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ABSTRACT

We examine whether hedge funds experience contagion. First, we consider whether extreme movements in equity, fixed income, and currency markets are contagious to hedge funds. Second, we investigate whether extreme adverse returns in one hedge fund style are contagious to other hedge fund styles. To conduct this examination, we estimate binomial and multinomial logit models of contagion using daily returns on hedge fund style indices as well as monthly returns on indices with a longer history. Our main finding is that there is no evidence of contagion from equity, fixed income, and foreign exchange markets to hedge funds, except for weak evidence of contagion for one single daily hedge fund style index. By contrast, we find strong evidence of contagion across hedge fund styles, so that hedge fund styles tend to have poor coincident 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 led regulators to become concerned about the risks that hedge funds might create for the financial system. Hedge funds could create systemic risk if normal relations between hedge funds and financial markets break down when financial markets perform poorly, and the probability of extreme negative returns for hedge funds when financial markets experience extreme negative returns is much higher than could be predicted based on correlations between hedge funds and financial markets. Paradoxically, however, a major reason for the tremendous growth in assets managed by hedge funds is that investors believe these funds offer a valuable source of diversification because of low correlations between hedge fund returns and returns on other asset classes. 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.[2] If there is contagion between hedge funds and financial markets, the diversification benefit of investing in hedge funds would be least valuable when it is needed most, i.e., when financial markets in general perform poorly. In this paper, we investigate whether there is contagion between hedge funds and financial markets and within the hedge fund sector.

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 risk factors are not stationary.[3] 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

[1] A survey by Hedge Fund Manager magazine and Advent Software administered in November, 2005, which included 44 hedge fund administrators, indicated that assets of about $1.3 trillion are managed by U.S. hedge funds. The total assets under management worldwide is estimated at over $2 trillion. See full results at: http://www.advent.com/collateral/HFMAdventNOV2006surveyfinal.pdf

[2] 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.

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

lead to misleading inferences about the 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 regardless of the general correlation between assets, during bad times these assets tend to move together more closely than could be predicted using correlations. Hence, contagion measures a nonlinear effect that is not captured by correlation. For instance, during periods of contagious emerging market crises, there is a greater probability that many markets perform poorly which is not what one would expect if relying solely on correlations (see, for instance, Bae, Karolyi, and Stulz, 2003, hereafter BKS).

The possibility of contagion from traditional asset classes to hedge funds as well as between hedge funds is important 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 good 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, because in bad times a significant number of hedge funds will perform poorly.

Our paper 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), 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 extreme returns in risk factors and hedge funds to study contagion. We follow the existing contagion literature and adopt the binomial logit approach pioneered by Eichengreen, Rose, and Wyplosz (1996) and a multinomial logit extension thereof. The multinomial logit approach is similar to that used by BKS, who study financial contagion in Latin America and Asia, and focuses on extreme positive and extreme negative returns. Rather than calculating correlations, BKS measure joint occurrences of extreme returns and estimate a model of these occurrences using a multinomial logit regression. They find that large negative returns appear to be contagious within Latin America, and that Latin American returns tend to spread to other regions in the world.

We avoid parametric tests of correlations in this study because, as Baig and Goldfajn (2002) and Forbes and Rigobon (2002) argue, there are statistical difficulties involved in testing changes in correlations across up and down markets. Further, 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 contagion approach specifically focuses on nonlinearities in return distributions.

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 find that, while 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 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, which uses copulas, makes it possible to examine tail dependence without resorting to using correlations, it does not permit explicit conditioning on additional risk factors and, hence, makes it difficult to explore the determinants of contagion. A third approach is used by Chan, Getmansky, Haas, and Lo (2005). They address systemic risk using risk 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 use both daily and monthly hedge fund index return data for our analysis. The use of daily data represents an important innovation since earlier hedge fund research uses monthly data only. There are both benefits and costs in using daily data. The main benefit of using daily data is that it makes our tests more powerful. We focus on 5% tail events which 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 would be based on a sample with only nine tail events. 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 less affected by these problems, but their sample size is much smaller. To cope with the reduced sample size, we focus on 15% tail events (rather than 5%) when we use monthly returns.

Using the daily returns, we examine whether hedge fund styles move with each other and with broad market indices differently during extreme market conditions. That is, when broad markets have extreme returns, are hedge funds more likely to have extreme returns than could be predicted based on the normal relation between market and hedge fund returns? Additionally, when one hedge fund style has an extreme return, are other hedge fund styles more likely to have extreme returns than could be predicted using the normal relation between hedge fund style returns? If the behavior of hedge funds when markets have extreme returns or when other hedge funds have extreme returns can be understood by relations that hold when returns are not extreme, there is no contagion, in the sense that there is no nonlinear effect of extreme returns.[4]

We use two sets of daily hedge fund indices: the first provided by Standard and Poor's (S&P) encompasses the period from October 1, 2002 to June 15, 2005, and the second provided by Hedge Fund Research (HFR) begins April 1, 2003. While the S&P data covers a longer time period, the HFR set is more detailed. We condition on a number of economic control variables, including interest rates, exchange rates, market volatility, and broad market indices.

The S&P data covers three comprehensive hedge fund style categories: Arbitrage, Directional/Tactical, and Event Driven. Though the number of observations is limited as daily data is not available before October 1, 2002, the time frame does cover a variety of market conditions including the period of poor performance of the U.S. markets at the end of 2002.

The HFR data covers eight hedge fund style categories: Convertible Arbitrage, Distressed Securities, Equity Hedge, Equity Market Neutral, Event Driven, Macro, Merger Arbitrage, and Relative Value arbitrage. The HFR data series is shorter than the S&P data series (it begins April 1, 2003) but includes more styles. We study the S&P data with a binomial logit approach, and the HFR data using both a binomial logit and a multinomial logit approach.

[4] See also Forbes and Rigobon (2002).

Our study of the S&P hedge fund indices results in two key findings. First, we find no evidence of contagion from equity or currency markets to any of the three hedge fund indices. In contrast, there is strong evidence of contagion *between* the three hedge fund indices. If one index experiences an extreme negative return, the increases in probability that each of the other indices will experience an extreme negative return are statistically significant. The results using the HFR daily data are generally consistent with the S&P results, with the exception that there is evidence of contagion from fixed income markets to Arbitrage hedge funds, but not to Directional or Event Driven hedge funds. In addition, the evidence of contagion between hedge fund styles is slightly weaker than for the S&P indices, although there is still evidence of contagion between Event Driven and Arbitrage funds and Event Driven and Directional funds.

The second part of the paper examines contagion within sub-categories of hedge fund styles, using the HFR daily data. Since the HFR data encompasses eight separate hedge fund styles, rather than three as with the S&P data, we employ a multinomial logit model to study whether contagion affects more than one sub-category of each hedge fund style concurrently. We group the individual eight styles into the three broad S&P categories (Arbitrage, Directional, and Event Driven) and count the number of sub-category indices within each index category that experience extreme returns on a given day. This *COUNT* variable is assigned a value of zero (no extreme returns), one (one sub-category has an extreme return), or two (two or more sub-categories have extreme returns) and is the dependent variable in a multinomial logit model.

The results from the multinomial logit analysis of the HFR index data show clear evidence of contagion between all three hedge fund styles and evidence of contagion from fixed income markets to Arbitrage hedge funds. Contagion between Directional hedge funds and Event Driven hedge funds is quite strong. In particular, it is more likely that one, two or more sub-categories in either of these styles experience extreme poor returns the more sub-categories in the other style experience poor performance. The relationship between the Arbitrage and the Event Driven styles suggests that the likelihood of one

sub-category experiencing an extreme poor return increases the more sub-categories in the other style experience a poor return. Finally, the relationship between the Arbitrage and Directional styles suggests that the likelihood of two or more sub-categories experiencing an extreme poor return increases the more sub-categories in the other style experience a poor return. This evidence indicates that the somewhat weaker contagion results for the HFR aggregated indices are likely due to the aggregation method, as documented by the stronger contagion evidence uncovered once the styles are disaggregated.

The final section of the paper performs the above analyses using monthly hedge fund data from HFR which has the same categories as the daily data. The monthly data covers the period January 1990 to May 2005. As noted above, we use a 15% cut-off for extreme returns rather than the 5% cut-off used for daily data. The results from the monthly analysis indicate no significant evidence of contagion to hedge funds from broad markets. However, there is strong evidence of contagion between Event Driven and Arbitrage and Event Driven and Directional funds, consistent with the daily results.

The paper is organized as follows. In Section I we describe the data for daily hedge fund index returns. Section II uses the S&P (and HFR) daily hedge fund indices, first analyzing the determinants of extreme returns for each hedge fund style and next studying the relationship between extreme hedge fund returns and broad market returns. This section concludes by examining the incidence of co-movements between hedge fund styles. Section III uses the HFR daily index data and a multinomial logit approach to investigate the occurrence of contagion within and between the eight HFR hedge fund style categories. Section IV repeats the tests from Section II using HFR monthly data, Section V performs robustness checks, and Section VI concludes.

I. Data

We discuss successively the S&P data and the HFR data that we use. In our study of contagion, we focus on contagion between hedge funds and three representative markets: the stock market, the fixed-income markets, and the currency markets. We use the return of the Russell 3000 index to proxy for the

return of equities, the daily return on the Lehman Bond index to proxy for the return of the fixed-income markets, and the change in the FRB Dollar index to proxy for the return of the currency markets. We therefore also present data on these indices.

I.1. Daily hedge fund index data from Standard and Poor's (S&P)

Standard and Poor's (S&P) provides daily hedge fund index data at the industry level and the style level. It has indices for three broad styles: Arbitrage, Directional/Tactical, and Event Driven. Each style in turn consists of three strategies. The goal of the Arbitrage style is to exploit pricing discrepancies between closely related securities, and contains the following three strategies: Equity Market Neutral, Fixed Income Arbitrage, and Convertible Arbitrage. The goal of the Directional/Tactical style is to exploit broad market trends in equities, interest rates, or commodity prices, and contains the following three strategies: Equity Long/Short, Managed Futures, and Macro.[5] The final style, Event Driven, attempts to exploit discrete events such as bankruptcies, mergers, and takeovers, and contains the following three strategies: Merger Arbitrage, Distressed, and Special Situations. S&P does not provide separate index data for the strategies within each style category.

Daily returns on the indices are reported since October 1, 2002. Each style index is an equally-weighted measure of the three strategies that comprise the index. The strategies are equally-weighted to ensure well-rounded representation and to avoid overrepresentation of any one strategy. The number of individual funds in each of the nine strategies ranges from 3 to 5, for a total of forty funds. In determining the number of funds in each index, S&P performed both qualitative and statistical analyses and concluded that forty funds represents a reasonable sample that fairly represents the risk, return, style, and correlation characteristics of the broader hedge fund universe.[6]

S&P requires that funds have at least $100 million in assets under management and a three-year track record to be eligible for inclusion in the index. Additionally, funds must be open to new investment,

[5] Appendix A contains detailed descriptions of the nine S&P strategies.

