# The Persistence of Hedge Fund Risk: Evidence and Implications for Investors

MARTIN M. HERZBERG AND HAIM A. MOZES

**MARTIN M. HERZBERG**
is director of quantitative research at Spring Mountain Capital.
**mh@smcinvest.com**

**HAIM A. MOZES**
is an associate professor of accounting at Fordham University Graduate School of Business Administration.
**mozes@fordham.edu**

In recent years, as equity markets have weakened and interest rates declined, investors have increased their allocations to alternative investments, notably hedge funds. Fueling investor interest in alternative investments is the perception that their returns may not be dependent on the performance of various traditional markets, and thus offer investors a means by which to limit exposure to volatile markets while, at the same time, serving to diversify portfolios already containing significant market exposure.

If hedge fund performance is not affected by the direction of equity, debt, or other markets, then hedge fund performance is likely to be driven by manager-specific idiosyncratic investment strategies. These strategies typically attempt to capitalize on various market inefficiencies, or anticipate various markets' directional trends. Therefore, successful hedge fund investing requires the identification of managers who have the skill to capitalize on market inefficiencies and trends and adapt their strategies when the opportunities they have been exploiting are arbitraged away by other investors.

Two questions for investors are whether the success of managers' idiosyncratic investment strategies persists over time, and whether quantitative techniques can be employed to identify "superior" hedge fund managers based on past performance. The evidence on the predictability of investment performance is not supportive. Both a recent publication by Morgan Stanley Dean Witter [2000] and academic research (e.g., Brown, Goetzmann, and Ibbotson [1999], Agarwal and Naik [2000a and 2000b] conclude that hedge fund returns are not predictable and that prospective investors in hedge funds should simply invest in a diversified portfolio of hedge fund managers.[1] Likewise, research into the persistence of mutual fund performance finds only very weak support for the notion that superior mutual funds continue to outperform (e.g., Elton, Gruber, and Blake [1996] and Carhart [1997]).

In this article, we investigate the persistence and determinants of hedge fund performance and arrive at different conclusions. We find that while hedge fund *returns* are not persistent, hedge fund *risk* is highly persistent, and that less risky hedge funds on average outperform more risky hedge funds. In addition, portfolios of low-risk hedge funds, whose past superior performance is more likely to persist, systematically outperform 1) portfolios consisting of past hedge fund "winners," and 2) portfolios consisting of all hedge funds (i.e., the "average" hedge fund). For the purposes of this article, a fund's risk is measured by the annualized standard deviation of its monthly returns.

Our results might be explained as follows. Riskier funds with superior prior performance are more likely to have achieved their returns in one of several ways: they took excessive risk, they were correlated with some underlying market's returns, or they were the fortuitous recipients of a "lucky break." Each of these drivers of returns is likely to revert, as risk-taking eventually exerts its toll, the underlying market's direction reverses, and "lucky breaks" do not persist. By contrast, a less risky fund's superior prior performance is more likely to have been generated by an idiosyncratic strategy generating modest but steady returns, which is only weakly correlated to underlying markets and not dependent on excessive risk-taking or isolated incidents of good fortune. Therefore, less risky funds' performance is more persistent, because it is more likely based on fundamental investment skill. Consistent with this explanation, we find that riskier funds are more highly correlated with equity markets than less risky funds.

Two important implications of our findings are that it may be more efficient for an investor to externally leverage an investment in less risky hedge funds than to make an unlevered investment in more risky hedge funds and that one should not consider riskier funds based on the returns they are expected to generate. The role of riskier funds in hedge fund portfolios, if any, should be to diversify the risk of the portfolio's other funds, with which the riskier funds are negatively correlated.

In addition to providing evidence on the relation between risk and hedge fund performance, we identify assets under management, growth in assets under management, and length of investment history as additional variables affecting hedge fund performance. Further, we demonstrate the seasonality effects inherent in hedge fund returns, providing the rationale for differentially weighting prior results for different calendar months in calculating prior period performance. Finally, we analyze the relationship between a fund's redemption policy and performance, with inconclusive results regarding whether redemption policy is a useful criterion for selecting hedge funds.

## DATA

We combined the HedgeFund.Net, Altvest, and Spring Mountain Capital databases, to create a database containing information on approximately 3,300 funds. The data begins January 1990, although the majority of the 3,300 funds have a more limited history. Data items include monthly returns, assets under management, and strategy designations.[2, 3] We combine the various strategy types in the two databases to form the following six strategy groups: Long-Short Equity, Market-Neutral Equity, Relative Value, Event Driven, Fixed Income, and Futures Trading. We omit funds investing in emerging markets, because there is an insufficient sample size for these funds and they do not fit into any other category. Funds focusing on merger arbitrage and distressed situations are classified into the event driven group. Funds with no data on strategy type are classified as Unknown, in effect, creating a seventh strategy group. To avoid double-counting, hedge funds designated as fund of funds are excluded from the analysis altogether.[4]

Exhibit 1 provides data on risk, return, and correlations with several indices, for each of the strategy groups. The indices we examine are the S&P 500 index (SP500), the Russell 2000 index (R2000), the Lehman Aggregate Bond Index (LABI), and the Goldman Sachs Commodity Index (GSCI). There are several noteworthy results. First, relative value funds have the lowest standard deviations, the highest Sharpe ratios, the lowest maximum drawdowns, and the lowest correlations with the various indices. This suggests that, on average, the less risky funds may have better performance. Second, futures trading funds have the second highest standard deviation but the lowest correlation with the SP500 and R2000 indices. This suggests that despite their high risk, futures trading funds may help reduce portfolio risk because they are uncorrelated with equity markets.[5] Third, as would be expected during a period of strong equity market returns, long-short equity funds had relatively high returns but also relatively high standard deviations, resulting in mediocre Sharpe ratios. Fourth, hedge fund results appear to have deteriorated in more recent years, with the 1998–2001 period providing poorer results than the 1995–1997 period (*see Panel B*). Fifth, the larger categories of hedge funds are long-short equity and event driven, the smaller categories of hedge funds are fixed income and futures trading, and only 10.7% of the hedge funds in our database have an unknown strategy designation. Sixth, sample size increases sharply over time, corresponding to the increase in assets allocated to hedge funds over our sample period (*see Panel B*).

## PERSISTENCE OF BASIC FUND ATTRIBUTES

We begin by demonstrating the persistence of a fund's return, Sharpe ratio, maximum drawdown, standard deviation, and correlation with the SP500, R2000, LABI, and GSCI indices. The approach is to calculate on each December 31 the Rank Information Coefficients (Rank ICs) between the value of a given variable for the

## EXHIBIT 1
**Univariate Statistics**

**Panel A**
**Results by Strategy**

| Strategy | Number | Average Monthly Return | Monthly Standard Deviation | Annualized Sharpe Ratio | Maximum Drawdown | Correlation S&P 500 Index | Correlation Lehman Bond Index | Correlation Futures Index | Correlation Russell 2000 |
|---|---|---|---|---|---|---|---|---|---|
| Long/Short | 2,655 | 1.4% | 6.4% | 0.75 | -14.8% | 0.33 | 0.01 | 0.09 | 0.41 |
| Market Neutral | 747 | 1.2% | 3.9% | 0.99 | -8.6% | 0.20 | 0.04 | 0.05 | 0.25 |
| Relative Value | 557 | 1.0% | 1.9% | 2.52 | -3.8% | 0.13 | 0.02 | 0.00 | 0.16 |
| Event Driven | 1,602 | 1.2% | 3.4% | 1.36 | -7.3% | 0.25 | 0.00 | 0.07 | 0.35 |
| Fixed Income | 445 | 0.9% | 2.4% | 1.86 | -5.4% | 0.23 | 0.05 | 0.02 | 0.25 |
| Futures Trading | 488 | 1.1% | 5.4% | 0.48 | -11.5% | 0.00 | 0.18 | 0.05 | 0.04 |
| Unknown | 780 | 1.1% | 4.5% | 1.21 | -9.9% | 0.19 | 0.06 | 0.06 | 0.24 |

**Panel B**
**Results by Year**

| Year | Number | Average Monthly Return | Monthly Standard Deviation | Annualized Sharpe Ratio | Maximum Drawdown | Correlation S&P 500 Index | Correlation Lehman Bond Index | Correlation Futures Index | Correlation Russell 2000 |
|---|---|---|---|---|---|---|---|---|---|
| 1995 | 368 | 1.7% | 3.0% | 1.88 | -4.9% | 0.15 | -0.05 | 0.05 | 0.24 |
| 1996 | 516 | 1.7% | 3.3% | 1.92 | -5.5% | 0.23 | 0.03 | 0.12 | 0.24 |
| 1997 | 708 | 1.6% | 3.8% | 1.68 | -7.0% | 0.30 | 0.22 | 0.02 | 0.33 |
| 1998 | 938 | 0.7% | 5.5% | 0.39 | -15.5% | 0.39 | -0.21 | 0.02 | 0.39 |
| 1999 | 1,247 | 2.4% | 5.0% | 1.66 | -7.4% | 0.25 | 0.08 | 0.10 | 0.36 |
| 2000 | 1,572 | 0.9% | 5.5% | 1.10 | -13.0% | 0.17 | 0.14 | 0.08 | 0.30 |
| 2001 | 1,925 | 0.5% | 4.2% | 0.51 | -11.5% | 0.22 | -0.01 | 0.06 | 0.26 |

prior 36-month period and its value for the subsequent 12-month period. Panel A displays the average Rank ICs across the entire sample period for each strategy group, Panel B displays the sample-wide Rank ICs on a year by year basis, and Panel C displays the average within-group Rank ICs on a year-by-year basis.[6]

The results in Exhibit 2 show that attributes pertaining to risk, namely maximum drawdown, standard deviation, and correlation with the SP500 and R2000, are strongly correlated over time.[7] However, attributes related to performance, namely monthly returns and Sharpe ratios, are weakly or negatively correlated over time. The implication is that the more risky funds continue to be more risky, funds that are more highly correlated with equity markets continue to be more highly correlated with equity markets, and performance is as likely to mean revert as to persist. The persistence of a fund's correlation with the LABI is positive but considerably weaker than that of a fund's correlation with the SP500 and R2000 indices, while the persistence of a fund's correlation with the GSCI is very weak. These results hold whether calculating the correlations across all funds or within strategy groups and the results hold for each of the strategy groups.

