UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

An Empirical Evaluation of the Return and Risk Neutrality of Market Neutral Hedge Funds

Bachelor Thesis in Finance

Gothenburg University – School of Business, Economics, and Law

Institution: Centre for Finance

Supervisor: Marcin Zamojski

Ludwig Skogman and Sebastian Zettergren

Gothenburg, Sweden

Spring 2017

Acknowledgments

We would like to thank our supervisor, Marcin Zamojski, for his invaluable advice and the considerable amount of time he spent to guide us in the right direction. Also, we would like to thank our dear friend and mentor, Stefan Padjen, for always motivating us to keep striving for excellence, especially in times when we needed it the most. Last, but not least, we would like to thank our families for their support.

Abstract

Market neutral is a widely-used investment style for hedge funds. By analysing a data set consisting of 7913 hedge funds, we assess their historical ability to stay neutral towards the U.S. equity market in terms of return and return volatility. The chosen hedge fund strategies either claims to invest in a market neutral style, or have the ability to do so. During times of both normal and abnormal market volatility, we find significant evidence against market neutrality in terms of returns and/or return volatility for all the chosen strategies.

Keywords: Hedge Funds, Hedging, Market Neutrality, GARCH, Financial instability

JEL-Codes: G11, G17, G23

I. Introduction

In times where traditional investments generate poor returns, hedge funds may become an interesting option for any investor who would like to diversify their portfolio. Asness, Krail, and Liew (2001) explain that, by being able to take both long and short positions, hedge fund managers can offer an investment vehicle which does not only generate attractive returns, but also offer a low to zero correlation to the asset class in which the manager trades.

Market neutral hedge funds seek to generate returns independently of the market environment, and they should therefore not be state-dependent, both in terms of return and return volatility. In this paper, we test if the term market neutrality is used in an imprudent manner. Therefore, we study these two relationships and examine if hedge fund managers are successful in converting increased market volatility into higher returns.

The SEC (2012) states that a hedge fund is an investment vehicle that gathers investment capital from investors - typically institutional investors and wealthy individuals - with the aim to generate positive returns. Furthermore, the SEC (2012) states that hedge funds typically use more flexible strategies than mutual funds, including, but not limited to, high levels of short-selling, leverage, and other speculative investment practices. However, Vaughan (2003) states that there are multiple views on how to define hedge funds.

In a mean-variance environment, weak, as well as negative, correlations with the market allow for the diversification of market risk. The need of hedging such risk could, to some extent, explain the increasing popularity of hedge funds among both investors and in the academia. Barclay Hedge (2017) estimates that assets under management within hedge funds is currently over 3 trillion USD worldwide. Further, Agarwal, Mullally, and Naik (2015) note that from 2005 to 2015, the number of papers published regarding the hedge fund industry, in top-tier finance journals, increased more than six-fold compared to the number of papers published before 2005.

However, the industry was heavily criticized by both regulators and investors during the financial crisis of 2007 to 2009 when several hedge funds filed for bankruptcy. As Watts (2017) reports, 2008 was the year when the largest number of hedge funds closed ever, and 2009 is third on that list. In the aftermath of these events, the question regarding whether hedge funds are capable of offering a low to zero correlation to the market arose. Given that the increasing amount of AUM within hedge funds is at least partly determined by the need to hedge risks, it would be in every investor’s interest to determine if they can do so.

Earlier empirical research has been inconclusive to the success of market neutrality. Asness, Krail and Liew (2001); and Brooks and Kat (2002) examine the correlation between hedge fund returns and different equity market indices. For all hedge fund strategies, they both find high positive correlations with the stock market, except for the managed futures, convertible arbitrage, and equity market neutral strategies. Further, Mitchell and Pulvino (2001); and Agarwal and Naik (2004) find strong correlations between the returns of the merger arbitrage strategy, and the ones of the market.

Patton (2008) tests hedge fund strategies for five types of market neutrality. He defines the first type of market neutrality as "correlation neutrality", where he analyses the relationship between market neutral hedge funds and the market by first using Pearson correlation, and then a bootstrap method. His results imply that there is significant evidence against correlation neutrality for the sample of market neutral hedge funds. In our paper, we find similar results.