[6] See *Standard and Poor's Hedge Fund Index: Structure, Methodology, Definitions, and Practices,* January, 2003, http://www3.standardandpoors.com/spf/pdf/index/S&PHedgeFundPaper.pdf.

provide daily pricing, and pass a number of due diligence tests, including manager background checks. All portfolio positions are verified independently by a third party. Additionally, S&P reserves the right to remove funds from the index for various reasons, including style drift, legal or ethical problems, major business disruptions, lack of operational compliance, or lack of capacity for additional investment. If funds are removed from the index, regardless of the reason, the index's history is not restated. Additions and deletions to the index are scheduled annually in January, unless during another time a special event occurs and the Index Committee deems changes are necessary. All S&P hedge fund indices are rebalanced to equal weighting in January, and any changes are announced in advance on the S&P website.

Thus, according to S&P, the indices are representative, investible (although not directly), and transparent. There are two issues with the indices that might affect our analysis. First, the requirement that funds have at least $100 million in assets restricts the indices to relatively large funds. To the extent that large and small funds might have systematically different returns or other characteristics, this could be a cause of concern, and in interpreting the index results it is important to keep this in mind.

The second issue is that the S&P index data are published daily but "finalized" monthly after a review of the month's returns. Due to illiquidity in some holdings or difficulty in obtaining prices, there may be differences between the daily and monthly series. S&P does not restate the daily data to match finalized month-end values. We investigate whether this is an issue for our analysis by aggregating the daily return series into a monthly series and comparing it to the "finalized" S&P monthly series published on their website. The simple correlations between the finalized monthly returns and the returns aggregated from the daily data are 0.83, 0.98, and 0.94 for Arbitrage, Directional, and Event Driven, respectively. The t-tests of differences in means are never significant at standard levels. Finally, we count the number of times that the monthly index is lower than the aggregated daily index to determine if there is a systematic bias, and find that for the Arbitrage index, the daily aggregated returns are lower than the "finalized" monthly returns 12 out of 26 times and are higher 14 out of 26 times. For the Directional and Event Driven indices, the counts are lower 12 and 10 times and higher 14 and 16 times than the finalized

indices, respectively. Thus, the correlations are high and there appears to be no systematic directional bias between the aggregated daily and finalized monthly index returns. Given these results and our understanding of the S&P methodology, we use these indices in the analyses that follow, subject to the above caveats.

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

In addition to the S&P indices, we also use the Hedge Fund Research (HFR) daily indices. These indices are published by HFR and consist of eight single strategy indices. 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. The eight single-strategy indices include: Convertible Arbitrage, Distressed Securities, Equity Hedge, Equity Market-neutral, Event Driven, Macro, Merger Arbitrage, and Relative Value Arbitrage.[7] All indices contain only hedge funds that are open for new investment. The individual strategy indices are rebalanced on a quarterly basis and have been designed to offer daily pricing, consistent fund selection through cluster analysis, stringent risk management, and strict reporting standards.

Additionally, HFR imposes a minimum asset size of $50 million and a minimum track record of 2 years, slightly different from the S&P requirements of $100 million and 3 years. There are currently sixty-nine funds in the index, spread across the 8 styles as appropriate to ensure that the styles are representative of the strategies they represent. The more detailed categorization of the HFR indices – eight versus three categories – allows us to perform additional analyses. Specifically, in Section III, we use a multinomial logit model to test contagion at the sub-index level.

I.3. Monthly hedge fund index data from Hedge Fund Research (HFR)

In Section IV, we perform tests of contagion using monthly data provided by HFR. This data extends from 1990 to 2005 and covers a much longer time frame than the daily data. While the HFR monthly data covers the same eight categories as the HFR daily data, the indices are constructed differently. The first

[7] See Appendix B for HFR's description of the eight style categories.

difference relates to the number of funds in the indices. While the daily indices include only sixty-nine funds, the monthly indices include over 1,600 funds. Second, there is no required asset-size minimum for inclusion in the indices, in contrast with the daily indices which require a fund have at least $50 million in assets for inclusion. Third, there is no required length of time a fund must be trading to be included, as compared to the daily indices which require at least 2 years of trading history. Finally, the monthly indices also include funds that are closed to new investment.[8]

II. Hedge fund contagion with daily index returns

In this section, we investigate hedge fund contagion using daily returns. 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 other realizations of the risk factors. Section II.1a describes the risk factors and reports summary statistics for the three S&P hedge fund indices, and Section II.1b reports summary statistics for the HFR indices. Section II.2 presents the approach we use to estimate contagion. Section II.3 studies contagion between equity, fixed income, and currency markets and the hedge fund indices, and Section II.4 examines contagion between hedge fund indices.

II.1a. Daily S&P hedge fund indices: Summary statistics

The data used are daily returns for the period October 1, 2002 through June 15, 2005 (684 daily observations) from the S&P hedge fund indices which include the Arbitrage index, the Directional/Tactical index, and the Event Driven index. Table I.A reports correlations and summary statistics for the three hedge fund indices and the market indices. Panel 1 reports the returns and correlations for the three hedge fund styles and the control variables. Among the three styles, the Event Driven style has the highest average return (about 0.037% per day) and the lowest standard deviation.

[8] See Appendix C for further detail on the construction of the HFR monthly indices.

The correlations are not particularly high among the hedge fund indices, but there are several high correlations between the hedge fund indices and the control variables. These correlations indicate that our chosen risk factors appear to capture the linear risks of hedge funds quite well.

The Arbitrage index is positively correlated with S&P 500 implied volatility and the return on the LB bond index and negatively correlated with the proxy for a long put option and the Russell 3000 index. The Directional index is positively correlated with the proxy for a long put option, the Russell 3000 index, the return on the LB bond index, and the Treasury bill return, and negatively correlated with changes in the FRB dollar index and changes in S&P 500 implied volatility. Finally, the Event Driven index is positively correlated with the proxy for a long put option and the Russell 3000 index but negatively correlated with changes in S&P 500 implied volatility and the return on the LB bond index.

We also examine autocorrelation for each hedge fund index. First-order autocorrelation is negative for the Arbitrage index, and positive and marginally significant for the Directional and Event Driven indices. The Ljung-Box test rejects the hypothesis of no autocorrelation for the first six lags of returns for both the Arbitrage and Event Driven indices. While there is some evidence of autocorrelation, it is not as strong as found in previous literature (see, e.g., Asness, Krail, and Liew, 2001, and Getmansky, Lo, and Makarov (2004)). For example, Getmansky, Lo, and Makarov report first and second-order serial correlation among Event Driven hedge funds as 20.8% and 6.4%, while we report much lower values of 6.3% and 2.9%. The reason serial correlations differ so much is likely due to differences in data: they use monthly, individual hedge fund data over a longer time frame while we use daily index data over a shorter time frame. Another possible explanation for lower autocorrelation is that funds that price daily generally have more liquid assets or less discretion in pricing.

It is well-known that hedge fund returns are not normally distributed. For example, Geman and Kharoubi (2003) find that hedge funds exhibit high kurtosis and that Jarque-Bera tests strongly reject normality. Similarly in our sample, all three S&P style indices also exhibit high excess kurtosis, and Jarque-Bera tests strongly reject normality.

Table I.B provides a first look at the relationship among hedge fund index returns and market returns during up and down market conditions. Up markets are defined as periods when the market return is in the top half of all returns for the period, while down markets comprise periods where the market return is in the bottom half of returns. Our choices of conditioning market returns include the Russell 3000, LB bond index, and the FRB dollar index. Using this simple categorization of up and down markets, the conditional correlations among 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.

II.1b. Daily HFR Indices: Summary statistics

The HFR indices are reported for eight categories, in contrast with three categories for the S&P indices. To compare the HFR results with the S&P results, we aggregate the HFR indices into the same three categories.[9] The combined HFR Arbitrage style index includes the HFR sub-categories of Convertible Arbitrage, Relative Value, and Equity Market Neutral. The combined HFR Directional style index includes the HFR sub-categories Macro Index and Equity Hedge. Finally, the combined HFR Event Driven style index includes the HFR sub-categories of Merger Arbitrage, Distressed Securities, and Event Driven. While recognizing that our grouping methodology is imperfect and the time frames covered are not exactly the same, our methodology nonetheless allows us to analyze contagion in roughly the same way as for the S&P hedge fund indices.

Table II.A reports summary statistics for the HFR combined categories. The data are daily for the period April 4, 2003 through June 15, 2005 for a total of 557 observations. The mean returns and unconditional correlations are mostly consistent with the results for the S&P indices, with a few exceptions. One difference between the S&P and HFR indices is that the S&P Arbitrage index has a positive mean while the HFR Arbitrage index has a negative mean. Also, the HFR Arbitrage and HFR Event Driven indices are positively correlated while the S&P Arbitrage and S&P Event Driven indices are negatively correlated. The correlation between the Directional and Event Driven indices is higher for the

[9] We follow the methodology of S&P and calculate equally-weighted average returns within each style.

HFR than for the S&P indices, although in both cases the correlation is positive. Similar to the S&P indices, the return series of each group exhibits excess kurtosis and normality tests are strongly rejected.

The HFR Arbitrage style exhibits negative autocorrelation at lag one, while the other two styles show significant positive autocorrelation at lag one and up to lag 3, respectively. In addition, Ljung-Box tests reject the hypothesis of no autocorrelation in the first six lags for both the Event Driven and Directional indices. These significant positive autocorrelations are higher than in the earlier results for the S&P indices, and are more in line with what we would expect based on previous literature. While the negative autocorrelation should not introduce spurious results into the analysis, the positive values for the Directional and the Event Driven indices should be kept in mind when interpreting the results. To address this issue, in Section V we perform robustness checks that control for autocorrelation. The results of Section V are consistent with the results in this section.

Table II.B presents the conditional correlations among the combined HFR hedge fund indices and the market indices. The results are again similar to those for the S&P indices with one notable exception. For the HFR indices, when the conditioning (market) variable is below the median, there is generally a positive correlation among the three hedge fund indices as compared with the S&P hedge fund index correlations which are not always positive. The next section introduces the model we use for contagion tests.

II.2 The regression approach

Below, we use a logit model to examine contagion in hedge funds by estimating the probability that a hedge fund will have an extreme return. 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 probability that a hedge fund will have an extreme return. By contrast, with contagion from a specific risk factor, the probability that a hedge fund will have 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 enter linearly, indicator variables that take the value one when the risk factors have extreme realizations.

Much of the analysis uses a binomial logit model. However, some of the analysis also uses a multinomial logit model. The following paragraphs describe the multinomial logit model closely following the description in BKS. Multinomial logistic regression models are used to estimate the probabilities associated with events captured in a polychotomous variable (see Maddala (1986) and Hosmer and Lemeshow (1989)). If P_i is the probability associated with a category *i* of *m* possible categories, then we define a multinomial distribution as

$$P_i = \frac{G(\beta_i' x)}{[1 + \sum_{j=1}^{m-1} G(\beta_j' x)]} \qquad (1)$$

where *x* is the vector of covariates and β_i the vector of coefficients associated with the covariates. The function $G(\beta_i' x)$ is often simplified using a logistic function $\exp(\beta_i' x)$, reducing Equation (1) to a multinomial logistic model. Maximum likelihood with the (log-) likelihood function is used to estimate the model for a sample of *n* observations as

$$\log L = \sum_{i=1}^{n} \sum_{j=1}^{m} I_{ij} \log P_{ij} \qquad (2)$$

where I_{ij} is an indicator variable that equals one if the *i*th observation is in the *j*th category, and zero otherwise.

