4771	**0.9997**	**-2.8719**	**1.504**	0.3991	0.3024
	(-3.93)	(-1.30)	(-1.17)	(2.28)	(-6.16)	(2.61)	(0.96)	(0.44)
S&P volatility	**-0.0793**	-0.0345	**0.0598**	**-0.0557**	**-0.032**	**0.0633**	**0.1143**	0.0209
	(-3.48)	(-1.45)	(-2.69)	(-2.65)	(-2.52)	(-2.84)	(-5.13)	(-1.50)
FRB dollar index volatility	-0.0382	-0.0508	0.0705	-0.0389	**-0.1798**	***0.0981***	**0.1405**	-0.038
	(-0.62)	(-0.90)	(-1.13)	(-0.81)	(-5.14)	(-1.70)	-2.19	(-0.84)
LB bond index volatility	-0.0192	0.0699	***-0.0678***	**0.5185**	**0.3481**	0.008	-0.0045	**0.2919**
	(-0.22)	(-0.58)	(-1.69)	(-3.01)	(-3.20)	(-0.08)	(-0.05)	(-2.12)
ABS Factors								
Wilshire DJ small cap – large cap	***0.343***	***-0.356***	**-0.7354**	**-0.5983**	**-2.3963**	**-0.8604**	**0.5963**	**-0.8511**
	(1.67)	(-1.73)	(-3.69)	(-3.08)	(-14.64)	(-4.18)	(2.86)	(-4.20)
Change in 10 year Treasury note yield	0.0199	0.1411	**0.5419**	**0.2856**	**0.4141**	**0.3703**	0.0652	-0.0489
	(0.20)	(1.61)	(6.16)	(3.23)	(4.59)	(3.66)	(0.65)	(-0.51)
Change in credit spread Baa - Aaa	-0.0883	0.0893	**0.2533**	**0.3653**	0.0882	**0.1681**	-0.0716	**0.3599**
	(-0.97)	(1.00)	(2.99)	(5.07)	(1.24)	(2.03)	(-0.82)	(5.10)
Market Indicator (Contagion) Variables								
Same direction extreme event Russell 3000	***-1.1366***	***-0.7025***	-0.7896	**1.3108**	**-0.6851**	**-0.77**	**-0.9188**	0.1549
	(-1.78)	(-1.73)	(-1.54)	(3.24)	(-3.61)	(-2.54)	(-2.34)	(0.73)
Same direction extreme event Bond index	***0.9785***	-0.5806	0.3836	-0.3879	0.0142	1.0273	**1.164**	-23.7851
	(1.86)	(-1.15)	(0.83)	(-0.68)	(0.03)	(1.63)	(2.03)	(-0.00)
Same direction extreme event FRB index	-0.2437	0.0155	0.3023	**1.8052**	**0.9325**	***-0.8736***	-0.7153	***-0.5746***
	(-0.44)	(0.03)	(0.70)	(3.44)	(3.56)	(-1.68)	(-1.29)	(-1.81)
Other Hedge Fund Index Indicator Variables								
Arbitrage								
CA: Convertible Arbitrage		0.5117	**0.8802**	-0.6863	-23.6039	-0.5488	**1.7834**	0.3949
		(1.58)	(3.28)	(-1.44)	(-0.00)	(-1.09)	(9.20)	(1.30)
RV: Relative Value	***0.5543***		***0.5478***	**0.7371**	0.1213	0.0464	**-0.9824**	**1.4568**
	(1.66)		(1.93)	(3.56)	(0.60)	(0.17)	(-2.48)	(8.86)
EM: Equity Market Neutral	**0.918**	***0.535***		0.4067	**0.5363**	0.1492	***0.4578***	**-1.4025**
	(3.38)	(1.84)		(1.56)	(2.24)	(0.47)	(1.68)	(-5.29)
Directional								
MM: Macro Index	***-1.016***	**0.5408**	0.0416		0.1485	0.3161	0.1385	**0.8564**
	(-1.84)	(1.97)	(0.13)		(0.83)	(1.23)	(0.40)	(4.64)
EH: Equity Hedge	-23.7423	-0.2897	***0.6408***	**0.9311**		**0.5161**	0.4215	**0.7135**
	(-0.00)	(-0.84)	(1.71)	(3.34)		(2.22)	(1.22)	(4.77)
Event Driven								
MA: Merger Arbitrage	-0.2604	-0.1422	-0.0349	**0.965**	***0.2695***		-0.057	**0.4191**
	(-0.49)	(-0.45)	(-0.10)	(4.04)	(1.88)		(-0.18)	(2.66)
DS: Distressed Securities	**1.8151**	-0.6329	**0.6779**	0.37	**0.7355**	-0.1193		**1.4749**
	(9.31)	(-1.55)	(2.40)	(1.35)	(3.47)	(-0.43)		(8.36)
ED: Event Driven	0.3186	**1.2424**	-0.2807	0.3434	**0.8093**	**0.914**	**1.5907**	
	(0.74)	(4.40)	(-0.70)	(1.24)	(5.76)	(3.96)	(6.01)	
McFadden's Pseudo R^2	0.117	0.085	0.092	0.235	0.482	0.198	0.141	0.423