These results may be explained by the fact that volatility, drawdowns, and correlations to markets are a function of a fund's investment *style*, and investment style persists over time. For example, a fund that operates by taking large market bets tends to continue to take large market bets. Similarly, a fund's tolerance for risk and its risk management disciplines are also behavioral in nature and likely to persist. Returns, on the other hand, are a function of the *success* of a particular investment style, and the success of a particular investment style varies over time. That is, the fact that a fund's market bets were successful in the past is not a strong indication that those bets will be successful in the future.

Next, we demonstrate that a fund's standard deviation is, in part, driven by its correlation with various markets. This relation is important because the fact that these correlations persist helps explain why a fund's standard deviation persists. We demonstrate the relation in two ways: with a regression model relating the within-strategy rank of a fund's absolute correlation with various indices to the

## EXHIBIT 2

**Average Rank Information Coefficients (Rank ICs) for Persistence in Subsequent 12-Month Period Based on Prior 36-Month Realizations Computed Annually** (1995–2001)

### Panel A
### Average Rank ICs Within Strategy

| Strategy | Average Monthly Return | Standard Deviation of Monthly Returns | Annualized Sharpe Ratio | Peak to Trough Maximum Drawdown | Correlation: S&P 500 Index | Correlation: Russell 2000 Index | Correlation: Lehman Bond Index | Correlation: Goldman Sachs Index |
|---|---|---|---|---|---|---|---|---|
| Long-Short Equity | 0.02 | 0.63 | -0.10 | 0.54 | 0.61 | 0.65 | 0.06 | 0.17 |
| Market Neutral Equity | -0.04 | 0.78 | -0.01 | 0.56 | 0.49 | 0.56 | -0.01 | 0.18 |
| Relative Value | -0.14 | 0.39 | -0.03 | 0.40 | 0.32 | 0.23 | 0.14 | 0.15 |
| Event Driven | -0.20 | 0.66 | -0.12 | 0.57 | 0.49 | 0.59 | 0.03 | 0.10 |
| Fixed Income | -0.31 | 0.50 | -0.13 | 0.48 | 0.35 | 0.54 | 0.26 | -0.08 |
| Futures Trading | -0.08 | 0.73 | -0.01 | 0.58 | 0.35 | 0.18 | 0.39 | -0.13 |
| Unknown | -0.08 | 0.76 | -0.16 | 0.70 | 0.58 | 0.66 | 0.06 | -0.01 |

### Panel B
### Average Rank ICs by Year

| Year | Average Monthly Return | Standard Deviation of Monthly Returns | Annualized Sharpe Ratio | Peak to Trough Maximum Drawdown | Correlation: S&P 500 Index | Correlation: Russell 2000 Index | Correlation: Lehman Bond Index | Correlation: Goldman Sachs Index |
|---|---|---|---|---|---|---|---|---|
| 1995 | -0.21 | 0.76 | -0.30 | 0.65 | 0.50 | 0.66 | 0.00 | -0.01 |
| 1996 | -0.17 | 0.74 | -0.25 | 0.64 | 0.40 | 0.73 | -0.03 | -0.01 |
| 1997 | -0.25 | 0.76 | -0.26 | 0.68 | 0.54 | 0.72 | 0.32 | 0.02 |
| 1998 | -0.02 | 0.77 | -0.05 | 0.60 | 0.52 | 0.71 | 0.14 | 0.21 |
| 1999 | -0.37 | 0.68 | 0.11 | 0.61 | 0.62 | 0.63 | -0.04 | 0.05 |
| 2000 | 0.08 | 0.65 | -0.07 | 0.64 | 0.49 | 0.54 | 0.04 | 0.26 |
| 2001 | 0.05 | 0.69 | -0.01 | 0.69 | 0.66 | 0.59 | 0.10 | 0.05 |

### Panel C
### Average of Within-Strategy Rank ICs by Year

| Year | Average Monthly Return | Standard Deviation of Monthly Returns | Annualized Sharpe Ratio | Peak to Trough Maximum Drawdown | Correlation: S&P 500 Index | Correlation: Russell 2000 Index | Correlation: Lehman Bond Index | Correlation: Goldman Sachs Index |
|---|---|---|---|---|---|---|---|---|
| 1995 | -0.19 | 0.55 | -0.27 | 0.51 | 0.44 | 0.51 | 0.06 | 0.00 |
| 1996 | -0.28 | 0.62 | -0.03 | 0.54 | 0.36 | 0.51 | 0.14 | 0.03 |
| 1997 | -0.30 | 0.70 | -0.18 | 0.58 | 0.45 | 0.47 | 0.35 | -0.01 |
| 1998 | 0.01 | 0.68 | 0.01 | 0.54 | 0.42 | 0.50 | 0.12 | 0.13 |
| 1999 | -0.34 | 0.65 | 0.07 | 0.51 | 0.58 | 0.50 | 0.05 | 0.04 |
| 2000 | -0.02 | 0.63 | -0.09 | 0.58 | 0.37 | 0.46 | 0.02 | 0.20 |
| 2001 | -0.02 | 0.63 | -0.08 | 0.56 | 0.54 | 0.46 | 0.18 | -0.01 |

within-strategy rank of its standard deviation, and with a nonparametric test showing that a fund's absolute correlation with various indices is not independent of its standard deviation.[8] To avoid data overlap across successive periods, we use non-overlapping 12-month measurement periods.

The regression results presented in Panel A of Exhibit 3 show that a fund's absolute correlation with the various indices over the past 12 months are all significantly positively correlated with its contemporaneous standard deviation, with the results strongest for the correlations with

## EXHIBIT 3
**Standard Deviations of Return and Correlations with Various Indices**

### Panel A
### Regression Results

| Std_dev = | a | + $b_1$*SP500_corr | + $b_2$*R2000_corr | + $b_3$*LABI_corr | + $b_4$*GSCI_corr |
|---|---|---|---|---|---|
| | .278 | .165 | .211 | .042 | .029 |
| | (22.6) | (10.5) | (13.53) | (3.26) | (2.28) |

Model R-squared = 11.3%, F-value = 174.6, N =5439

### Panel B
### Nonparametric Analysis

| Standard Deviation Quintile | Quintile of abs. corr. with S&P 500 | | | | | Chi-Square Statistic | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | Value | Probability |
| 1 | **32.9%** | **25.4%** | **16.0%** | **14.0%** | **11.7%** | **444.7** | **< 0.0001** |
| 2 | 29.8% | 22.8% | 16.4% | 15.3% | 15.7% | | |
| 3 | 20.0% | 20.6% | 24.6% | 16.7% | 18.1% | | |
| 4 | 11.5% | 19.2% | 23.7% | 21.7% | 23.9% | | |
| 5 | **4.6%** | **12.3%** | **20.1%** | **32.5%** | **30.5%** | | |

| Standard Deviation Quintile | Quintile of abs. corr. with LABI | | | | | Chi-Square Statistic | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | Value | Probability |
| 1 | **16.2%** | **17.8%** | **21.4%** | **22.4%** | **22.2%** | **35.1** | **< 0.004** |
| 2 | 19.1% | 18.7% | 18.4% | 21.5% | 22.4% | | |
| 3 | 20.0% | 20.2% | 19.8% | 20.7% | 19.4% | | |
| 4 | 20.3% | 20.7% | 22.8% | 18.4% | 17.8% | | |
| 5 | **23.2%** | **22.9%** | **18.4%** | **17.2%** | **18.3%** | | |

| Standard Deviation Quintile | Quintile of abs. corr. with Russell 2000 | | | | | Chi-Square Statistic | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | Value | Probability |
| 1 | **32.2%** | **25.5%** | **14.3%** | **14.6%** | **13.4%** | **481.6** | **< 0.0001** |
| 2 | 32.7% | 20.9% | 17.5% | 14.6% | 14.3% | | |
| 3 | 22.1% | 21.4% | 21.7% | 15.5% | 19.3% | | |
| 4 | 9.1% | 19.1% | 22.1% | 24.9% | 24.9% | | |
| 5 | **2.7%** | **13.4%** | **25.2%** | **30.7%** | **28.1%** | | |

| Standard Deviation Quintile | Quintile of abs. corr. with GSCI | | | | | Chi-Square Statistic | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | Value | Probability |
| 1 | **25.4%** | **23.4%** | **20.3%** | **17.5%** | **13.4%** | **92.6** | **< 0.0001** |
| 2 | 19.9% | 23.8% | 20.1% | 19.6% | 16.6% | | |
| 3 | 19.7% | 19.4% | 21.7% | 19.6% | 19.7% | | |
| 4 | 16.9% | 18.4% | 16.7% | 23.5% | 24.5% | | |
| 5 | **17.0%** | **15.2%** | **22.0%** | **20.0%** | **25.8%** | | |