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

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

In Section III, this multinomial logit model is used to test whether the eight HFR indices exhibit contagion. In the following analysis the binomial logit version is used for the S&P hedge fund indices. The indicator variable I_i on a given day i is set equal to one if an index's return on that day is in the top or bottom five percent of all the daily returns for that index for the entire sample period. If the index's return on that day is not in the top (bottom) five percent, the indicator variable is set equal to zero. If a return is in the top or bottom five percent of all returns it is called an "extreme return." Positive and negative outcomes are estimated separately. Then, using the notation for the multinomial logit (which is easily reduced to the binomial logit form), the probability of an extreme return outcome of a specific level P_i is computed by evaluating the covariates at their unconditional values,

$$P_i^* = \frac{\exp(\beta_i' x^*)}{1 + \sum_{j=1}^{m-1} \exp(\beta_j' x^*)} \tag{4}$$

where x^* is the unconditional mean of x. From this measure and following Greene (2000, chapter 19), we compute the marginal effects – the change in probability for a small change in one of the independent covariates – to assess the economic significance of this change.

II.3. Contagion between daily S&P hedge fund indices and market indices

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 at-the-money put options on the S&P 500 index.[10] We follow Agarwal and Naik (2004) and control for the general distribution of hedge fund returns using the following risk factors: the return on the Russell 3000 index, the change in the Federal Reserve Bank competitiveness-weighted dollar index (hereafter FRB dollar index), the return on the Lehman Brothers U.S. fixed-income index (hereafter LB bond index), and the return on the three-month U.S. Treasury Bill. Additionally, we control for the negative portion of the S&P 500 returns to proxy for the payoffs from a long put option, and the change in implied volatility on the S&P 500 index which is calculated as the simple average of the implied volatilities from call and put options on the S&P 500.

In our regressions, we let hedge fund returns be related linearly to the index returns that represent the equity market (Russell 3000), the fixed-income market (LB bond index), and the currency market (FRB dollar index) to allow for correlation effects. In addition, we include indicator variables that represent extreme returns (top or bottom 5%) for each of these markets to allow for non-linear contagion effects. For the "negative tail" case, the "same-direction" market indicator variable is set to one if the relevant market has an extreme negative return and zero otherwise. When both the hedge fund index and a market experience extreme negative returns, the coefficient on the market indicator variable will be positive, indicating contagion among extreme poor returns. In contrast, a negative coefficient on the market 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 indicator variable is set to one if the market has an extreme positive return and zero otherwise. When both the hedge fund index and the market index experience extreme positive returns, this indicates contagion among good returns. We are most interested in

[10] See, for example, Fung and Hsieh (1997, 2001), Ackermann, McEnally and Ravenscraft (1999), Liang (1999), Mitchell and Pulvino (2001), and Agarwal and Naik (2000, 2004).

instances of contagion during down periods as indicated by a positive coefficient on the "negative tail" market indicator variable.

Table III presents the results of this analysis. The first two regressions are for the negative and positive tails of the Arbitrage style index. Focusing on the linear measures of the risk factors, the Arbitrage style index is significantly more likely to have an extreme negative return and significantly less likely to have an extreme positive return when the Russell 3000 has a high return. In addition, the Arbitrage index is more likely to have an extreme negative return when changes in the FRB dollar index are positive and when returns on the T-Bill are high. For example, for a return on the Russell 3000 that is 1% higher than its mean return in the sample, the probability that the Arbitrage index will have a negative extreme return increases by 2%, and for a 1% increase in the FRB dollar index, the probability that the Arbitrage return will have a negative extreme return increases by 2%. Given the large standard deviations of these two control variables, these marginal effects are economically relevant.[11] However, the large marginal effect of 1.166 on the T-Bill is economically irrelevant; a one standard deviation return shock of 0.006% in the T-Bill results in an economically very small change in probability of approximately only 0.007% that an extreme negative event occurs in the Arbitrage index.

Turning to the contagion variables which model non-linear effects, an extreme return on the Russell 3000 index makes it significantly less likely that the hedge fund index will have an extreme return in the same direction. Consequently, extreme returns on the Russell 3000 are not contagious. There is no evidence that extreme returns on the hedge fund index are related to same direction extreme returns on the LB bond index or the FRB dollar index.

[11] It is helpful to compare these results with prior literature, which uses different data. Agarwal and Naik (2004) use a linear measure of the hedge fund index return as the dependent variable in their regressions, as opposed to our logit approach which uses an indicator variable. Using a number of Arbitrage indices, they show a positive relationship with a short put option on the S&P 500 and a positive relationship with the Russell 3000 index, in contrast with our results which indicate no relationship with the negative part of the S&P 500 index (our proxy for a put option) and a negative relationship with the Russell 3000. Clearly, extreme events in the Arbitrage style have different exposures to market factors than do linear measures of the same style.

The next two regressions are for the Directional style index. A higher return on the FRB dollar index makes it more likely that the hedge fund index will have an extreme negative return and less likely that it will have an extreme positive return. A large negative return on the LB bond index makes an extreme negative return less likely and an extreme positive return more likely. Further, a high return on the Russell 3000 makes an extreme positive return more likely, and a large negative return on the S&P 500 index (our proxy for a long put option) makes an extreme positive return less likely.[12] The results for the market indicator variables provide no evidence of contagion; rather, they indicate the opposite, which is that these hedge funds are less likely to have extreme returns when stocks, bonds, and currencies have extreme returns. This is because, strikingly, all six indicator variables have negative coefficients (of which four are statistically significant), so that extreme market realizations make it less likely that the hedge fund index will have a same-direction extreme return.

The last two regressions are for the S&P Event Driven index. This index is more likely to have either an extreme negative or an extreme positive return when the FRB dollar index return is high and is more likely to have an extreme positive return when the Russell 3000 index has a high return. Finally, the Event Driven index is more likely to have an extreme negative return when the return on the LB bond index is high.[13] There is no evidence of contagion from market risks whatsoever, but there is weak evidence of crash protection against extremely poor returns in fixed income markets.

As a robustness check, Table IV performs the same analysis for the HFR aggregate indices. While there are some differences with the S&P indices with respect to the linear measures of market risk, the results for extreme returns are fairly consistent. The main differences are that for the HFR Arbitrage

[12] We again compare our results to those of Agarwal and Naik (2004) (who use a linear measure of the hedge fund index return as the dependent variable in their regressions, as opposed to our logit approach which uses an indicator variable). Using a Directional index, they show a positive relationship with the Russell 3000 index, similar to our results which indicate a positive relationship with the Russell 3000. In this case, extreme positive returns in the Directional style have similar exposures to market factors as linear measures of the same style.

[13] Using a linear measure for the Event Driven index, Agarwal and Naik (2004) show a positive relationship with a short put option on the S&P 500 and a positive relationship with the Russell 3000 index and lagged Russell 3000, in contrast to our results for the negative part of the S&P 500 but similar to our results for the Russell 3000 index.

index there is no evidence that extreme negative returns in the Russell 3000 make extreme negative returns on the indices less likely, and there is evidence that extreme positive returns in the Russell 3000 are contagious to the HFR Arbitrage index. Also for the HFR Arbitrage index, in contrast to the S&P Arbitrage index, there is evidence of contagion in extreme poor returns from fixed income markets to Arbitrage funds. For the Event Driven index, there is no evidence of the downside protection against fixed income markets observed with the S&P daily index. Finally, the explanatory power for the HFR regressions is typically lower compared to the S&P regressions, perhaps due to the shorter sample period for the HFR indices or the aggregation method.

Except for weak evidence of contagion in negative returns from fixed income markets to Arbitrage hedge funds, we find no evidence of contagion between hedge fund indices and the equity, fixed-income, and currency markets. Additionally, there is evidence that Directional hedge funds are less likely to incur extreme losses when extreme negative returns take place in these markets. The next section examines contagion between hedge fund indices.

II.4. Are extreme returns contagious between daily S&P hedge fund style indices?

In this section, we focus on contagion between hedge fund styles. If there is a high probability of contagion between hedge fund styles, diversification within this asset class will not offer protection against extremely poor returns in a specific style. Additionally, contagion of bad performance between hedge fund styles raises the concern of systemic risk.

To explore contagion between hedge fund styles, we include additional variables in the above regressions. In particular, we create separate positive and negative same-direction extreme return indicator variables for each hedge fund index. The indicator variable is set to one if the return on the hedge fund index is an extreme positive (negative) return and zero otherwise. There are six indicator variables in total: one positive and one negative for each index.

These regressions include all previous linear measures of risk factors as well as the market indicator variables from Tables III and IV. It is important to include these risk factors as they help explain hedge

fund returns. By contrast, we do not include linear measures of the hedge fund index returns in the regressions that follow since these returns are correlated with the included broad market risk factors which subsume the linear hedge fund index data (see Tables I and II). Our approach is consistent with prior literature (see, for example, Agarwal and Naik (2004)), and implies that the broad market risk factors act in our regressions as instrumental variables for the general risks inherent in hedge fund returns.

We focus on the coefficients on the same-direction indicator variables representing extreme events in the other two hedge fund styles. The interpretation of the coefficients is similar to previous tables: a positive coefficient on the indicator variable in the case of negative extreme returns implies contagion between negative returns, while a negative coefficient implies weak-form downside protection. A positive coefficient on the indicator variable in the case of positive extreme returns implies contagion between positive returns. Again, we are most interested in evidence of negative contagion. Table V performs this analysis for the S&P hedge fund indices.

For the Arbitrage index, there is contagion in extreme negative returns with both the Directional and Event Driven indices. This result is particularly striking since the Arbitrage and Event Driven indices are negatively correlated. Additionally, there is contagion in extreme positive returns with the Directional index. For the Directional style there is evidence of contagion in extreme negative returns with both the Arbitrage and Event Driven indices. There is also contagion in extreme positive returns with the Arbitrage index. Finally, for the Event Driven style, there is weak evidence of contagion in extreme negative returns with both the Directional and Arbitrage indices although the results are not significant at traditional levels. Taken together, these results indicate contagion between hedge fund styles, particularly with respect to extreme negative returns.

As a robustness check, the same analysis is performed in Table VI using the HFR aggregate hedge fund indices in lieu of the S&P hedge fund indices. The results in Table VI are generally consistent with the S&P index results, with two exceptions. First, the evidence of contagion between negative returns in Arbitrage and Directional indices no longer exists. Second, the evidence of contagion between

Directional and Event Driven is stronger and more significant. As before, the Pseudo R^2s for the analysis of HFR indices are typically lower (particularly for the Arbitrage style) than for the analysis of the S&P hedge fund indices.

In summary, while there is little evidence of contagion between broad market indices and hedge fund indices, there is substantially more evidence of contagion between hedge fund indices. The next section presents a more detailed analysis of this phenomenon, using the daily HFR index data.