Appendix A: Description of HFR Monthly Indices

The HFRI Monthly Indices (HFRI) are equally weighted performance indexes, utilized by numerous hedge fund managers as a benchmark for their own hedge funds. The HFRI are broken down into 37 different categories by strategy, including the HFRI Fund Weighted Composite, which accounts for over 1600 funds listed on the internal HFR Database. Due to mutual agreements with the hedge fund managers listed in the HFR Database, we are not at liberty to disclose the particular funds behind any index to non-database subscribers.

Funds included in the HFRI Monthly Indices must:

- Report monthly returns
- Report Net of All Fees Returns
- Report assets in USD

Indices Notes:

- All HFRI are fund weighted (equal weighted).
- There is no required asset-size minimum for fund inclusion in the HFRI.
- There is no required length of time a fund must be actively trading before inclusion in the HFRI.
- The HFRI are updated three times a month: Flash Update (5th business day of the month), Mid Update (15th of the month), and End Update (1st business day of following month)
- The current month and the prior three months are left as estimates and are subject to change. All performance prior to that is locked and is no longer subject to change.
- If a fund liquidates/closes, that fund's performance will be included in the HFRI as of that fund's last reported performance update.
- The HFRI Fund of Funds Index is not included in the HFRI Fund Weighted Composite Index.
- Both domestic and offshore funds are included in the HFRI.

In cases where a manager lists mirrored-performance funds, only the fund with the larger asset size is included in the HFRI.

Appendix B

This appendix contains descriptions of the eight hedge fund strategies included in the HFR hedge fund indices. The source of these descriptions is Hedge Fund Research.

Convertible Arbitrage

Convertible Arbitrage involves taking long positions in convertible securities and hedging those positions by selling short the underlying common stock. A manager will, in an effort to capitalize on relative pricing inefficiencies, purchase long positions in convertible securities, generally convertible bonds, convertible preferred stock or warrants, and hedge a portion of the equity risk by selling short the underlying common stock. Timing may be linked to a specific event relative to the underlying company, or a belief that a relative mispricing exists between the corresponding securities. Convertible securities and warrants are priced as a function of the price of the underlying stock, expected future volatility of returns, risk free interest rates, call provisions, supply and demand for specific issues and, in the case of convertible bonds, the issue-specific corporate/Treasury yield spread. Thus, there is ample room for relative misvaluations.

Distressed Securities

Distressed Securities managers invest in, and may sell short, the securities of companies where the security's price has been, or is expected to be, affected by a distressed situation. Distressed Securities managers invest primarily in securities and other obligations of companies that are encountering significant financial or business difficulties, including companies which (i) may be engaged in debt restructuring or other capital transactions of a similar nature while outside the jurisdiction of Federal bankruptcy law, (ii) are subject to the provisions of Federal bankruptcy law or (iii) are experiencing poor operating results as a result of unfavorable operating conditions, over-leveraged capital structure, catastrophic events, extraordinary write-offs or special competitive or product obsolescence problems. Managers will seek profit opportunities arising from inefficiencies in the market for such securities and other obligations.

Negative events, and the subsequent announcement of a proposed restructuring or reorganization to address the problem, may create a severe market imbalance as some holders attempt to sell their positions at a time when few investors are willing to purchase the securities or other obligations of the troubled company. If manager believes that a market imbalance exists and the securities and other obligations of the troubled company may be purchased at prices below the value of such securities or other obligations under a reorganization or liquidation analysis, the manager may purchase the securities or other obligations of the company. Profits in this sector result from the market's lack of understanding of the true value of the deeply discounted securities. Results are generally not dependent on the direction of the markets, and have a low to moderate expected volatility.

Equity Hedge

Equity Hedge, also known as long/short equity, combines core long holdings of equities with short sales of stock or stock index options. Equity hedge portfolios may be anywhere from net long to net short depending on market conditions. Equity hedge managers generally increase net long exposure in bull markets and decrease net long exposure or even are net short in a bear market. Generally, the short exposure is intended to generate an ongoing positive return in addition to acting as a hedge against a general stock market decline. Stock index put options are also often used as a hedge against market risk. Profits are made when long positions appreciate and stocks sold short depreciate. Conversely, losses are incurred when long positions depreciate and/or the value of stocks sold short appreciates. Equity hedge managers' source of return is similar to that of traditional stock pickers on the upside, but they use short selling and hedging to attempt to outperform the market on the downside.