## EXHIBIT 4
**Length of History and Performance**

### Panel A
### Parametric Results

| Average Monthly Returns | | | |
|---|---|---|---|
| Year | History < 3 | History >= 3 | t- stat |
| **1995** | 1.73% | 1.56% | 1.16 |
| **1996** | **1.88%** | **1.41%** | **4.60** |
| **1997** | **1.73%** | **1.46%** | **2.50** |
| **1998** | 0.88% | **0.43%** | **3.20** |
| **1999** | **2.67%** | **2.11%** | **3.56** |
| **2000** | 0.95% | 0.77% | 1.51 |
| **2001** | 0.44% | 0.52% | (0.86) |

| Average Sharpe Ratios | | | |
|---|---|---|---|
| Year | History < 3 | History >= 3 | t- stat |
| **1995** | 1.95 | 1.79 | 0.81 |
| **1996** | 2.06 | 1.76 | 1.75 |
| **1997** | 1.68 | 1.68 | 0.04 |
| **1998** | 0.55 | 0.23 | 3.49 |
| **1999** | 1.74 | 1.59 | 1.42 |
| **2000** | 1.13 | 1.08 | 0.43 |
| **2001** | 0.41 | 0.58 | (1.87) |

### Panel B
### Nonparametric Analysis

| Quintile of Returns | | | | | |
|---|---|---|---|---|---|
| History Quintile | Lower 1 | 2 | 3 | 4 | Higher 5 |
| **1 Younger** | **17.2%** | **18.7%** | **18.8%** | **21.2%** | **24.1%** |
| **2** | 18.0% | 19.4% | 21.1% | 20.4% | 21.1% |
| **3** | 20.8% | 18.3% | 21.9% | 19.4% | 19.6% |
| **4** | 21.7% | 21.1% | 17.7% | 20.3% | 19.2% |
| **5 Older** | **20.6%** | **22.9%** | **21.3%** | **19.5%** | **15.7%** |

| Chi-Square Statistic | |
|---|---|
| Value | Probability |
| **56.4** | **< 0.0001** |

| Quintile of Sharpe Ratio | | | | | |
|---|---|---|---|---|---|
| History Quintile | Lower 1 | 2 | 3 | 4 | Higher 5 |
| **1 Younger** | **17.3%** | **20.7%** | **19.0%** | **20.2%** | **22.9%** |
| **2** | 19.6% | 19.6% | 21.2% | 19.9% | 19.7% |
| **3** | 20.2% | 20.3% | 18.9% | 20.6% | 20.0% |
| **4** | 21.1% | 20.7% | 19.8% | 19.4% | 19.1% |
| **5 Older** | **20.1%** | **19.6%** | **22.3%** | **20.5%** | **17.6%** |

| Chi-Square Statistic | |
|---|---|
| Value | Probability |
| **22.8** | **< 0.1184** |

the SP500 and R2000. While the results presented in Exhibit 2 address the persistence of the *effects* of style preferences, whatever those styles may be, the results presented in Exhibit 3 suggest that the returns distribution itself may shed light on the fund's style preferences. Specifically, a fund's standard deviation is related to its exposures to various underlying markets, and that funds with higher volatility tend to take greater explicit or implicit market bets. To the extent that 1) market bets are a source of volatility (as suggested by the results presented in Exhibit 3), and 2) style preferences persist (as suggested by the results presented in Exhibit 2), a fund currently taking greater market bets should have higher volatility in the future. In fact, we find that funds' absolute correlations with the four indices are all positively correlated with their standard deviation in subsequent periods.

The nonparametric results presented in Panel B of Exhibit 3 show that funds in the bottom quintile (i.e., with the lowest absolute correlations) with respect to their correlation with the SP500 (R2000) index are in the bottom quintile of the standard deviation distribution (i.e., with the lowest standard deviations) approximately 34% (36%) of the time, but they are in the top quintile of the standard deviation distribution only approximately 14% (14%) of the time. Likewise, funds in the top quintile with respect to their correlation with the SP500 (R2000) index are in the top quintile of the standard deviation distribution approximately 31% (34%) of the time, but they are in the bottom quintile of the standard deviation distribution only approximately 10% (9%) of the time. More generally, for each of the four indices, the chi-square test for the independence of funds' contemporaneous standard deviation and correlation with the index can be rejected at the 1% confidence level.

## FACTORS AFFECTING HEDGE FUND PERFORMANCE

In this section, we examine factors affecting the persistence of hedge fund performance and provide the rationale for our *eligible universe*. The eligible universe is the set of hedge funds meeting various criteria we impose and which may therefore be included in the various hedge fund portfolios we construct.

### Length of Fund History

Fung and Hsieh [2000] estimate that due to survivorship bias, the use of hedge fund databases to estimate historical hedge fund returns overestimates returns by approximately 3% annually, while Liang [2000] estimates that the bias exceeds 2% annually. In Exhibit 4, we present a similar difference in returns between newer funds (with fewer than three years of experience) and older funds (with more than three years of experience).

The results presented in Panel A show that funds with less than three years of history, on average, have annualized returns approximately 3%-4% higher than funds with more than three years of history, and that this differential is consistent over time (until 2001). However, the difference in Sharpe ratios is not as consistent. In the results presented in Panel B, for each year we partition all funds based on their number of months of experience and on relative performance over the prior 12 months, and construct a $5 \times 5$ contingency table testing the independence of funds' experience and performance. The chi-square test for the independence of experience and return is significant at the 1% confidence level, implying that funds with limited experience generate higher returns than more experienced funds. However, the chi-square test for the independence of experience and Sharpe ratios is not significant, implying that funds with limited experience do not generate higher Sharpe ratios than funds with longer histories.

Our explanation for these results is that funds with a short history tend to be more experimental in their investment strategy with fewer controls or rigorous investment guidelines, may be reporting unaudited, or, perhaps, simulated rather than actual results, and may self-select in the timing of when they start reporting results. The implication is that one should discount results from a fund's earlier years of operation. Consequently, the eligible universe requires a minimum track record of 36 months. This approach may also serve to indirectly control for survivorship bias.

### Assets Under Management

The eligible universe requires that a fund either have a minimum of \$50M in assets under management or that its assets under management be above the 40th percentile.[9] The rationale is that funds with low levels of assets under management may not have the capacity to absorb large amounts of additional capital or have not yet demonstrated the ability to manage large amounts of capital. Further, because managing large amounts of capital may require alternative strategies and approaches to those used in managing smaller amounts, the performance of funds that currently have lower amounts of funds under management may not be predictive of their performance when assets under management increase.

As evidence, we find that among funds with three or more years of history, funds that are both below the 40th percentile in assets under management and have less than \$50M in assets outperform funds with more assets under management. While the difference in returns between the smaller and larger funds is only marginally significant (1.11% vs. 0.98%, t-stat = 1.70), the difference in Sharpe ratios is highly significant (1.13 vs. 0.75, t-stat = 6.13). The implication is that smaller funds, on average, out-

# Exhibit 5
**Change in Asset Size and Performance**

| Change in Asset Size | Change in Returns (+) 1 | 2 | 3 | 4 | (-) 5 | Chi-Square Statistic Value | Probability |
|---|---|---|---|---|---|---|---|
| 1 (-) | 26.3% | 26.3% | 17.6% | 11.5% | 18.3% | **159.8** | **< 0.0001** |
| 2 | 17.4% | 22.1% | 24.2% | 19.7% | 16.6% | | |
| 3 | 16.6% | 25.5% | 20.8% | 21.8% | 15.3% | | |
| 4 | 18.3% | 16.6% | 21.9% | 25.1% | 18.1% | | |
| 5 (+) | **9.3%** | **17.2%** | **21.3%** | **23.9%** | **28.1%** | | |

| Change in Asset Size | Change in Sharpe Ratio (+) 1 | 2 | 3 | 4 | (-) 5 | Chi-Square Statistic Value | Probability |
|---|---|---|---|---|---|---|---|
| 1 (-) | 28.3% | 23.0% | 17.0% | 15.7% | 16.1% | **102.5** | **< 0.0001** |
| 2 | 25.7% | 20.7% | 19.8% | 17.3% | 16.5% | | |
| 3 | 22.8% | 22.0% | 21.6% | 17.6% | 16.0% | | |
| 4 | 19.6% | 18.6% | 19.1% | 22.6% | 20.3% | | |
| 5 (+) | **16.8%** | **14.6%** | **18.0%** | **21.6%** | **29.1%** | | |

perform larger funds. Since our conservative approach omits seemingly superior funds, our results may not be comparable to hedge fund indices that consider all funds.

To further demonstrate that a fund's investment success at one level of capital may not translate into similar performance with a higher level of capital, we compare the change in performance for funds that have experienced large capital increases with those that have not. The test procedure is as follows. Each year, we partition all funds meeting the requirements for assets under management based on their 1) percentage change in assets under management over the prior 12-month period, 2) change in returns over the subsequent 12-month period, and 3) change in Sharpe ratios over the subsequent 12-month period. We then construct $5 \times 5$ contingency tables testing the null hypothesis of the independence of a fund's change in assets under management with its subsequent change in performance.

Results presented in Exhibit 5 suggest that changes in assets under management are predictive of changes in returns and Sharpe ratios, as the chi-square tests reject the null hypotheses of independence at the .01 levels. In particular, large relative *increases* in assets under management are strongly predictive of *decreases* in future performance. That is to say, funds with unusually large increases in assets over short periods of time often exhibit deterioration in subsequent performance. This may be due to the fact that additional assets are often placed in cash equivalents until additional ideas can be generated for their use, or even worse, they are invested in lower probability positions. We conclude that the level of assets under management is *negatively* related to performance when the fund has not previously operated at its current size. Therefore, the eligible universe requires that otherwise eligible funds with more than \$500M in assets under management did not double their assets over the prior 12- month period.