III. Multinomial logit tests of daily HFR indices

In this section we investigate contagion in more detail using all eight HFR sub-indices. We test whether an extreme event in a financial market affects more than one sub-index within an aggregated hedge fund style. Furthermore, we examine whether the occurrence of simultaneous extreme events within an aggregated hedge fund style predicts extreme events for several sub-indices of either of the other two aggregated hedge fund styles. In this respect, the multinomial analysis is more detailed as it allows us to identify how many of the sub-indices within each broad index are affected by contagion.

We proceed as follows with the multinomial analysis. 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 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 estimated coefficients for the market indicators and the *COUNT* variables are reported in Table VII. The table reports for each independent variable of interest two coefficients – one is related to the event that the hedge fund style examined has an extreme return in only one sub-index (*COUNT=1*) and the other is related to the event that the style has extreme returns in two or more sub-indices (*COUNT=2*). The omitted variable, *COUNT=0*, is the base case and all results are reported relative to this case.

To facilitate the interpretation of the coefficients, the table reports marginal effects calculated at the mean of the explanatory variables. Generally speaking, a positive coefficient on a broad market indicator variable implies contagion in the same direction from that market to the hedge fund style. A positive coefficient on a *COUNT* variable for any of the other hedge fund indices implies contagion in the same direction between styles. Negative coefficients on the other hand imply weak-form downside protection.

As before, we focus on extreme negative returns. For the Arbitrage hedge fund style, there is mixed evidence of contagion with fixed-income markets. When the LB bond index has an extreme negative return, the probability that one Arbitrage sub-index will have an extreme negative return increases significantly. However, the probability that two or more Arbitrage sub-indices will have an extreme negative return decreases significantly in this situation, providing evidence of downside protection against poor outcomes in fixed income markets. For the HFR Directional and Event Driven styles, there is evidence of crash protection with the LB bond index. Specifically, the probability that two or more of the HFR Directional or Event Driven sub-indices will have extreme negative returns decreases when the LB bond index has an extreme negative return. This same form of crash protection is provided against falling currency markets by the Directional index but not by the Event Driven index. These results indicate that even when examining sub-indices there is little evidence of contagion from broad markets to hedge funds.

The table also offers valuable additional insight into contagion between hedge funds. While prior tests on the HFR aggregate indices in Table VI indicate no contagion between the Arbitrage and

Directional indices, the results from the more detailed analysis do indicate contagion. The more Directional sub-indices experience extreme negative returns, the more likely it is that two or more of the Arbitrage sub-indices will also experience extreme negative returns. Additionally, the contagion from Event Driven to Arbitrage documented in Table VI holds for one, but not more Arbitrage sub-indices. The same result holds for contagion from Arbitrage to Event Driven – the more Arbitrage sub-indices experience extreme bad returns, the more likely it is that one, but not more, Event Driven sub-index will experience extreme negative returns. This contagion from Arbitrage to Event Driven funds was not evident in the aggregate tests performed in Table VI.

Finally, the strong contagious relationship between Directional and Event Driven funds continues to hold in this more detailed analysis. The more Directional sub-indices that experience extreme poor returns, the more likely it is that one, two, or more Event Driven sub-indices will experience extreme poor returns. This relationship also holds in reverse, from Event Driven to Directional. The results of this table are consistent with the aggregate analysis of the S&P hedge fund indices presented in Table V and suggest that the weaker results reported for the equally-weighted average HFR indices in Table VI are likely the consequence of the aggregation method.

The results of this section imply that except for conflicting results regarding contagion from fixed income markets to Arbitrage hedge funds, there is little evidence of contagion from broad markets to HFR indices at the sub-index level. However, when examining contagion between hedge fund indices, certain relationships that do not exist or are rather weak at the aggregate level are quite significant at the sub-index level. These sub-index results indicate strong contagion between HFR hedge fund sub-indices which is consistent with the results reported for the S&P indices in Table V.

IV. Tests of contagion using HFR monthly index data

As noted earlier, there is a trade-off between using daily and monthly hedge fund data to perform contagion tests. The daily data provide more observations but cover a shorter time period. By contrast,

monthly data provide fewer observations over a longer time period, but using a 5% tail cut-off to define "extreme returns" with monthly data results in too few tail observations. However, the longer time period available for monthly data – which encompasses a number of market crises, including the Asian and Mexican currency crises and the failure of Long Term Capital Management – makes a monthly analysis worthwhile on its own. To improve the power of the monthly tests that follow, we use a 15%, rather than a 5%, cut-off to define "extreme" or "tail" returns. The logic for using 15% is that with a 15% threshold the monthly analysis has roughly the same number of extreme events as the daily analysis. The monthly index data is provided by HFR and is categorized and aggregated in the same manner as the daily data. The data is available from January 1990 to May 2005.

Table VIII.A. provides summary statistics and correlations for the HFR monthly indices. The data in Panel 1 indicate much higher positive unconditional correlations between hedge fund indices for monthly data than for daily data as reported in Table II. Two reasons that these correlations are higher than for daily data are that the monthly data includes over 1,600 funds, so that there is more diversification at the index level, and that monthly returns are likely less volatile at the fund level than daily returns, perhaps because hedge funds reporting daily are invested in more liquid assets than the general population of hedge funds. Additionally, in contrast to the daily data statistics in Table II, the correlations with the Russell 3000 index and the put proxy on the S&P 500 index are large and positive for all the HFR monthly hedge fund indices. The results for the put proxy are broadly consistent with Agarwal and Naik (2004) and Mitchell and Pulvino (2001) who show that hedge fund returns are positively correlated with the returns on long put options.

There is a fairly high degree of first-order autocorrelation for all three indices, 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 consistent with Getmansky, Lo, and Makarov (2004) and other prior literature. Finally, the respective normality tests are strongly rejected for the Arbitrage and the Event Driven styles but not for the Directional style (see Panel 3).

Turning to the conditional correlations in Table VIII.B., the strong positive correlations among the hedge fund indices persist, regardless of the conditioning variable and regardless of the direction of the market. This finding is consistent with Liang (2004) and Capocci and Hubner (2004) who report large and positive correlations among monthly hedge fund data in both up and down markets.[14] For the correlations with market indices, Table VIII.B shows that, in five of the six cases, all hedge fund styles show strong positive correlations with the Russell 3000 index. The exception occurs when the conditioning variable is the Russell 3000 being above the median. Additionally, the correlations with the FRB Dollar index are typically small and not statistically significant, while correlations with the LB Bond index are positive and sometimes statistically significant.

Though some of the correlations – both between hedge fund indices and between hedge fund indices and market indices – are fairly high, this does not affect our analysis as our contagion tests investigate the nonlinear relationship between hedge fund indices and between hedge fund indices and broad markets. Furthermore, we control for this correlation by including the linear market factors as control variables which act as instruments for the general risk exposures of hedge funds. In the following table we test for contagion over and above the linear relationship implied by these relatively high correlations.

Table IX examines contagion between the HFR monthly hedge fund indices and market indices as well as contagion between hedge fund indices. The regressions are identical to those performed in Tables V and VI for daily data, except that the definition of "extreme return" uses a 15% tail cut-off rather than 5%. The 15% cut-off is used for both the hedge fund index returns and the same-direction market indicator variables. As in Tables V and VI, a positive coefficient on the same direction market indicator variable indicates contagion in both the negative and positive tail cases, while a negative coefficient indicates downside protection in the negative tail case.

[14] Liang uses monthly individual fund and index provided by Zurich Capital Markets. Capocci and Hubner use monthly individual fund and index data provided by Managed Account Reports (MAR) and Hedge Fund Research (HFR). Their results hold for both index and aggregated individual fund data.

Examining Table IX, the results for contagion from broad market indices to hedge funds are consistent with the daily results – there is no evidence of contagion. In contrast to the daily results, there is evidence that the Arbitrage style provides downside protection against extreme returns in the Russell 3000, while there is no evidence that either the Directional style or the Event Driven style provides downside protection against any of the broad markets.

Next, we turn to the tests of contagion between hedge fund indices. Consistent with the findings using HFR daily data, the results indicate evidence of contagion between hedge fund styles. There is strong evidence of contagion between the Arbitrage and Event Driven styles, the Directional and Event Driven styles, and the Event Driven and both the Arbitrage and Directional styles. These results are strong for both extreme good and extreme negative returns, in contrast to the daily results which are typically only significant for extreme negative returns.

In summary, the results from the monthly tests are generally consistent with the results from the daily tests. While there is no evidence of contagion from broad markets to hedge funds, there is strong evidence of contagion between all three hedge fund styles. These results suggest that the daily contagion results are not confined to the shorter period of time for which daily data is available, but rather, that non-linearities have been prevalent in hedge fund returns for the last fifteen years.

V. Robustness tests

This section performs robustness tests on the daily and monthly data. First, we investigate whether we miss contagion from fixed-income markets because of a flight to safety phenomenon. For instance, during the crisis of 1998, interest rates fell. We re-estimate our regressions allowing for extreme positive returns in fixed-income markets to increase the probability of extreme negative returns for hedge fund indices. This robustness test does not lead us to alter our conclusions.

Second, as discussed in Sections II.1a. and II.1.b., both the S&P and HFR daily indices exhibit some evidence of autocorrelation in returns. Additionally, the monthly HFR indices discussed in Section

IV also exhibit autocorrelation. To ensure that autocorrelation is not driving our contagion results in Tables V (S&P daily), VI (HFR daily) and IX (HFR monthly), we perform additional tests.

For each of the indices, we remove the autocorrelation by fitting individual autoregressive time-series models of varying lag lengths for the returns. The lag length for each series is selected based on the partial autocorrelation coefficients following the Box-Jenkins methodology (see, for example, Hamilton (1994)). These "filtered" returns are then used in the analyses.

For the S&P daily indices, we use an AR(2) structure for the Arbitrage index and AR(1) structures for each of the Directional and Event Driven indices. Results from this analysis (not reported, but available from the authors) are consistent with the results in Table V. Specifically, there is no evidence of contagion from broad markets to hedge funds, while there is strong evidence of contagion between hedge fund indices.

For the HFR daily indices, we use AR(1) structures for the Arbitrage and Directional indices and an AR(2) structure for the Event Driven index. The results from this analysis are also consistent with the results in Table VI. Finally, for the HFR monthly indices, we use an AR(3) structure for the Arbitrage index and AR(1) structures for the Directional and Event Driven indices. The results from this analysis are consistent with the results in Table IX. There is no evidence of contagion from broad markets to hedge funds and the evidence of contagion between hedge fund indices remains strong.

VI. Conclusion

In this paper, we use a unique approach to study contagion in hedge funds. Our approach, which builds on Bae, Karolyi, and Stulz (2003), avoids many of the issues inherent in tests of correlations. This methodology uses the binomial and multinomial logit models and focuses on co-incidences of extreme returns in markets of interest. Specifically, we examine the co-incidence of extreme returns (very good and very poor returns) between hedge fund indices and broad markets, and analyze this relationship between hedge fund indices.

Strikingly, we find almost no evidence of contagion after accounting for correlation between market factors and hedge fund returns. In other words, extreme market returns do not have a heightened impact on hedge fund returns. For daily returns, extreme returns in market factors often make it less likely that a hedge fund will experience an extreme return, which is the opposite of what one would expect if contagion were present (the exception is contagion between fixed income markets and Arbitrage hedge funds, and this result only holds using aggregated HFR daily data). We also find no evidence of contagion using monthly returns.