Equity Market Neutral
"Equity market neutral" strategies strive to generate consistent returns in both up and down markets by selecting positions with a total net exposure of zero. Trading Managers will hold a large number of long equity positions and an equal, or close to equal, dollar amount of offsetting short positions for a total net exposure close to zero. A zero net exposure is referred to as "dollar neutrality" and is a common characteristic of all equity market neutral managers. By taking long and short positions in equal amounts, the equity market neutral manager seeks to neutralize the effect that a systematic change will have on values of the stock market as a whole.

Some, but not all, equity market neutral managers will extend the concept of neutrality to risk factors or characteristics such as beta, industry, sector, investment style and market capitalization. In all equity market neutral portfolios stocks expected to outperform the market are held long, and stocks expected to under perform the market are sold short. Returns are derived from the long/short spread, or the amount by which long positions outperform short positions.

Event Driven
Event Driven investment strategies or "corporate life cycle investing" involves investments in opportunities created by significant transactional events, such as spin-offs, mergers and acquisitions, industry consolidations, liquidations, reorganizations, bankruptcies, recapitalizations and share buybacks and other extraordinary corporate transactions. Event Driven trading involves attempting to predict the outcome of a particular transaction as well as the optimal time at which to commit capital to it. The uncertainty about the outcome of these events creates investment opportunities for managers who can correctly anticipate their outcomes. As such, Event Driven trading embraces merger arbitrage, distressed securities, value-with-a-catalyst, and special situations investing.

Some Event Driven Trading managers will utilize a core strategy and others will opportunistically make investments across the different types of events. Dedicated merger arbitrage and distressed securities managers are not included in the Event Driven index. Instruments include long and short common and preferred stocks, as well as debt securities, warrants, stubs, and options. Trading Managers may also utilize derivatives such as index put options or put option spreads, to leverage returns and to hedge out interest rate and/or market risk. The success or failure of this type of strategy usually depends on whether the Trading Manager accurately predicts the outcome and timing of the transactional event. Event Driven Trading Managers do not rely on market direction for results; however, major market declines, which would cause transactions to be repriced or break, may have a negative impact on the strategy.

Macro
Macro strategies attempt to identify extreme price valuations in stock markets, interest rates, foreign exchange rates and physical commodities, and make leveraged bets on the anticipated price movements in these markets. To identify extreme price valuations, Trading Managers generally employ a top-down global approach that concentrates on forecasting how global macroeconomic and political events affect the valuations of financial instruments. These approaches may be systematic trend following models, or discretionary. The strategy has a broad investment mandate, with the ability to hold positions in practically any market with any instrument. Profits are made by correctly anticipating price movements in global markets and having the flexibility to use any suitable investment approach to take advantage of extreme price valuations. Trading Managers may use a focused approach or diversify across approaches. Often, they will pursue a number of base strategies to augment their selective large directional bets.

Merger Arbitrage

Merger Arbitrage, also known as risk arbitrage, involves investing in securities of companies that are the subject of some form of extraordinary corporate transaction, including acquisition or merger proposals, exchange offers, cash tender offers and leveraged buy-outs. These transactions will generally involve the exchange of securities for cash, other securities or a combination of cash and other securities. Typically, a manager purchases the stock of a company being acquired or merging with another company, and sells short the stock of the acquiring company. A manager engaged in merger arbitrage transactions will derive profit (or loss) by realizing the price differential between the price of the securities purchased and the value ultimately realized when the deal is consummated. The success of this strategy usually is dependent upon the proposed merger, tender offer or exchange offer being consummated.

When a tender or exchange offer or a proposal for a merger is publicly announced, the offer price or the value of the securities of the acquiring company to be received is typically greater than the current market price of the securities of the target company. Normally, the stock of an acquisition target appreciates while the acquiring company's stock decreases in value. If a manager determines that it is probable that the transaction will be consummated, it may purchase shares of the target company and in most instances, sell short the stock of the acquiring company. Managers may employ the use of equity options as a low-risk alternative to the outright purchase or sale of common stock. Many managers will hedge against market risk by purchasing S&P put options or put option spreads.

Relative Value Arbitrage

"Relative value arbitrage" is a multiple investment strategy approach. The overall emphasis is on making "spread trades" which derive returns from the relationship between two related securities rather than from the direction of the market. Generally, Trading Managers will take offsetting long and short positions in similar or related securities when their values, which are mathematically or historically interrelated, are temporarily distorted. Profits are derived when the skewed relationship between the securities returns to normal. In addition, relative value managers will decide which relative value strategies offer the best opportunities at any given time and weight that strategy accordingly in their overall portfolio. Relative value strategies may include forms of fixed income arbitrage, including mortgage-backed arbitrage, merger arbitrage, convertible arbitrage, statistical arbitrage, pairs trading, options and warrants trading, capital structure arbitrage, index rebalancing arbitrage and structured discount convertibles (which are more commonly known as Regulation D securities) arbitrage.

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