We also analyze the relation between assets under management and performance for the eligible universe. In each year, we equally divide all funds in the eligible universe according to assets under management, returns, and risk. The smaller hedge funds in the universe are denoted as "medium-sized" and the larger ones as "'large-sized." Two $2 \times 2$ contingency tables are used to test the null hypotheses of 1) the independence of a fund's then current assets under management and returns for the subsequent 12-month period, 2) the independence of a fund's then current assets under management and risk for the subsequent 12-month period, and 3) the independence of a fund's then current assets under management and Sharpe ratios for the subsequent 12-month period. Results

## EXHIBIT 6

**Assets Under Management and Performance Conditional on Fund Meeting Minimum Asset Requirements**

| | Returns Partition | |
|---|---|---|
| Size Partition | Below Median | Above Median |
| Medium | 47.2% | 52.8% |
| Large | 52.8% | 47.2% |

| Chi-Square Statistic | |
|---|---|
| Value | Probability |
| 6.22 | < 0.013 |

| | Risks Partition | |
|---|---|---|
| Size Partition | Below Median | Above Median |
| Medium | 42.8% | 57.2% |
| Large | 57.2% | 42.8% |

| Chi-Square Statistic | |
|---|---|
| Value | Probability |
| 42.5 | < 0.0001 |

| | Sharpe Partition | |
|---|---|---|
| Size Partition | Below Median | Above Median |
| Medium | 51.7% | 48.3% |
| Large | 48.3% | 51.7% |

| Chi-Square Statistic | |
|---|---|
| Value | Probability |
| 2.08 | < 0.149 |

are presented in Exhibit 6.

We see that the chi-square tests reject the null of independence at the .01 levels for the first two tests. The implications are that large-sized funds have lower returns and lower risk than medium-sized funds. Large-sized funds' lower risk may result from the possibilities that they 1) have larger asset bases and are thus better positioned to either diversify their risks within a given strategy or utilize several investment strategies, 2) have better and more systematic risk-management procedures, 3) can afford to take a longer-term investment perspective, and 4) are more experienced in investment management. The finding that Sharpe ratios do not significantly differ for large- and medium-sized funds suggests that given a minimum amount of assets under management accompanied by stability in asset size, larger- and medium-sized funds perform comparably.

### Seasonality in Hedge Fund Returns

Hedge fund performance is not equally distributed across calendar months. We identify three distinct seasonal effects that increase performance, in descending order of magnitude: a December effect, a January effect, and a quarter-end effect. Possible explanations for these effects relate to 1) hedge funds' incentives in how and when they report their results (the December and quarter-end effects), 2) hedge funds' ability to drive up month-end prices in an illiquid market with relatively low volume transactions, and 3) the seasonal performance of the underlying markets that the hedge funds invest in (the January effect in equity markets). Funds have incentives to report higher returns in December because incentive fees and annual performance results are generally determined based on year-end results. In addition, because volume may be lighter and markets more illiquid in December, it may be easier for managers to drive up month-end prices of their holdings with relatively low volume transactions at the end of December. For funds that collect their management or performance fees on a quarterly basis, there is an incentive for reporting higher results at quarter-end, because doing so may serve to increase fees. While reporting higher January results would not affect fees any more than reporting higher results in February, results may be higher in January because the underlying markets that hedge funds invest in may do better in January. For example, year-end tax plays and mutual fund inflows may contribute to rising equity prices in January.

**E X H I B I T 7**
**Seasonality Effects**

| Average Monthly Returns | | | |
|---|---|---|---|
| Strategy | December | Other Months Excluding Dec. & Jan. | t - stat |
| Long/Short | 3.57% | 0.65% | 13.13 |
| Market Neutral | 2.01% | 0.91% | 3.14 |
| Relative Value | 0.90% | 0.85% | 0.23 |
| Event Driven | 2.55% | 0.83% | 8.33 |
| Fixed Income | 1.35% | 0.61% | 3.79 |
| Futures Trading | 3.18% | 0.85% | 4.30 |
| Unknown | 2.99% | 0.73% | 6.39 |
| For All Strategies | 2.80% | 0.75% | 18.06 |

| Average Monthly Returns | | | |
|---|---|---|---|
| Strategy | January | Other Months Excluding Dec. & Jan. | t - stat |
| Long/Short | 2.13% | 0.65% | 6.45 |
| Market Neutral | 1.35% | 0.91% | 1.22 |
| Relative Value | 1.91% | 0.85% | 4.92 |
| Event Driven | 1.58% | 0.83% | 3.94 |
| Fixed Income | 1.77% | 0.61% | 4.37 |
| Futures Trading | 1.05% | 0.85% | 0.73 |
| Unknown | 1.74% | 0.73% | 2.27 |
| For All Strategies | 1.80% | 0.75% | 8.59 |

| Average Monthly Returns | | | |
|---|---|---|---|
| Strategy | Avg. Qtr. End Mar-Jun-Sep | Other Months Excluding Dec. & Jan. | t - stat |
| Long/Short | 0.72% | 0.61% | 0.49 |
| Market Neutral | 1.12% | 0.82% | 1.26 |
| Relative Value | 0.87% | 0.85% | 0.25 |
| Event Driven | 0.83% | 0.82% | 0.11 |
| Fixed Income | 0.40% | 0.69% | (1.85) |
| Futures Trading | 1.14% | 0.72% | 1.09 |
| Unknown | 1.20% | 0.53% | 2.44 |
| For All Strategies | 0.85% | 0.70% | 1.96 |

Each of the aforementioned seasonal effects is calculated independent of the other effects. The December effect is calculated by comparing December returns to the returns of all months other than December and January; the January effect is calculated by comparing January returns to the returns of all months other than December and January; and the quarter-end effect is calculated by comparing March, June, and September results

## EXHIBIT 8
**Redemption Policy, Returns, and Risk**

| Average Monthly Returns | | | |
|---|---|---|---|
| Strategy | More Liquidity | Less Liquidity | t - stat |
| Long/Short | 0.92% | 1.08% | (0.91) |
| Market Neutral | 1.03% | 1.17% | (0.43) |
| Relative Value | 0.97% | 0.84% | 0.71 |
| Event Driven | 0.93% | 0.99% | (0.54) |
| Fixed Income | 0.79% | 0.71% | 0.41 |
| Futures Trading | 1.08% | 0.86% | 0.92 |
| Unknown | 0.94% | 0.87% | 0.26 |
| For All Strategies | 0.94% | 1.00% | (0.68) |

| Average Standard Deviation | | | |
|---|---|---|---|
| Strategy | More Liquidity | Less Liquidity | t - stat |
| Long/Short | 6.26% | 5.25% | 3.43 |
| Market Neutral | 3.46% | 4.79% | (2.15) |
| Relative Value | 1.96% | 1.39% | 1.59 |
| Event Driven | 2.42% | 2.96% | (2.46) |
| Fixed Income | 1.80% | 1.81% | (0.01) |
| Futures Trading | 4.93% | 3.02% | 4.14 |
| Unknown | 3.63% | 3.91% | (0.48) |
| For All Strategies | 3.97% | 4.06% | (0.48) |

to the results of all other months with the exception of December and January. In Exhibit 7 we display results for the three seasonality effects, for the entire sample and for individual strategy groups. It is noteworthy that the December and January effects hold for most strategy groups, the December and January results are especially strong for futures trading and equity-related funds, and the quarter-end effect is strongest for futures trading funds.[10]

### Redemption Policy

Funds differ in their redemption policies, with some funds offering monthly or even more frequent redemptions, and other funds offering quarterly or even less frequent redemptions. An interesting question is whether a fund's redemption policy is related to its volatility.[11] Results presented in Exhibit 8 illustrate this relation for each of the seven strategy groups.

It is evident that the relation between a fund's volatility and redemption policy differs across strategy groups. Specifically, lower volatility funds provide more frequent redemptions for the market neutral equity and event driven groups, while higher volatility funds provide more frequent redemptions for the long-short equity, relative value, and futures trading groups. Therefore, the eligible universe does not impose any constraints pertaining to redemption policy.[12]

## RISK-RETURN PROFILE OF HEDGE FUNDS

Given the previously reported results on the persistence of hedge fund risk, it is reasonable to use *observed* risk in period t as a proxy for risk in period t + 1. We test whether a fund's observed risk in prior periods can be used to predict its performance in *subsequent* periods. To do so, we estimate several models linking the within-strategy rank of funds' standard deviation over the *past* 36 months (ending November 30) with their within-strategy rank for returns and Sharpe ratios over the *subsequent* 12 months (beginning January 1). The sample includes all funds in the eligible universe. Panel A of Exhibit 9 provides the pooled regression results for the entire sample, Panel B provides the separate regression estimates for each strategy group, and Panel C provides the separate regression estimates for each year. We also partition the funds into quintiles based on their within-strategy ranks on risk,

## EXHIBIT 9
**Risk and Performance**

### Panel A
### Aggregate Results

| | | | |
|---|---|---|---|
| Return_forward12 = | a | + $b_1$*Stddev_past36 | $R^2$ |
| | 0.459 | 0.065 | 0.4% |
| | (44.08) | (3.46) | |
| Sharpe_forward12 = | a | + $b_1$*Stddev_past36 | $R^2$ |
| | 0.653 | -0.300 | 8.5% |
| | (62.80) | (-16.00) | |