However, we find strong evidence of contagion *between* hedge fund styles. Our data is categorized into three styles representing Arbitrage, Directional, and Event Driven hedge funds, and we find evidence of contagion between all three styles. These contagion effects are strongest among extreme poor returns for both daily and monthly indices, and exist in both the S&P and HFR return series, with the exception that the daily HFR indices do not indicate contagion between Arbitrage and Directional funds.

This contagion continues to exist when we perform our tests using sub-index data and a multinomial logit approach. The three indices (Arbitrage, Directional, and Event Driven) are further divided into eight sub-indices, and we examine the co-incidences of extreme returns in other hedge fund indices conditional upon the number of sub-indices that experience extreme returns within an aggregate index. These tests provide even stronger evidence of contagion between hedge fund indices, including evidence of contagion between Arbitrage and Directional funds which was not found in the aggregated daily HFR tests.

Our study is the first to examine contagion among hedge fund returns and also the first to use daily hedge fund data, which only recently became available. Our results are relevant for investors, policymakers, and regulators. Our finding of little contagion from financial markets to hedge funds suggests an additional benefit from investing in hedge funds. While the literature has emphasized the diversification benefit from investing in hedge funds, our paper suggests that there is an additional benefit in that hedge funds appear to be relatively insulated from extreme negative returns in the traditional asset classes.

However, our finding of significant contagion between hedge fund styles indicates that diversifying between hedge funds within a portfolio does not reduce downside risk associated with extremely poor returns. Finally, from the perspective of regulators and policymakers, poor performance in one sector of the hedge fund industry is likely to be associated with poor performance throughout the industry. However, there is little evidence that poor performance in the broad markets is contagious to the hedge fund industry. These results imply that systemic risk arising from poor performance in the broad markets is not amplified by contagion to the hedge fund industry.

Table I.A: Summary statistics of daily returns for S&P hedge fund indices and common risk factors: October 1, 2002 to June 15, 2005

Summary statistics for daily data on the S&P 500 hedge fund indices and the risk factors used in the paper are reported below. The hedge fund indices include Arbitrage, Directional, and Event Driven and are described more fully in Section II and Appendix A. The risk factors are from Datastream and include the negative portion of the S&P 500 returns to proxy for a long put option, the change in implied volatility on the S&P 500 index calculated as the average of the implied volatilities from call and put options on the S&P 500, the return on the Russell 3000 index, the change in the Federal Reserve Bank competitiveness-weighted dollar index (the FRB Dollar Index), the daily return on the Lehman Brothers U.S. Bond Index, and the daily return on the three-month U.S. Treasury Bill. Number of observations is 684. Correlations between all the variables are reported in Panel 1. The autocorrelations for each of the hedge fund indices as well as Ljung-Box test statistics for autocorrelation from lags 1-6 are reported in Panel 2. The second row in the autocorrelation table reports t-values in parentheses. Panel 3 reports Jarque-Bera test statistics for normality with p-values reported in parentheses. Bold and italic bold results indicate significance at the 5% level or better and the 10% level, respectively.

Panel 1: Summary statistics and simple correlations

	Arbitrage return	**Directional return**	**Event Driven return**	**-[S&P 500] return**	**Δ in S&P 500 implied volatility**	**Russell 3000 return**	**Δ in FRB dollar index**	**Return on LB bond index**	**T Bill return**
Number of observations	684	684	684	684	684	684	684	684	684
Mean	0.007%	0.025%	0.037%	-0.331%	-0.038%	0.066%	-0.019%	0.011%	-0.001%
Median	0.002%	0.033%	0.038%	0.000%	-0.506%	0.081%	-0.009%	0.056%	0.000
Standard deviation	0.211	0.305	0.127	0.539	5.539	0.979	0.293	0.419	0.006
Skewness	0.092	-0.279	0.254	-2.013	0.639	0.315	0.311	-2.335	0.643
Excess kurtosis	0.983	1.386	3.006	4.552	1.001	1.612	0.533	14.331	7.119
Correlations									
Arbitrage	1.000			**-0.405**	**0.308**	**-0.520**	-0.031	**0.119**	0.035
Directional	-0.030	1.000		**0.200**	**-0.163**	**0.207**	**-0.535**	**0.134**	**0.146**
Event Driven	**-0.178**	**0.218**	1.000	**0.316**	**-0.297**	**0.406**	-0.054	**-0.095**	-0.058

Panel 2: Autocorrelations and Ljung-Box test

Autocorrelations	**Arbitrage**	**Directional**	**Event Driven**
lag 1	**-0.20658**	**0.09757**	*0.06301*
	(-5.40)	(2.55)	*(1.65)*
lag 2	**-0.11755**	-0.0143	0.02932
	(-2.95)	(-0.37)	(0.76)
lag 3	0.02289	0.01355	**0.10095**
	(0.57)	(0.35)	(2.63)
lag 4	0.01588	0.04638	0.06609
	(0.39)	(1.20)	(1.70)
lag 5	0.00122	0.00307	0.00934
	(0.03)	(0.08)	(0.24)
lag 6	0.05511	-0.04427	0.04502
	(1.37)	(-1.14)	(1.16)
Ljung-Box test (1-6)	**41.46**	9.65	**14.82**
p-value	(0.000)	(0.140)	(0.022)

Panel 3: Normality test

	Arbitrage	**Directional**	**Event Driven**
Jarque-Bera Test	**27.612**	**62.076**	**259.549**
***p*-value**	(0.000)	(0.000)	(0.000)

Table I.B: S&P daily hedge fund index correlations conditioned on financial market variables

Conditional correlations for the hedge fund indices and three market variables are calculated. The conditioning market variables include the return on the Russell 3000 index, the return on the Lehman Brothers U.S. Bond Index, and the change in the Federal Reserve Bank competitiveness-weighted dollar index. Correlations are conditional upon the market variable being above or below its median for the entire time period studied. Bold and italic bold 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			**-0.419**	-0.007	0.045	1.000			**-0.310**	-0.032	***0.096***
Directional	0.015	1.000		-0.040	**-0.526**	**0.138**	**0.107**	1.000		**0.174**	**-0.584**	**0.224**
Event Driven	**-0.130**	***0.093***	1.000	**0.253**	0.019	-0.026	0.013	**0.223**	1.000	**0.275**	**-0.158**	-0.086

Conditioning variable: LB Bond Yield

	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			**-0.521**	-0.028	0.020	1.000			**-0.495**	-0.028	0.049
Directional	-0.032	1.000		**0.283**	**-0.489**	0.066	-0.889	1.000		**0.250**	**-0.543**	-0.051
Event Driven	***-0.100***	**0.263**	1.000	**0.407**	-0.041	**-0.110**	**-0.257**	**0.211**	1.000	**0.393**	**-0.113**	-0.085

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			**-0.531**	0.015	***0.100***	1.000			**-0.504**	0.058	**0.120**
Directional	***-0.090***	1.000		**0.249**	**-0.446**	0.037	-0.036	1.000		**0.275**	**-0.312**	***0.099***
Event Driven	**-0.244**	**0.284**	1.000	**0.411**	**-0.136**	**-0.115**	***-0.104***	**0.185**	1.000	**0.402**	-0.022	-0.070

Table II.A: Summary statistics of daily returns for HFR hedge fund indices and common risk factors: April 4, 2003 to June 15, 2005

Summary statistics for daily data on the Hedge Fund Research hedge fund indices and the risk factors used in the paper are reported below. The hedge fund indices include Arbitrage, Directional, and Event Driven and are described more fully in Section II and Appendix B. The risk factors are from Datastream and include the negative portion of the S&P 500 returns to proxy for a long put option, the change in implied volatility on the S&P 500 index calculated as the average of the implied volatilities from call and put options on the S&P 500, the return on the Russell 3000 index, the change in the Federal Reserve Bank competitiveness-weighted dollar index (the FRB Dollar Index), the daily return on the Lehman Brothers U.S. Bond Index, and the daily return on the three-month U.S. Treasury Bill. Number of observations is 557. Correlations between all the variables are reported in Panel 1. The autocorrelations for each of the hedge fund indices as well as Ljung-Box test statistics for autocorrelation from lags 1-6 are reported in Panel 2. The second row in the autocorrelation table reports t-values in parentheses. Panel 3 reports Jarque-Bera test statistics for normality with p-values reported 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 return	**Directional return**	**Event Driven return**	**-[S&P 500] return**	**Δ in S&P 500 implied volatility**	**Russell 3000 return**	**Δ in FRB dollar index**	**Return on LB bond index**	**T Bill return**
Number of observations	557	557	557	557	557	557	557	557	557
Mean	-0.001%	0.018%	0.031%	-0.267%	-0.047%	0.072%	-0.017%	0.006%	-0.001%
Median	-0.001%	0.031%	0.039%	0.000%	-0.689%	0.093%	-0.017%	0.054%	0.000%
Standard deviation	0.123	0.241	0.127	0.428	5.553	0.783	0.313	0.430	0.006
Skewness	0.194	-0.358	-0.288	-1.711	0.751	-0.002	0.300	-2.449	-0.093
Excess kurtosis	2.049	1.070	0.257	2.446	1.166	-0.023	0.265	15.300	2.925
Correlations									
Arbitrage	1.000			-0.023	-0.001	***0.070***	**-0.143**	***0.071***	***0.077***
Directional	**0.099**	1.000		**0.403**	**-0.260**	**0.466**	**-0.462**	-0.015	**0.112**
Event Driven	**0.172**	**0.460**	1.000	**0.434**	**-0.365**	**0.527**	**-0.091**	-0.059	-0.008

Panel 2: Autocorrelations and Ljung-Box test

Autocorrelations	**Arbitrage**	**Directional**	**Event Driven**
lag 1	-0.07683	**0.22279**	**0.14352**
	(-1.81)	(5.26)	(3.39)
lag 2	-0.0197	0.0688	**0.20597**
	(-0.46)	(1.55)	(4.76)
lag 3	0.0771	0.06131	**0.11312**
	(1.81)	(1.37)	(2.52)
lag 4	0.02665	0.00793	0.07891
	(0.62)	(0.18)	(1.74)
lag 5	**0.08517**	0.02287	0.08952
	(1.98)	(0.51)	(1.96)
lag 6	0.01166	-0.0191	**0.11224**
	(0.27)	(-0.43)	(2.44)
Ljung-Box test (1-6)	11.43	**33.10**	**57.67**
p-value	0.076	0.000	0.000

Panel 3: Normality test

	Arbitrage	**Directional**	**Event Driven**
Jarque-Bera Test	**98.177**	**37.358**	**9.059**
***p*-value**	(0.000)	(0.000)	(0.011)

Table II.B: HFR daily hedge fund index correlations conditioned on financial market variables

Conditional correlations for the hedge fund indices and three market variables are calculated. The conditioning market variables include the return on the Russell 3000 index, the return on the Lehman Brothers U.S. Bond Index, and the change in the Federal Reserve Bank competitiveness-weighted dollar 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			***-0.112***	-0.046	-0.010	1.000			0.056	**-0.247**	**0.177**
Directional	0.014	1.000		**0.246**	**-0.476**	-0.023	**0.254**	1.000		**0.419**	**-0.509**	0.070
Event Driven	**0.135**	**0.274**	1.000	**0.405**	-0.025	-0.065	**0.285**	**0.466**	1.000	**0.416**	**-0.158**	0.010