### Panel B
### Results by Strategy

Return_forward12 = a +$b_1$*Stddev_past36

| Strategy | a | $b_1$ | $R^2$ |
|---|---|---|---|
| **Long/Short** | 0.499 | **-0.210** | 0.0% |
| t - stat | 28.20 | -0.65 | |
| **Market Neutral** | 0.398 | 0.213 | 4.0% |
| t - stat | 10.16 | 3.10 | |
| **Relative Value** | 0.436 | 0.113 | 1.0% |
| t - stat | 12.20 | 1.81 | |
| **Event Driven** | 0.412 | 0.156 | 2.4% |
| t - stat | 20.18 | 4.28 | |
| **Fixed Income** | 0.368 | 0.219 | 4.6% |
| t - stat | 8.82 | 3.13 | |
| **Futures Trading** | 0.443 | 0.124 | 1.1% |
| t - stat | 11.27 | 1.70 | |
| **Unknown** | 0.556 | **-0.161** | 2.1% |
| t - stat | 18.21 | -2.78 | |

Sharpe_forward12 = a +$b_1$*Stddev_past36

| Strategy | a | $b_1$ | $R^2$ |
|---|---|---|---|
| **Long/Short** | 0.499 | **-0.210** | 0.0% |
| t - stat | 28.20 | -0.65 | |
| **Market Neutral** | 0.398 | 0.213 | 4.0% |
| t - stat | 10.16 | 3.10 | |
| **Relative Value** | 0.436 | 0.113 | 1.0% |
| t - stat | 12.20 | 1.81 | |
| **Event Driven** | 0.412 | 0.156 | 2.4% |
| t - stat | 20.18 | 4.28 | |
| **Fixed Income** | 0.368 | 0.219 | 4.6% |
| t - stat | 8.82 | 3.13 | |
| **Futures Trading** | 0.443 | 0.124 | 1.1% |
| t - stat | 11.27 | 1.70 | |
| **Unknown** | 0.556 | **-0.161** | 2.1% |
| t - stat | 18.21 | -2.78 | |

return, and Sharpe ratios, and construct two 5 × 5 contingency tables to test the independence of funds' risk, returns, and Sharpe ratios. Results are presented in Panel D.

The results in Panel A show that while there is a marginally positive relation between individual hedge funds' risk and returns, there is a far stronger negative relation between hedge funds' risk and Sharpe ratios. The implication is that while riskier funds on average generate marginally higher expected returns, they *do not* generate adequate increases in returns to compensate investors for assuming increased risk. Results in Panel B show that these results generally hold for most strategies (other than futures trading).

We next analyze whether the relation between risk, return, and Sharpe ratios differs over time. Results presented in Panel C show that in years in which the average hedge fund performs well (e.g., 1996, 1997, 1999) the relation between hedge funds' risk and returns is strongly positive, and in years in which the average hedge fund performs poorly (e.g., 1998, 2000, 2001) the relation between hedge funds' risk and returns is negative or insignificant. This suggests that the riskier funds may simply provide additional exposure to the underlying markets driving hedge fund performance, and behave as if inefficiently leveraged to the performance of less risky funds in their strategy group.[13] The rationale behind this

## EXHIBIT 9
**Risk and Performance** (continued)

### Panel C
### Results by Year

| Year | a | $b_1$ | $R^2$ |
|---|---|---|---|
| **1995** | 0.383 | 0.218 | 4.5% |
| t - stat | 7.77 | 2.60 | |
| **1996** | 0.320 | 0.310 | 9.9% |
| t - stat | 8.26 | 4.60 | |
| **1997** | 0.365 | 0.263 | 7.5% |
| t - stat | 11.59 | 4.79 | |
| **1998** | 0.499 | **-0.044** | **0.0%** |
| t - stat | 17.46 | -0.89 | |
| **1999** | 0.305 | 0.359 | 13.3% |
| t - stat | 13.33 | 8.63 | |
| **2000** | 0.536 | **-0.110** | **1.1%** |
| t - stat | 24.21 | -2.72 | |
| **2001** | 0.561 | **-0.105** | **0.9%** |
| t - stat | 27.40 | -2.77 | |

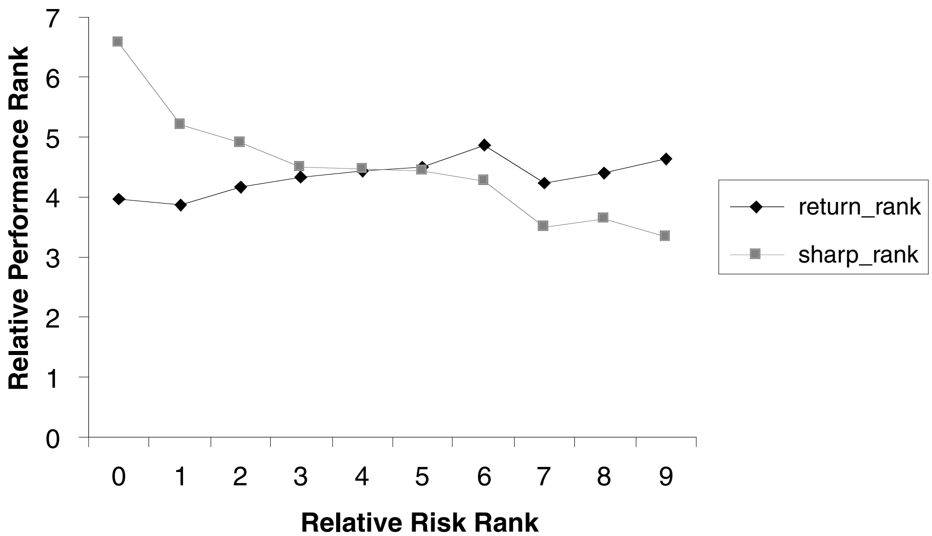
| Year | a | $b_1$ | $R^2$ |
|---|---|---|---|
| **1995** | 0.641 | -0.265 | 7.0% |
| t - stat | 13.20 | -3.21 | |
| **1996** | 0.636 | -0.255 | 6.3% |
| t - stat | 15.81 | -3.65 | |
| **1997** | 0.732 | -0.408 | 17.3% |
| t - stat | 23.68 | -7.57 | |
| **1998** | 0.579 | -0.199 | 3.8% |
| t - stat | 19.72 | -3.90 | |
| **1999** | 0.607 | -0.195 | 3.3% |
| t - stat | 23.67 | -4.19 | |
| **2000** | 0.704 | -0.433 | 16.9% |
| t - stat | 33.07 | -11.13 | |
| **2001** | 0.656 | -0.284 | 7.0% |
| t - stat | 31.82 | -7.45 | |

### Panel D
### Nonparametric Results

| | Return | | | | | Chi-Square Statistic | |
|---|---|---|---|---|---|---|---|
| Risk | (-) 1 | 2 | 3 | 4 | (+) 5 | Value | Probability |
| **1 (-)** | 12.6% | 26.7% | 32.4% | 19.6% | 8.7% | **373.3** | **< 0.0001** |
| **2** | 12.7% | 26.2% | 26.7% | 21.7% | 12.7% | | |
| **3** | 16.7% | 18.7% | 19.8% | 24.3% | 20.5% | | |
| **4** | 22.7% | 16.6% | 13.9% | 22.4% | 24.5% | | |
| **5 (+)** | **35.1%** | 12.1% | 7.7% | 11.8% | **33.3%** | | |

| | Sharpe Ratio | | | | | Chi-Square Statistic | |
|---|---|---|---|---|---|---|---|
| Risk | (-) 1 | 2 | 3 | 4 | (+) 5 | Value | Probability |
| **1 (-)** | **8.9%** | **13.9%** | **13.2%** | **21.0%** | **43.0%** | **360.6** | **< 0.0001** |
| **2** | 15.3% | 17.7% | 21.4% | 21.9% | 23.8% | | |
| **3** | 20.0% | 19.2% | 23.4% | 20.5% | 16.7% | | |
| **4** | 22.4% | 24.8% | 23.4% | 20.8% | 8.6% | | |
| **5 (+)** | **33.3%** | **24.1%** | **18.4%** | **15.8%** | **8.5%** | | |

## EXHIBIT 10
**Risk, Returns, and Sharpe Ratios**




observation is that if the risks assumed by the riskier hedge funds were unrelated to those assumed by less risky hedge funds, one would expect that the more risky hedge funds would generate greater returns, on average, in all years, regardless of the performance of the average hedge fund.

Results presented in Panel D demonstrate that a fund with lower risk relative to its strategy group peers is *less* likely to generate *either* lower or higher returns as compared to its strategy group peers. In contrast, a fund with higher relative risk is *more* likely to generate *either* lower or higher returns as compared to its strategy group peers. That is, the riskier funds appear to take larger "bets," with either much higher or much lower payoffs than those of the average fund in their strategy group. However, as shown by the results presented in Panels A-C, the overall relationship between risk and return is weak. This implies that the riskier funds lose their "bets" almost as often as they win their "'bets." Based on the prior results, the nature of riskier hedge funds' "bet" may be that of a leveraged bet on the factors that drive performance in their strategy group. While the bet may pay off in terms of returns, it is less likely to pay off in terms of Sharpe ratios. Results in Panel D show that funds with low risk relative to their strategy peer group have a greater likelihood of achieving a higher relative Sharpe ratio, while funds with higher relative risk are more likely to achieve a lower relative Sharpe ratio.