Conditioning variable: LB Bond Yield

	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			***-0.104***	***-0.093***	0.072	1.000			-0.002	**-0.146**	-0.068
Directional	0.035	1.000		**0.505**	**-0.418**	0.029	0.164	1.000		**0.441**	**-0.518**	**-0.121**
Event Driven	**0.211**	**0.488**	1.000	**0.527**	-0.084	***-0.099***	**0.148**	**0.434**	1.000	**0.524**	**-0.135**	-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			-0.003	***-0.099***	-0.001	1.000			**-0.144**	**-0.133**	**0.129**
Directional	***0.102***	1.000		**0.519**	**-0.376**	***-0.107***	0.036	1.000		**0.479**	**-0.272**	-0.056
Event Driven	**0.205**	**0.485**	1.000	**0.553**	**-0.202**	***-0.100***	**0.125**	**0.460**	1.000	**0.501**	0.055	-0.030

Table III: Contagion of extreme events in financial markets to extreme events in S&P daily hedge fund indices

The event of an extreme daily positive or negative return in each S&P hedge fund index is separately modeled as the outcome of a binary variable and estimated as a logit model. A daily return is classified as extreme if it belongs to either the top or bottom 5% of all returns of that style. The independent variables include the negative portion of the S&P 500 returns to proxy for a long put option, the change in implied volatility on the S&P 500 index calculated as the average of the implied volatilities from call and put options on the S&P 500, the return on the Russell 3000 index, the change in the Federal Reserve Bank competitiveness-weighted dollar index (the FRB Dollar Index), the daily return on the Lehman Brothers U.S. Bond Index, and the daily return on the three-month U.S. Treasury Bill. The extreme event dummy variables on the equity, bond, and currency markets are equal to one if the respective return belongs to either the top or the bottom 5% of all values of that series. Below the coefficients are the t-values in parentheses and the marginal effects. The marginal effects are calculated at the means of the explanatory variables (see Greene, 2000, equation (19-12)). 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.

	S&P Arbitrage		**S&P Directional**		**S&P Event Driven**	
Continuous Variables	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Constant	**-4.0596**	**-3.5678**	**-4.8546**	**-4.9582**	**-3.3636**	**-3.2932**
	(-11.93)	(-10.49)	(-7.65)	(-9.88)	(-9.47)	(-10.48)
-[S&P 500]	-1.2826	0.3138	-1.5453	**-1.7829**	0.3061	-0.2322
	(-1.63)	(0.46)	(-1.48)	(-2.34)	(0.34)	(-0.25)
	-0.02	0.00	-0.01	-0.02	0.00	0.00
Russell 3000	**1.4413**	**-1.8585**	-0.4002	**1.7856**	-0.7591	**1.1333**
	(5.22)	(-3.05)	(-0.59)	(4.12)	(-0.97)	(2.95)
	0.02	-0.02	0.00	0.02	-0.01	0.02
Change in S&P500 implied volatility	0.0034	-0.0253	0.0025	0.0173	0.0656	0.0267
	(0.08)	(-0.60)	(0.04)	(0.39)	(1.42)	(0.65)
	0.00	0.00	0.00	0.00	0.00	0.00
Change in FRB dollar index	**1.5119**	0.0914	**6.6468**	**-5.6213**	**1.6274**	***1.3174***
	(2.00)	(0.13)	(6.31)	(-5.21)	(2.21)	(1.77)
	0.02	0.00	0.03	-0.05	0.02	0.02
Return on LB bond index	1.1305	**-0.8128**	**-2.0335**	***2.0936***	**1.6053**	0.2233
	(1.44)	(-2.01)	(-2.85)	(1.83)	(2.84)	(0.49)
	0.02	-0.01	-0.01	0.02	0.02	0.00
3 month T-Bill return	**78.2507**	-17.6722	-6.5566	-34.4914	32.5143	-18.111
	(2.19)	(-0.84)	(-0.22)	(-1.09)	(1.01)	(-0.68)
	1.166	-0.23	-0.03	-0.30	0.47	-0.33
Market Indicator Variables						
Same direction extreme event Russell 3000	**-13.6863**	**-10.0511**	***-2.2974***	**-3.1774**	0.3223	-0.7641
	(-9.93)	(-9.73)	(-1.84)	(-1.98)	(0.42)	(-0.81)
	-0.20	-0.13	-0.01	-0.03	0.00	-0.01
Same direction extreme event LB bond index	1.1558	0.8556	-4.6236	-0.8387	**-13.3734**	**-13.8387**
	(1.00)	(1.22)	(-1.58)	(-0.79)	(-16.33)	(-30.53)
	0.02	0.01	-0.02	-0.01	-0.19	-0.25
Same direction extreme event FRB dollar index	1.1821	-0.9891	**-9.3316**	**-8.1582**	0.0254	-1.3483
	(1.23)	(-0.79)	(-9.80)	(-8.38)	(0.02)	(-1.14)
	0.02	-0.01	-0.04	-0.07	0.00	-0.02
McFadden's Pseudo R^2	0.215	0.212	0.421	0.289	0.155	0.127

Table IV: Contagion of extreme events in financial markets to extreme events in HFR aggregated daily hedge fund indices

This table repeats the analysis of Table III, using the HFR aggregated hedge fund indices in lieu of the S&P hedge fund indices. The event of an extreme daily positive or negative return in each HFR hedge fund index is separately modeled as the outcome of a binary variable and estimated as a logit model. A daily return is classified as extreme if it belongs to either the top or bottom 5% of all returns of that style. The independent variables include the negative portion of the S&P 500 returns to proxy for a long put option, the change in implied volatility on the S&P 500 index calculated as the average of the implied volatilities from call and put options on the S&P 500, the return on the Russell 3000 index, the change in the Federal Reserve Bank competitiveness-weighted dollar index (the FRB Dollar Index), the daily return on the Lehman Brothers U.S. Bond Index, and the daily return on the three-month U.S. Treasury Bill. The extreme event dummy variables on the equity, bond, and currency markets are equal to one if the respective return belongs to either the top or the bottom 5% of all values of that series. Below the coefficients are the t-values in parentheses and the marginal effects. The marginal effects are calculated at the means of the explanatory variables (see Greene, 2000, equation (19-12)). 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**	
Continuous Variables	**Negative**	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Constant	**-3.3687**	**-2.8036**	**-4.2942**	**-3.7672**	**-3.4911**	**-3.1171**
	(-9.49)	(-8.89)	(-9.69)	(-7.64)	(-9.41)	(-8.69)
-[S&P 500]	-0.8156	***1.4259***	-1.2038	3.7039	1.4852	0.4077
	(-0.94)	(1.75)	(-1.60)	(1.63)	(1.62)	(0.42)
	-0.03	0.06	0.00	0.02	0.02	0.01
Russell 3000	0.0397	**-1.5489**	-0.8488	**1.6512**	**-2.2054**	0.9011
	(0.08)	(-3.27)	(-1.29)	(2.90)	(-2.70)	(1.57)
	0.00	-0.06	0.00	0.01	-0.04	0.02
Change in S&P500 implied volatility	-0.0435	-0.0729	-0.0514	0.0561	**0.1314**	0.046
	(-0.79)	(-1.43)	(-0.84)	(1.18)	(3.25)	(0.98)
	0.00	0.00	0.00	0.00	0.00	0.00
Change in FRB dollar index	***1.1475***	-0.5065	**4.3471**	**-4.2898**	***1.5122***	-0.5846
	(1.79)	(-0.62)	(5.26)	(-4.27)	(1.77)	(-0.66)
	0.05	-0.02	0.02	-0.02	0.02	-0.01
Return on LB bond index	0.3418	-0.3766	0.9385	-0.2983	0.7868	-0.1226
	(0.58)	(-0.59)	(1.18)	(-0.40)	(0.97)	(-0.27)
	0.01	-0.02	0.00	0.00	0.01	0.00
3 month T-Bill return	-5.272	27.2759	-25.8921	-11.699	-10.5594	19.2303
	(-0.16)	(1.15)	(-0.62)	(-0.26)	(-0.23)	(0.79)
	-0.225	1.10	-0.10	-0.06	-0.17	0.43
Market Indicator Variables						
Same direction extreme event Russell 3000	-0.2727	**2.2845**	-0.0847	**-2.9542**	-0.44	0.1981
	(-0.29)	(2.59)	(-0.11)	(-2.26)	(-0.58)	(0.21)
	-0.01	0.09	0.00	-0.02	-0.01	0.00
Same direction extreme event LB bond index	**1.7496**	1.2031	**-16.5539**	-0.8785	-0.206	-0.1873
	(1.97)	(1.42)	(-11.69)	(-0.60)	(-0.15)	(-0.16)
	0.07	0.05	-0.07	0.00	0.00	0.00
Same direction extreme event FRB dollar index	0.4744	0.2065	**-12.2192**	**-8.8852**	0.1204	**-11.694**
	(0.40)	(0.18)	(-14.62)	(-9.24)	(0.09)	(-16.26)
	0.02	0.01	-0.05	-0.05	0.00	-0.26
McFadden's Pseudo R^2	0.040	0.051	0.301	0.260	0.240	0.082

Table V: Contagion of extreme events between S&P 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 variable and estimated as a logit model. A daily return is classified as extreme if it belongs to either the top or bottom 5% of all returns of that style. The continuous variables and market indicator variables are described in Table IV, above. The other hedge fund index indicator variables are set equal to one if the return is classified as an extreme return in the respective style on the same day. Below the coefficients are the t-values in parentheses and the marginal effects. The marginal effects are calculated at the means of the explanatory variables (see Greene, 2000, equation (19-12)). 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.

	S&P Arbitrage		**S&P Directional**		**S&P Event Driven**	
	Negative	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Continuous variables						
Constant	**-4.2602** (-11.31)	**-3.6171** (-10.45)	**-4.9821** (-7.45)	**-5.2314** (-9.13)	**-3.4427** (-9.82)	**-3.2811** (-10.44)
-[S&P 500]	-0.8556 (-1.05) -0.01	0.5396 (0.76) 0.00	-0.961 (-1.09) 0.00	***-1.336*** (-1.95) -0.01	0.3958 (0.46) 0.01	-0.2899 (-0.31) 0.00
Russell 3000	**1.5468** (5.19) 0.02	**-2.1226** (-3.31) -0.01	-0.9134 (-1.64) 0.00	**1.8816** (4.40) 0.01	-0.8138 (-1.13) -0.01	**1.0902** (2.83) 0.01
Change in S&P500 implied volatility	-0.0028 (-0.07) 0.00	-0.0202 (-0.45) 0.00	-0.0002 (-0.00) 0.00	0.0277 (0.63) 0.00	0.0392 (0.94) 0.00	0.0202 (0.55) 0.00
Change in FRB dollar index	0.0098 (0.22) 0.00	-0.0346 (-0.77) 0.00	-0.0105 (-0.18) 0.00	0.0203 (0.46) 0.00	0.0542 (1.16) 0.00	0.0259 (0.65) 0.00
Return on LB bond index	0.6967 (1.04) 0.01	0.482 (0.71) 0.00	**6.6813** (6.02) 0.03	**-6.0911** (-5.02) -0.04	1.0719 (1.41) 0.02	***1.4229*** (1.95) 0.02
3 month T-Bill return	1.3521 (1.58) 0.02	**-0.9396** (-2.19) -0.01	**-2.274** (-3.37) -0.01	***2.2424*** (1.90) 0.02	**1.6114** (2.78) 0.02	0.1866 (0.42) 0.00
Market indicator variables						
Same direction extreme event Russell 3000	**-14.8796** (-10.71) -0.18	**-10.517** (-9.66) -0.06	***-2.1526*** (-1.66) -0.01	**-3.3492** (-1.99) -0.02	0.4734 (0.60) 0.01	-0.6931 (-0.73) -0.01
Same direction extreme event LB bond index	1.3685 (1.17) 0.02	0.7647 (1.05) 0.00	**-5.2419** (-2.24) -0.02	-0.9474 (-0.95) -0.01	**-12.1843** (-14.74) -0.18	**-12.766** (-28.30) -0.14
Same direction extreme event FRB dollar index	0.853 (0.93) 0.01	-1.2127 (-0.96) -0.01	**-9.2206** (-9.13) -0.04	**-7.6628** (-7.00) -0.05	-0.3743 (-0.35) -0.01	-1.4302 (-1.21) -0.02
Other hedge fund index indicator variables						
Arbitrage			**2.4199** (3.35) 0.01	**2.5305** (3.50) 0.02	1.2163 (1.30) 0.02	**-12.213** (-29.02) -0.13
Directional	**1.8049** (2.63) 0.02	**1.9777** (2.80) 0.01			0.8353 (1.40) 0.01	0.3567 (0.47) 0.00
Event Driven	***1.4104*** (1.71) 0.02	**-14.1298** (-33.36) -0.08	***0.9656*** (1.67) 0.00	0.5899 (0.77) 0.00		
McFadden's Pseudo R^2	0.244	0.238	0.446	0.322	0.170	0.133

Table VI: Contagion of extreme events between HFR daily aggregated hedge fund indices

This table repeats the analysis of Table VI, using the HFR aggregated hedge fund indices in lieu of the S&P 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 variable and estimated as a logit model. A daily return is classified as extreme if it belongs to either the top or bottom 5% of all returns of that style. The continuous variables and market indicator variables are described in Table IV, above. The other hedge fund index indicator variables are set equal to one if the return is classified as an extreme return in the respective style on the same day. Below the coefficients are the t-values in parentheses and the marginal effects. The marginal effects are calculated at the means of the explanatory variables (see Greene, 2000, equation (19-12)). 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**
Continuous variables						
Constant	**-3.4292**	**-3.0027**	**-4.7641**	**-4.0123**	**-3.6747**	**-3.3206**
	(-9.41)	(-9.37)	(-8.73)	(-7.87)	(-9.31)	(-9.13)
-[S&P 500]	-0.8144	***1.4612***	**-1.4867**	3.7058	**2.1206**	0.2249
	(-0.97)	(1.74)	(-2.14)	(1.48)	(2.25)	(0.24)
	-0.03	0.05	0.00	0.02	0.03	0.00
Russell 3000	0.0478	**-1.795**	-0.6275	**1.83**	**-2.2045**	***1.0137***
	(0.10)	(-3.44)	(-1.04)	(3.04)	(-2.77)	(1.68)
	0.00	-0.07	0.00	0.01	-0.03	0.02
Change in S&P500 implied volatility	-0.0564	***-0.0865***	***-0.117***	0.0567	**0.1469**	0.0521
	(-1.04)	(-1.74)	(-1.75)	(1.15)	(3.24)	(1.08)
	0.00	0.00	0.00	0.00	0.00	0.00
Change in FRB dollar index	1.1542	-0.2457	**4.1629**	**-4.28**	0.2145	-0.4116
	(1.45)	(-0.29)	(5.18)	(-4.23)	(0.24)	(-0.49)
	0.05	-0.01	0.01	-0.02	0.00	-0.01
Return on LB bond index	0.3184	-0.266	0.6275	-0.3085	0.744	0.085
	(0.55)	(-0.55)	(0.83)	(-0.48)	(0.85)	(0.21)
	0.01	-0.01	0.00	0.00	0.01	0.00
3 month T-Bill return	-6.3725	25.7483	-25.8255	-15.5838	-19.0641	13.0152
	(-0.20)	(1.03)	(-0.68)	(-0.34)	(-0.39)	(0.51)
	-0.27	0.95	-0.09	-0.07	-0.27	0.27
Market indicator variables						
Same direction extreme event Russell 3000	-0.2302	**2.2975**	0.3411	**-3.2104**	-0.2212	0.1198
	(-0.25)	(2.54)	(0.39)	(-2.94)	(-0.24)	(0.12)
	-0.01	0.09	0.00	-0.02	0.00	0.00
Same direction extreme event LB bond index	**1.7654**	1.2456	**-16.2682**	-0.8442	0.2771	-0.4253
	(1.96)	(1.61)	(-9.29)	(-0.61)	(0.19)	(-0.37)
	0.07	0.05	-0.05	0.00	0.00	-0.01
Same direction extreme event FRB dollar index	0.5184	0.2181	**-11.862**	**-8.7825**	-0.1821	**-11.6669**
	(0.43)	(0.20)	(-14.08)	(-9.68)	(-0.14)	(-17.04)
	0.02	0.01	-0.04	-0.04	0.00	-0.25
Other hedge fund index indicator						
Arbitrage			0.2117	***1.5163***	0.8972	**1.4246**
			(0.23)	(1.87)	(1.20)	(2.17)
			0.00	0.01	0.01	0.03
Directional	-0.4461	1.166			**2.6402**	0.5673
	(-0.49)	(1.56)			(3.61)	(0.93)
	-0.02	0.04			0.04	0.01
Event Driven	***1.0254***	**1.4111**	**2.5736**	0.4526		
	(1.68)	(2.17)	(4.02)	(0.69)		
	0.04	0.05	0.01	0.00		
McFadden's Pseudo R^2	0.047	0.081	0.383	0.278	0.324	0.105

Table VII: Contagion in HFR daily sub-indices

The number of extreme daily positive or negative returns within each HFR aggregate sub-index is separately modeled as the value of the *COUNT* variable and estimated as a multinomial logit model. The *COUNT* variable is set to zero (0) if no sub-indices have an extreme return on that day, one (1) if one sub-index has an extreme return on that day, and two (2) if two or more sub-indices have extreme returns on that day. The continuous variables (coefficients not reported) are as in Table VI. The market indicator *COUNT* variables on the equity, bond, and currency markets are set to one if the respective return belongs to either the top or the bottom 5% of all values of that series. The other hedge fund index indicator variables are the respective *COUNT* variables for each fund style on the same day.

	HFR Arbitrage		**HFR Directional**		**HFR Event Driven**	
	Negative	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Market indicator variables						
Same direction extreme event Russell 3000 (*COUNT=1*)	0.4136 (0.627) 0.04	-0.3789 (-0.332) -0.04	1.3458 (1.593) 0.06	0.3174 (0.478) 0.01	0.2594 (0.457) 0.02	-0.0952 (-0.142) 0.00
Same direction extreme event Russell 3000 (*COUNT=2*)	0.9787 (0.630) 0.00	1.7450 (1.541) 0.01	1.3675 (0.874) 0.00	**-19.7330** (-10.607) 0.00	-0.9051 (-0.782) 0.00	-2.1659 (-1.404) -0.00
Same direction extreme event LB bond index (*COUNT=1*)	**1.5266** (2.205) 0.17	0.3116 (0.499) 0.03	0.2897 (0.231) 0.01	-0.5467 (-0.705) -0.01	0.7170 (0.669) 0.06	-0.4219 (-0.610) -0.02
Same direction extreme event LB bond index (*COUNT=2*)	**-11.8027** (-5.447) -0.03	**3.6385** (3.158) 0.01	***-8.9119*** (-1.739) 0.00	**-16.0784** (-9.361) 0.00	**-15.0662** (-7.304) -0.04	**-15.0228** (-16.512) -0.02
Same direction extreme event FRB dollar index (*COUNT=1*)	-0.9303 (-0.872) -0.10	0.5982 (0.776) 0.06	1.2442 (1.081) 0.05	**-15.8922** (-26.338) -0.38	-0.7201 (-0.950) -0.06	**-14.5803** (-33.725) -0.69
Same direction extreme event FRB dollar index (*COUNT=2*)	0.3296 (0.220) 0.00	**-12.4802** (-15.463) -0.05	**-13.9306** (-8.094) -0.00	**-11.4700** (-4.385) 0.00	1.6310 (1.181) 0.00	**-12.0060** (-8.641) -0.02
Other hedge fund index indicator *COUNT* variables						
Arbitrage (*COUNT=1)*			0.5276 (1.440) 0.023	0.4614 (1.131) 0.011	**0.8921** (3.011) 0.070	**0.6536** (2.111) 0.031
Arbitrage (*COUNT=2)*			1.5601 (1.514) 0.000	**-13.2969** (-15.914) 0.000	0.1239 (0.176) 0.000	***1.3169*** (1.828) 0.002
Directional (*COUNT=1)*	0.4152 (1.183) 0.044	0.1068 (0.247) 0.010			**0.8666** (2.591) 0.068	0.1310 (0.372) 0.006
Directional (*COUNT=2)*	**1.5943** (2.565) 0.004	0.6933 (0.526) 0.003			**2.4318** (3.845) 0.006	-0.4252 (-0.579) -0.001
Event Driven (*COUNT=1)*	***0.5052*** (1.830) 0.054	***0.5476*** (1.773) 0.050	***0.7125*** (1.948) 0.031	0.2789 (0.946) 0.007		
Event Driven (*COUNT=2)*	0.2567 (0.646) 0.001	***1.1416*** (1.737) 0.005	**5.8336** (2.130) 0.000	**-15.3703** (-17.842) 0.000		
McFadden's Pseudo R^2	0.066	0.085	0.316	0.198	0.196	0.128

Table VIII.A: Summary statistics of monthly returns on aggregated HFR indices and risk factors: January, 1990 to May, 2005

Summary statistics for monthly data on the HFR hedge fund indexes and the risk 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 and Appendix C. The risk factors are from Datastream and include the negative portion of the S&P 500 returns to proxy for a long put option, the change in implied volatility on the S&P 500 index calculated as the average of the implied volatilities from call and put options on the S&P 500, the return on the Russell 3000 index, the change in the Federal Reserve Bank competitiveness-weighted dollar index (the FRB Dollar Index), the daily return on the Lehman Brothers U.S. Bond Index, and the daily return on the three-month U.S. Treasury Bill. The number of observations is 185. Correlations between all 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**	**-[S&P 500] Return**	**Δ in S&P 500 implied volatility**	**Russell 3000 return**	**Δ in FRB Dollar Index**	**Return on LB Bond Index**	**T Bill Return**
Number of observations	185	185	185	185	185	185	185	185	185
Mean	0.832%	1.307%	1.061%	-1.308%	1.198%	0.763%	-0.030%	0.614%	0.007%
Median	0.930%	1.255%	1.150%	0.000%	-0.878%	1.277%	0.018%	0.753%	0.003%
Standard deviation	0.755	2.225	1.458	2.413	17.060	4.209	1.873	1.372	0.055
Skewness	-1.178	0.237	-1.644	-2.468	0.997	-0.568	0.206	-0.140	0.950
Excess kurtosis	5.326	0.540	7.511	7.047	2.008	0.809	0.319	0.551	3.298
Correlations									
Arbitrage	1.000			**0.343**	**-0.264**	**0.375**	0.027	**0.212**	0.181
Directional	**0.592**	1.000		**0.557**	**-0.420**	**0.640**	**-0.003**	**0.192**	**0.114**
Event Driven	**0.669**	**0.688**	1.000	**0.654**	**-0.486**	**0.617**	0.053	**0.052**	0.011