Exhibit 10 illustrates the relation between risk and performance, on the individual fund level. On each December 31, all funds in the eligible universe are divided into deciles based on their within-strategy risk for the prior 36-month period, their within-strategy relative return for the subsequent 12-month period, and their within-strategy relative Sharpe ratio for the subsequent 12-month period. For each risk decile, the average return and Sharpe ratio rank are calculated. The results in Exhibit 10 suggest that 1) while expected returns increase as risk increases, the relationship is not monotonic, and 2) Sharpe ratios monotonically decrease as risk increases.[14]

In summary, there are two basic findings on the relationship between risk and performance on the individual fund level. First, although the relation between risk and returns is marginally positive, it is not monotonic and it is reversed in years where the average hedge fund performs poorly. Second, the relation between risk and Sharpe ratios is consistently and significantly negative, in all time periods and in virtually all strategy groups. The implication is that the higher returns generated by riskier funds are not sufficient to offset their increased risk. *Therefore, one should not consider riskier funds based on the returns they are expected to generate. The role of riskier funds in portfolios, if any, must be to diversify the risk of the portfolio's other funds, with which the riskier funds are negatively correlated.*

## EXHIBIT 11
**Comparison of HFSM Portfolio to Various Naïve Portfolios**

| HFSM Portfolio | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | Average |
| Portfolio Return (%) | 1.37 | 1.24 | 0.58 | 1.21 | 1.11 | 0.79 | 1.05 |
| Portfolio Standard Deviation (%) | 0.52 | 0.37 | 0.93 | 0.51 | 0.24 | 0.36 | 0.49 |
| **Sharpe Ratio** | **4.70** | **5.35** | **1.24** | **4.40** | **5.25** | **3.89** | **4.14** |

| Top 50 Prior Returns (No Diversification Across Strategies): Naïve1 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | Average |
| Portfolio Return (%) | 1.77 | 1.84 | 0.09 | 2.07 | (0.46) | (0.71) | 0.77 |
| Portfolio Standard Deviation (%) | 2.40 | 3.19 | 4.60 | 3.01 | 7.25 | 3.94 | 4.07 |
| **Sharpe Ratio** | **1.43** | **1.19** | **0.04** | **1.25** | **(0.18)** | **(0.37)** | **0.56** |

| Top 7 Returns in Each Strategy Group: Naïve2 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | Average |
| Portfolio Return (%) | 1.76 | 1.64 | (0.05) | 1.72 | 0.50 | (0.20) | 0.90 |
| Portfolio Standard Deviation (%) | 1.93 | 1.96 | 3.34 | 1.88 | 5.47 | 2.14 | 2.79 |
| **Sharpe Ratio** | **1.68** | **1.36** | **(0.03)** | **1.39** | **0.23** | **(0.15)** | **0.75** |

| Top 7 Sharpe Ratios in Each Strategy Group: Naïve3 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | Average |
| Portfolio Return (%) | 1.56 | 1.39 | 0.57 | 1.12 | 1.45 | 0.79 | 1.15 |
| Portfolio Standard Deviation (%) | 1.18 | 1.03 | 1.27 | 0.67 | 0.73 | 0.40 | 0.88 |
| **Sharpe Ratio** | **2.35** | **2.22** | **0.77** | **3.14** | **3.02** | **3.02** | **2.42** |

| All Funds Meeting Asset Size Requirements | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | Average |
| Portfolio Return (%) | 1.47 | 1.50 | 0.41 | 1.97 | 0.75 | 0.54 | 1.11 |
| Portfolio Standard Deviation (%) | 2.83 | 3.45 | 4.93 | 3.84 | 4.78 | 3.55 | 3.90 |
| **Sharpe Ratio** | **2.58** | **2.18** | **0.01** | **2.80** | **0.48** | **0.24** | **1.38** |

## HEDGE FUND SELECTION MODEL

### Identifying Hedge Funds Likely to Generate Superior Relative Performance

Quantitative methods are widely utilized by practitioners to enhance investment returns. We adapt techniques used for stock selection to develop a multifactor hedge fund selection model, henceforth referred to as HFSM. Our model ranks hedge funds in the eligible universe based on prior realizations of relevant factors such as a fund's return, maximum drawdown, standard deviation, assets under management, and change in assets under management. Sharpe, Sortino, Calmar, and Sterling ratios, various measures of risk-adjusted returns, are also among the factors considered.[15] These factors are measured in absolute terms, relative to other hedge funds, and for a number of past intervals, including 12, 36, and 48 months.

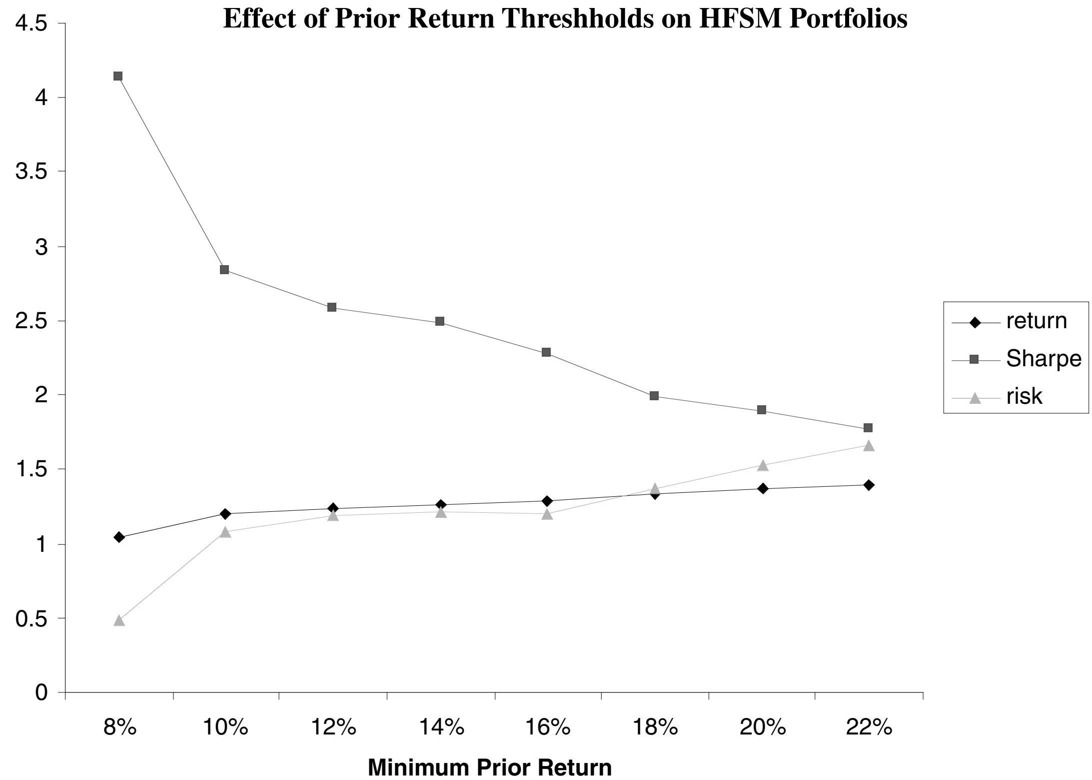
The HFSM methodology is essentially based on the two prior fundamental results: a fund's risk is highly persistent, and less risky funds, on average, outperform more risky funds. Accordingly, the HFSM assigns higher ranks