Panel 2: Autocorrelations

Autocorrelations	**Arbitrage**	**Directional**	**Event Driven**
lag 1	**0.4613**	**0.16984**	**0.37937**
	(6.27)	(2.31)	(5.16)
lag 2	**0.29172**	0.05951	0.09013
	(3.32)	(0.79)	(1.08)
lag 3	0.08883	0.0191	0.03808
	(0.96)	(0.25)	(0.45)
lag 4	0.10948	0.00881	-0.00961
	(1.17)	(0.12)	(-0.11)
lag 5	0.10874	0.02538	-0.02039
	(1.16)	(0.33)	(-0.24)
lag 6	**0.20529**	0.05503	-0.06363
	(2.17)	(0.72)	(-0.76)
Ljung-Box test (1-6)	**70.310**	6.890	**29.750**
p-value	0.000	0.332	0.000

Panel 3: Normality test

	Arbitrage	**Directional**	**Event Driven**
Jarque-Bera Test	**246.612**	3.579	**490.216**
***p*-value**	0.000	0.167	0.000

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

Conditional correlations for the hedge fund indices and three of the market variables are calculated. The conditioning market variables include the return on the Russell 3000 index, the negative of the change in the yield of the Lehman Brothers U.S. Bond Index, and the change in the Federal Reserve Bank competitiveness-weighted dollar 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			0.138	0.117	**0.239**	1.000			**0.378**	-0.016	0.169
Directional	**0.580**	1.000		0.182	0.129	0.093	**0.544**	1.000		**0.583**	-0.058	**0.271**
Event Driven	**0.551**	**0.601**	1.000	0.007	0.161	0.004	**0.695**	**0.628**	1.000	**0.704**	0.044	0.036

Conditioning variable: LB Bond Yield

	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			**0.267**	0.087	0.104	1.000			**0.474**	0.023	**0.259**
Directional	**0.580**	1.000		**0.628**	0.069	**0.227**	**0.604**	1.000		**0.669**	-0.059	0.158
Event Driven	**0.572**	**0.702**	1.000	**0.578**	0.077	0.098	0.775	**0.688**	1.000	**0.648**	0.017	0.079

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			**0.484**	0.150	0.110	1.000			**0.235**	-0.025	**0.347**
Directional	**0.624**	1.000		**0.683**	0.156	0.067	**0.549**	1.000		**0.599**	***-0.202***	**0.336**
Event Driven	**0.743**	**0.756**	1.000	**0.683**	0.088	-0.022	**0.535**	**0.590**	1.000	**0.556**	0.015	0.162

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

This table repeats the analysis of Table VI, using the HFR monthly aggregated hedge fund indices in lieu of the 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 variable and estimated as a logit model. A daily return is classified as extreme if it belongs to either the top or bottom 15% of all returns of that style. All explanatory variables are the same as in Table VII, above. Below the coefficients are the t-values in parentheses and the marginal effects. The marginal effects are calculated at the means of the explanatory variables (see Greene, 2000, equation (19-12)).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. Number of observations is 182.

	HFR Monthly Arbitrage		**HFR Monthly Directional**		**HFR Monthly Event Driven**	
	Negative	**Positive**	**Negative**	**Positive**	**Negative**	**Positive**
Continuous variables						
Constant	**-2.7475** (-4.38)	**-3.1387** (-6.64)	**-1.6151** (-2.50)	**-2.8059** (-4.77)	**-3.713** (-4.79)	**-2.5922** (-4.62)
-[S&P 500]	-0.232 (-0.92) -0.02	-0.2512 (-1.11) -0.02	**1.9407** (3.44) 0.00	0.3556 (0.89) 0.02	-0.0365 (-0.10) 0.00	0.2554 (0.55) 0.01
Russell 3000	-0.014 (-0.10) 0.00	0.2291 (1.45) 0.02	**-2.2222** (-3.82) 0.00	0.2095 (1.21) 0.01	-0.2102 (-0.75) -0.01	0.1787 (1.00) 0.01
Change in S&P500 implied volatility	-0.0058 (-0.25) 0.00	0.0045 (0.26) 0.00	-0.0075 (-0.33) 0.00	0.0201 (1.05) 0.00	-0.0125 (-0.53) 0.00	**-0.0522** (-2.76) 0.00
Change in FRB dollar index	0.0613 (0.35) 0.00	0.1381 (0.84) 0.01	-0.1535 (-0.72) 0.00	0.1826 (0.90) 0.01	0.0423 (0.20) 0.00	0.0496 (0.24) 0.00
Return on LB bond index	**-0.6555** (-2.09) -0.04	0.4004 (1.61) 0.04	-0.4193 (-1.40) 0.00	0.3703 (1.47) 0.02	0.1382 (0.54) 0.01	-0.1732 (-0.78) -0.01
3 month T-Bill return	***-11.1113*** (-1.69) -0.75	-2.1054 (-0.54) -0.21	-1.4732 (-0.25) 0.00	1.6535 (0.39) 0.11	4.185 (0.81) 0.22	5.3836 (1.31) 0.31
Market indicator variables						
Same direction extreme event Russell 3000	**-2.6097** (-1.97) -0.18	-0.505 (-0.48) -0.05	-0.1676 (-0.15) 0.00	0.1023 (0.12) 0.01	1.3636 (0.98) 0.07	-1.57 (-1.51) -0.09
Same direction extreme event LB bond index	-0.2186 (-0.22) -0.01	-0.1414 (-0.19) -0.01	0.8609 (0.85) 0.00	-0.8116 (-0.99) -0.05	0.2782 (0.27) 0.01	0.3773 (0.45) 0.02
Same direction extreme event FRB dollar index	1.4144 (1.58) 0.10	0.5841 (0.81) 0.06	-2.0426 (-1.34) 0.00	0.2394 (0.27) 0.02	-0.1066 (-0.10) -0.01	-0.2956 (-0.29) -0.02
Other hedge fund index indicator variables						
Arbitrage			0.678 (0.94) 0.00	0.9296 (1.63) 0.06	**3.2259** (3.58) 0.17	**1.3729** (2.45) 0.08
Directional	0.8211 (1.16) 0.06	0.8115 (1.34) 0.08			***1.2357*** (1.86) 0.07	**1.4344** (2.77) 0.08
Event Driven	**3.1891** (3.86) 0.21	**1.2993** (2.31) 0.13	0.3616 (0.49) 0.00	**1.418** (2.65) 0.09		
McFadden's Pseudo R^2	0.362	0.177	0.551	0.254	0.479	0.256

Appendix A

This appendix contains descriptions of the nine hedge fund strategies included in the S&P hedge fund indices. The source of these descriptions is Standard and Poor's.

Style: Arbitrage

Strategy: Equity Market Neutral

Funds take both long and short positions in equities. Stock positions are usually diversified, so that no one position has a disproportionate effect on the portfolio. Related short positions hedge out much of the systematic risk in the long positions on either a dollar- or beta-adjusted basis so that the overall portfolio has a limited exposure to market moves.

Strategy: Fixed Income Arbitrage

Funds exploit the relative values of fixed income instruments. The manager takes positions in government fixed incomes and investment-grade corporate fixed incomes, government agency securities and swap contracts, and futures and options based on fixed income instruments. The manager generally constructs the portfolio on a market neutral basis and often constrains it to be duration neutral within a given country (often developed countries).

Strategy: Convertible Arbitrage

Convertible fixed incomes range from investment-grade credits to busted convertibles, and a fund may concentrate on one or more of the high-delta, middle-delta, and low-delta convertible strategies. Convertible Arbitrage funds attempt to exploit the mispricing in convertible securities. As the mispricing in convertible securities is typically small, this strategy will usually employ leverage. A convertible manager takes an exposure to the volatility and/or credit risk of the fixed income, hedging out other factors such as maturity and coupon of the fixed income, the expected future dividends of the underlying share of stock, and the interest rate. The stock exposure is typically hedged out with a short position in the underlying company shares; thus, the strategy is typically market neutral.

Style: Event Driven

Strategy: Merger Arbitrage

The Merger Arbitrage strategy involves taking positions in companies that are either currently or likely to be engaged in corporate mergers and acquisitions. Merger Arbitrage funds typically buy shares in the target and sell an appropriate quantity of shares in the acquirer in a merger deal.

Strategy: Distressed

Distressed security funds generally invest in securities of financially troubled companies (companies involved in bankruptcies, exchange offers, workouts, financial reorganizations, and other special credit event-related situations). These managers may identify distressed securities in general or focus on one particular segment of the market. Investments may be accumulated with a view to an exit via the secondary market, or with the expectation that the company will be recapitalized, restructured, or liquidated, where the fund manager may either seek to be actively or passively involved in the process.

Appendix A (continued)

Style: Event Driven (continued)

Strategy: Special Situations

Special Situations encompasses funds that seek profit opportunities from a broad range of corporate events. Managers are either generalists, who engage in trading keyed to corporate events such as a merger, distressed finances or share prices, and changes to an index, or specialists who concentrate on a specific niche they can exploit. Value-oriented funds invest in undervalued obligations including bank debt, high-yield fixed incomes, trade claims, and equity securities created by discrete and often extraordinary events. Niche strategies include Capital Structure Arbitrage or other relative-value trades, such as trading between ADRs and local shares or voting versus non-voting shares, as well as strategies involving trading a holding company versus positions in its listed subsidiaries (a stub trade). It also includes Closed End Fund Arbitrage.

Style: Directional/Tactical

Strategy: Equity Long/Short

Equity Long/Short funds take long and short stock positions. The manager may attempt to profit from "alpha" generation on both long and short stock positions independently, or profit from the relative outperformance of long positions against short positions. Equity Long/Short managers specialize by region (e.g., global, U.S., Europe, or Asia) or by sector.

Strategy: Managed Futures

Managed Futures programs take long and short positions in liquid commodity or financial futures, such as currencies, interest rates, or stock market indices. Investment decisions are typically based on strict quantitative methods, notably trend-following models.

Strategy: Macro

Macro funds take long and short positions in currencies, fixed incomes, equities, and commodities. The manager tries to exploit perceived divergences between and within these various asset classes. The investment decisions are based on a manager's top-down or macro views of the world, economy, government policy, interest rates, inflation, market dynamics, and sentiment. The manager may also base investment decisions on relative valuations of financial instruments within or between asset classes.

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.

Appendix C: 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.

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