## EXHIBIT 12

**Various HFSM Portfolio Results**

| Prior Return > 8% | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | Average |
|---|---|---|---|---|---|---|---|
| **Portfolio Return (%)** | 1.37 | 1.24 | 0.58 | 1.21 | 1.11 | 0.79 | 1.05 |
| **Portfolio Standard Deviation (%)** | 0.52 | 0.37 | 0.93 | 0.51 | 0.24 | 0.36 | 0.49 |
| **Average Standard Deviation (%)** | 1.00 | 0.80 | 1.58 | 0.95 | 0.73 | 0.70 | 0.96 |
| **Sharpe Ratio** | **4.70** | **5.35** | **1.24** | **4.40** | **5.25** | **3.89** | **4.14** |
| **Benefit of Diversification (%)** | 48.00 | 54.00 | 41.00 | 46.00 | 67.00 | 49.00 | 50.83 |
| **Prior Return > 10%** | | | | | | | |
| **Portfolio Return (%)** | 1.41 | 1.44 | 0.70 | 1.57 | 1.21 | 0.85 | 1.20 |
| **Portfolio Standard Deviation (%)** | 0.78 | 0.67 | 2.55 | 0.96 | 1.09 | 0.43 | 1.08 |
| **Average Standard Deviation (%)** | 1.35 | 1.30 | 3.16 | 1.47 | 1.69 | 0.91 | 1.65 |
| **Sharpe Ratio** | **3.61** | **3.83** | **0.76** | **3.12** | **2.47** | **3.22** | **2.84** |
| **Benefit of Diversification (%)** | 42.00 | 48.00 | 19.00 | 45.00 | 36.00 | 53.00 | 40.50 |
| **Prior Return > 12%** | | | | | | | |
| **Portfolio Return (%)** | 1.40 | 1.48 | 0.71 | 1.69 | 1.27 | 0.86 | 1.24 |
| **Portfolio Standard Deviation (%)** | 0.97 | 0.99 | 2.49 | 1.15 | 1.07 | 0.48 | 1.19 |
| **Average Standard Deviation (%)** | 1.61 | 1.69 | 3.38 | 1.98 | 1.64 | 0.95 | 1.88 |
| **Sharpe Ratio** | **3.00** | **3.03** | **0.72** | **2.95** | **2.67** | **3.12** | **2.58** |
| **Benefit of Diversification (%)** | 40.00 | 41.00 | 26.00 | 35.00 | 35.00 | 49.00 | 37.67 |
| **Prior Return > 14%** | | | | | | | |
| **Portfolio Return (%)** | 1.38 | 1.58 | 0.73 | 1.68 | 1.40 | 0.81 | 1.26 |
| **Portfolio Standard Deviation (%)** | 1.10 | 0.93 | 2.57 | 1.12 | 1.04 | 0.54 | 1.22 |
| **Average Standard Deviation (%)** | 1.79 | 1.78 | 3.49 | 1.93 | 1.67 | 1.08 | 1.96 |
| **Sharpe Ratio** | **2.66** | **3.07** | **0.72** | **3.01** | **2.90** | **2.58** | **2.49** |
| **Benefit of Diversification (%)** | 39.00 | 48.00 | 26.00 | 42.00 | 38.00 | 50.00 | 40.50 |
| **Prior Return > 16%** | | | | | | | |
| **Portfolio Return (%)** | 1.38 | 1.63 | 0.71 | 1.75 | 1.52 | 0.75 | 1.29 |
| **Portfolio Standard Deviation (%)** | 1.11 | 0.97 | 2.35 | 1.16 | 1.01 | 0.58 | 1.20 |
| **Average Standard Deviation (%)** | 1.79 | 1.84 | 3.60 | 2.23 | 2.11 | 1.25 | 2.14 |
| **Sharpe Ratio** | **2.66** | **3.06** | **0.68** | **2.71** | **2.49** | **2.07** | **2.28** |
| **Benefit of Diversification (%)** | 38.00 | 47.00 | 34.00 | 48.00 | 52.00 | 54.00 | 45.50 |
| **Prior Return > 18%** | | | | | | | |
| **Portfolio Return (%)** | 1.40 | 1.77 | 0.70 | 1.93 | 1.47 | 0.76 | 1.34 |
| **Portfolio Standard Deviation (%)** | 1.18 | 1.20 | 2.32 | 1.59 | 1.33 | 0.59 | 1.37 |
| **Average Standard Deviation (%)** | 1.87 | 2.09 | 3.63 | 2.76 | 2.75 | 1.71 | 2.47 |
| **Sharpe Ratio** | **2.59** | **2.93** | **0.66** | **2.42** | **1.85** | **1.53** | **2.00** |
| **Benefit of Diversification (%)** | 37.00 | 43.00 | 36.00 | 42.00 | 52.00 | 65.00 | 45.83 |
| **Prior Return > 20%** | | | | | | | |
| **Portfolio Return (%)** | 1.42 | 1.72 | 0.70 | 2.11 | 1.44 | 0.82 | 1.37 |
| **Portfolio Standard Deviation (%)** | 1.23 | 1.23 | 2.57 | 1.87 | 1.61 | 0.68 | 1.53 |
| **Average Standard Deviation (%)** | 2.02 | 2.26 | 4.01 | 3.06 | 2.78 | 1.84 | 2.66 |
| **Sharpe Ratio** | **2.43** | **2.63** | **0.60** | **2.38** | **1.79** | **1.54** | **1.90** |
| **Benefit of Diversification (%)** | 39.00 | 46.00 | 36.00 | 39.00 | 42.00 | 63.00 | 44.17 |
| **Prior Return > 22%** | | | | | | | |
| **Portfolio Return (%)** | 1.37 | 2.03 | 0.70 | 2.14 | 1.39 | 0.74 | 1.40 |
| **Portfolio Standard Deviation (%)** | 1.36 | 1.55 | 2.74 | 1.95 | 1.76 | 0.62 | 1.66 |
| **Average Standard Deviation (%)** | 2.14 | 2.76 | 4.21 | 3.27 | 2.91 | 1.81 | 2.85 |
| **Sharpe Ratio** | **2.21** | **2.54** | **0.57** | **2.26** | **1.65** | **1.41** | **1.77** |
| **Benefit of Diversification (%)** | 36.00 | 44.00 | 35.00 | 40.00 | 40.00 | 66.00 | 43.50 |

## EXHIBIT 13
**Risk and Performance in HFSM Portfolios**




to funds in the eligible universe that have achieved superior rates of return in prior periods, but with low risk and high Sharpe and Sortino ratios relative to other funds in their strategy group. The prior period results on which we focus extend to 36 months, although the more recent results are weighted more heavily. We overweight funds with longer histories, as the performance of funds with longer histories is more persistent.[16] Based on the earlier result that a fund's correlation with equity markets significantly contributes to its risk, we overweight funds with low correlations to equity markets. Finally, past months' results are differentially weighted by taking into account the seasonality effects described earlier.

We construct a HFSM portfolio comprised of the 10 highest-ranked eligible funds in each of the seven strategy groups, resulting in overall portfolios containing approximately 50 to 60 funds.[17] We choose these portfolio sizes because 1) an accepted rule of thumb is that near-full diversification benefits are achieved with portfolio sizes between 15 and 20, 2) several of the funds highly ranked by the HFSM may either be closed to new investors or only available to offshore investors, 3) several of the funds may be duplicates, and 4) several of the strategies may not have 10 funds satisfying all the criteria. To avoid look-ahead bias, results through the period ending November 30 are used to select portfolios beginning on the following January 1, at which time the November results will already have been made available.[18]

HFSM portfolio returns and Sharpe ratios (using a 5% risk-free rate) for a 12-month holding period are compared in Exhibit 11 to those of three naïve portfolios and to a portfolio consisting of all hedge funds (the "ALL" portfolio). All three naïve portfolios use the eligibility criteria for assets under management and history. The first naïve model (Naïve1) selects the top 50 funds in the sample based on past returns, the second naïve model (Naïve2) selects the top seven funds in each strategy group based on past returns, and the third naïve model (Naïve3) selects the top seven funds in each strategy group based on past Sharpe ratios.

The forward-looking results presented in Exhibit 11 for the period 1996–2001 show that while there are years in which the Naïve1, Naïve2, and ALL portfolios generate higher returns than the HFSM portfolio, the HFSM portfolio generates higher Sharpe ratios than these three portfolios in every year, and it generates higher average returns than these three portfolios across the entire test period.[19] In fact, even the average hedge fund (the "ALL" portfolio) outperforms the Naïve1 and Naïve2 portfolios over the entire sample period. Moreover, there are two years in which the Naïve1 (2000 and 2001) and Naïve2 (1998 and 2001) portfolios generate negative returns, demonstrating that "chasing past returns" is a poor strategy.

We also observe that the Naïve1 and Naïve2 portfolios do well in periods where the average hedge fund performs well (e.g., 1996, 1997, 1999), but do poorly in periods where the average hedge fund performs poorly (e.g., 1998, 2000, 2001). In periods where the average hedge fund does well, it is reasonable to assume that strategies that performed well in the past will have continued to perform well, in which case funds that performed well in the past are more likely to have continued to perform well. However, in periods where the average hedge fund does poorly, it is reasonable to assume that strategies that performed well in the past did not maintain their performance, in which case funds that performed well in the past are less likely to have continued to do well. This is similar to the result reported earlier in Exhibit 9, that riskier funds generate higher returns in years in which the average hedge fund performs well, but generate lower returns in years when the average hedge fund does poorly.

A portfolio selected based on prior Sharpe ratios with strategy diversification provides reasonable performance, as demonstrated by the results for the Naïve3 portfolio.[20] However, the HFSM portfolio generates significantly higher Sharpe ratios than the Naïve3 portfolio in every year. This demonstrates the value of considering factors other than just past Sharpe ratios in constructing portfolios designed to generate high Sharpe ratios going forward, and suggests that quantitative methods can be employed to select superior hedge fund portfolios.

### The Risk-Return Profile in Hedge Fund Portfolios

The HFSM model is sufficiently robust to the point that it can be employed to select portfolios with varying levels of risk. By simultaneously increasing the minimum required return over the past 36 months and decreasing the minimum required Sharpe ratio over the same period, one can alter the risk-return profile of the selected portfolio. Using this approach, we compare the performance of hedge fund portfolios with different risk-return profiles.

If portfolios of riskier funds provide significantly greater diversification benefits, then these portfolios could possibly outperform portfolios of less risky funds, despite the earlier finding that on an individual fund basis, less risky funds tend to outperform more risky funds. Therefore, we also compare the diversification benefits from portfolios containing lower-risk funds to that from portfolios containing higher-risk funds, where the portfolio diversification benefit is calculated according to the ratio of the average risk of the portfolio's individual funds to the portfolio risk.

Exhibit 12 displays the forward-looking results for a variety of HFSM portfolios, and Exhibit 13 illustrates the relationship that can be achieved in the HFSM portfolios by trading off return against risk.[21] Comparing the performance of the various HFSM portfolios, there are two noteworthy results. First, while the general relation between hedge fund risk and return is not monotonic on an *individual* fund basis, *we are able to create a monotonically positive relationship between risk and expected returns on a portfolio basis, by carefully controlling for risk and prior performance (see Exhibit 13). This implies that hedge fund portfolio performance is predictable provided one adequately controls for risk.* Second, while we are able to increase portfolio returns by raising the required performance in prior periods, doing so lowers Sharpe ratios. The implication is that less risky HFSM portfolios offer better risk-return trade-offs than more risky HFSM portfolios and that less risky portfolios are more efficient than more risky portfolios at bearing risk. Hence, it would appear to be more efficient to externally leverage a lower-risk portfolio than it is to invest in a higher-risk portfolio. That is, it may be more efficient for an investor to bear risk *outside* of the underlying hedge fund investment rather than inside the hedge fund investment.[22]

With respect to the portfolio diversification benefits, results presented in Exhibit 12 show that, on average, the risk reduction benefits are slightly greater for the *more* risky portfolios.[23] Nevertheless, despite this finding, the more risky HFSM portfolios are still less efficient than the less risky portfolios, because the increased portfolio diversification benefits of the riskier funds are insufficient to compensate for their inefficiency at the individual fund level.

The diversification benefits are similar in most years at approximately 40%–50%, with calendar year 1998 being the exception, a year in which HFSM portfolios achieved lower diversification benefits. One explanation is that during crisis periods, strategies heretofore considered to be only weakly correlated tend to behave similarly.[24] In particular, the demise of the Long Term Capital hedge fund in 1998 negatively affected many different strategies, although at the time, they were generally assumed to be weakly correlated with one another.

## SUMMARY

Our basic findings are that a fund's risk is highly persistent and that, on average, less risky funds outperform more risky funds on a risk-adjusted basis. Accordingly, we develop a model that identifies hedge funds whose superior prior performance is likely based on an underlying investment skill rather than on risk-taking, and is therefore more likely to achieve persistently superior performance. Portfolios of such funds generate significantly higher risk-adjusted returns than portfolios containing all funds, portfolios of hedge funds selected solely on the basis of past returns, and portfolios constructed on the basis of past Sharpe ratios. In contrast, as prior studies have shown, simply chasing past returns is actually counterproductive, as it tends to capture funds whose performance is less persistent.

Our results provide two important implications for hedge fund investors. First, it may be more efficient for an investor to externally leverage an investment in less risky funds than to make an unlevered investment in more risky funds. Second, one should not consider riskier funds based on the returns they are expected to generate. The role of riskier funds in portfolios, if any, must be to diversify the risk of the portfolio's other funds, with which the riskier funds are negatively correlated. The rationale for these results is that the more risky funds, possibly taking excessive risk or being highly correlated to traditional markets, are not efficient at bearing risk. If the risk is strongly systematic, performance is unlikely to persist when the underlying markets revert. If the risk is unsystematic, higher risk does not automatically result in higher returns. It is the less risky funds, whose performance is based on some idiosyncratic investment skill, that bear risk more efficiently and whose returns are more likely to persist.

To the extent that, on average, hedge fund risk does not seem to be adequately compensated for with respect to higher returns, investors must inquire as to the source of risk they are assuming and the intended benefit from assuming the increased risk. If the risk is systematically related to some underlying market, then it might be more advantageous for investors to be directly invested in that market. If the role of the riskier funds is to generate higher returns and thus higher Sharpe ratios, our results suggest that in general such an objective will not be realized. If the role of riskier funds in portfolios is to improve Sharpe ratios by diversifying away the risk of the portfolio's other funds, then such benefits should be rigorously justified.

## ENDNOTES

[1]An exception to this conclusion is Edwards and Caglayan [2001a], who find that hedge funds' alphas are mildly persistent. However, their alphas are measured using a multi-factor model that does *not* measure alpha relative to an index of funds in the same strategy group.

[2]One limitation of this database, as well as many hedge fund databases, is the inadvertent duplication of hedge funds. While the funds in our database are all technically distinct, some of them are onshore-offshore variants offered by the same fund manager, employing the same strategy in both funds. In other instances, a fund becomes closed to new investors, while a new fund is established by the same fund manager also employing the same strategy. However, the database will treat the two funds as being distinct.

[3]Where data on assets under management is incomplete, we utilize an interpolation algorithm to estimate assets under management for dates on which the data is missing.

[4]Because strategy designations in Hedgefund.net and Altvest differ, we first had to standardize the strategy designations.

[5]In support of this, Edwards and Caglayan [2000b] find that in down markets for equities, commodity funds outperform other hedge funds, and the correlation between commodity funds and equity markets actually declines (becomes more negative). In contrast, the correlation between other hedge funds and equity markets tends to increase during down markets for equities.

[6]Note that because Panels A and C provide the correlations for returns *within strategy*, the results in those two panels are equivalent to what would be obtained if we calculated the Rank ICs for *alpha* rather than returns, where alpha is calculated as the fund's return minus the strategy's average return. While we could normalize the alpha by scaling it by its risk (e.g., the appraisal ratio in Agarwal and Naik [2000]), and that might possibly alter the within-strategy ranks computed using simple alphas, results in Agarwal and Naik suggest that the persistences of alpha and normalized alpha do not significantly differ.

[7]The finding that a fund's correlation with equity markets is strongly correlated over time occurs despite two strong arguments that the simple correlation we compute between a fund's return and equity market returns may significantly under-

state the fund's "true" relation to equity markets. First, Asness, Krail, and Liew [2001] find that a fund's return in a given month is positively related to lagged returns in equity markets, possibly due to the fund's holdings of illiquid securities which may be repriced with a lag. Second, Fung and Hsieh [1997, 1999] find that many hedge fund investment strategies are best described as a form of option position on underlying markets, which is not well-captured by a simple linear relationship. In addition, funds' exposures to various markets are not constant over time (Brealey and Kaplanis [2001]), which should also weaken the time-series correlation of a fund's correlation with equity markets. Our explanation for the strong results on the time-series correlation of a fund's correlation with equity markets is that 1) whatever the error in the measurement of the relation between the fund's return and equity markets, the error may be stable over time, and 2) our rank correlation tests simply require that the *ranking* of the correlations between funds' returns and equity market returns persist over time.

[8]We base the regression model on the ranks of the correlations and the standard deviations because the correlations understate the relation between the fund's returns and the various indices, and because of the possible nonstationarity of a fund's exposures over time (see endnote 4). The variables are reranked annually within strategy. We use a fund's *absolute* correlation with the various indices as explanatory variables for risk because positive and negative correlations with these indices contribute equally to risk.

[9]We use the 40th percentile criterion because in the earlier years of our sample, $50M in assets under management was a reasonably large amount. Results are similar whether the size percentiles are calculated within-strategy or across the entire population.

[10]The latter two results occur despite the fact that futures trading funds are presumed to invest in very liquid contracts with readily available market prices and little room for subjective pricing.

[11]The relation between a fund's redemption policy and volatility is not clear. On the one hand, less volatile funds may be more likely to offer more frequent redemptions because they are less likely to experience temporary setbacks that might trigger excessive redemptions. On the other hand, more volatile funds, which are highly correlated to underlying markets, may offer more frequent redemptions because their positions may be highly liquid and those funds may be better able to handle redemptions.

[12]However, we note that the results suggest that in certain circumstances, focusing on funds offering frequent liquidity may increase volatility. For example, if one were to allocate funds to more risky strategy groups such as futures trading or long-short equity, and emphasize funds offering monthly liquidity in an attempt to better manage risk, that might have the unintended consequence of actually increasing risk, because it directs investments to the riskier funds.

[13]Leverage would be efficient if the increase in risk and return were proportional, less the cost of additional borrowing. Among the reasons why risky funds may be inefficiently leveraged are 1) incentive fees are proportionally greater if based on a hurdle rate, 2) additional positions established using greater leverage may be lower probability positions, and 3) the use of greater leverage requires modification to trading strategies with respect to stop-losses, position sizes, diversification, etc.

[14]With equities, it is well-known that the efficient frontier is concave, so that the marginal increase in return from an increase in risk is a decreasing function of risk. What is interesting here with hedge funds is that the marginal increase in return appears so "small" and is, in some cases, virtually zero.

[15]Sortino, Calmar, and Sterling ratios provide alternative measures of risk-adjusted returns. They basically divide returns by downside deviation, maximum drawdown, and average maximum drawdown, respectively.

[16]Although earlier results show that the performance of funds with limited experience is greater than for funds with three or more years of experience, the greater the experience the more persistent the fund's performance.

[17]If the portfolio simply took the funds with the lowest risk in the entire universe, the lower-risk HFSM portfolios would be heavily skewed towards the relative value strategy group. Tilting towards relative value would actually slightly improve the lower-risk HFSM portfolio results in many years but it would adversely impact results for 1998, when relative value strategies performed poorly.

[18]The rationale for this treatment is that hedge fund results for a given month are often not available until the middle of the following month.

[19]Although the portfolio returns for 1995 are similar to those for other years, we do not report them because there are far fewer eligible funds per strategy group in 1995 than in subsequent years.

[20]Recall that IC results presented in Exhibit 2 show that Sharpe ratios are not persistent. However, this refers to the entire distribution of Sharpe ratios; if one were to rank a set of funds by Sharpe ratios in two successive periods, the ranks would be uncorrelated. However, at the extreme tail, where Sharpe ratios are high, the Sharpe ratios do persist. Our explanation is that at the extreme tail, high Sharpe ratios are driven by low volatility, which does persist. However, in the remainder of the distribution, Sharpe ratios are equally driven by returns, which do not persist.

[21]Portfolio results assume equal weights for each fund with monthly rebalancing of the fund weights, even though some funds only accept new investments on a quarterly basis. The rationale for the monthly rebalancing is that without it, a given month's portfolio returns will be based on the individual funds' performance from the start date through the beginning of that month. This dependence increases computational complexity and makes it difficult to compare results for different

longer holding periods. However, we note that the results are substantially unchanged if the results are calculated assuming no rebalancing. We also note that we merely rebalance the weights on the funds selected at the beginning of the year; we do not replace or add any funds in the rebalancing process.

[22]A contrary argument is that the amount at risk is greater with external leverage than with internal leverage. For example, with 3-1 internal leverage for an investment of $1, the maximum possible investment loss to investors is $1, while with external leverage the maximum possible investment loss is $3 plus the cost of borrowing on the $2 of external leverage. This distinction may be critical in the eventuality that the underlying investments perform extremely poorly.

[23]We note that if HFSM portfolios simply took the funds with the lowest risk in the entire universe, and did not explicitly diversify across strategy groups, the average portfolio risk reduction would be slightly lower.

[24]As evidence, Schneeweis and Martin [2001] find that hedge fund strategies are more highly correlated with one another during periods of poor performance for stocks and bonds than in other periods.

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