Secondly, Patton also test the funds for "variance neutrality", which, if fulfilled, implies that the hedge fund risk does not co-move with the market risk. According to Patton, this means that we do not expect the hedge fund risk to increase simultaneously as the market risk. To test for variance neutrality, Patton approximates the conditional variance of the market by a Taylor series where the conditional variance was designed to control for the ARCH effect, as described by Engle (1982). However, he finds no violation of variance neutrality, implying that market risk cannot be used to predict hedge fund risk. Our findings are the exact opposite.

Further, other research fails to find any significant and/or strong correlation between hedge funds and the market. For example, Kat and Lu (2002), find that US equity and bond markets can only explain 10 to 20% of the variation in hedge fund returns. They also conclude that the correlation of hedge fund returns towards the bond market is almost non-existent. These results are consistent with the ones of Capocci (2005) who tests market neutral hedge fund returns for market neutrality with the CAPM model, as introduced by Sharpe (1964). Capocci finds that, even though the obtained betas are significantly positive, market returns can only explain a moderate part of hedge fund returns. Wright (2002) shows similar results as he states that equity market neutral hedge funds have low correlation to both the S&P500 and the Russell 3000 Index.

The purpose of this paper is to examine market neutral hedge fund returns, and return volatilities, over time and shed light on whether they are truly market neutral. We test for return neutrality by running regressions on market neutral hedge fund returns by using the seven factor model introduced by Fung and Hsieh (2004).

To test for risk neutrality, we estimate the conditional variance of the returns of the hedge funds and the market portfolio using the GARCH(1,1) model of Engle (1982) and Bollerslev (1986). We then examine the relationship between the return volatilities, using an OLS-regression.

We also examine how market volatility affects the hedge fund returns. We evaluate the idea, introduced by Wrampelmeyer (2012), that market neutral hedge funds should be able to generate returns from increasing market volatility. This idea is tested by running a regression of the index returns on market volatility.

Finally, we examine how the second and third issue is affected by periods of financial instability. This is of interest since periods of financial instability is when a hedge towards market risk should have the highest demand.

We analyse the results from these four sections to draw conclusions to whether market neutral hedge funds are market neutral. Therefore, the hypothesis we seek to reject is the following:

"Market neutral hedge funds are market neutral in the sense that their returns, and their return volatility, is not affected by the market."

In line with the results of Kat and Lu (2002); Füss, Kaiser, and Adams (2007); and Kat and Brooks (2002) we do not expect the returns of the equity market neutral, fixed income arbitrage and convertible arbitrage strategies to exhibit a significant relationship towards the returns of the market portfolio. However, based on the argumentation of Wrampelmeyer (2012), we expect the variance of these three strategies to exhibit a positive relationship towards market risk. Consistent with Füss, Kaiser, and Adams (2007); and Kat and Brooks (2002), we expect to find a significant relationship between both the returns and the risk of the long/short equity hedge, event-driven, fund of funds, and multi strategy funds, with the return and risk of the market portfolio.

In line with the argumentation of Wrampelmeyer (2012), we expect the returns of the equity market neutral, convertible arbitrage, and fixed income arbitrage strategies to show a significant positive relationship with market risk. By extending on his argumentation, we should also find a significant relationship between hedge fund returns and market volatility for the long/short equity hedge funds. This, since long/short equity hedge funds follow a similar trading strategy as equity market neutral funds. Lastly, we expect the same relationship to hold

for event-driven funds. Such funds profit from corporate take-overs and distressed securities, which should be more common during volatile market times.

Since no previous empirical research has examined the risk neutrality of market neutral hedge funds during times of financial instability, our expected results for the fourth and fifth test follow the same reasoning as in the second and third test.

Our results show that the returns of all the examined hedge fund strategies exhibit a positive, significant relationship towards the market portfolio returns. This is in line with Patton (2008), Asness, Krail and Liew (2001) and Brooks and Kat (2002). Also, in line with the idea of Fuss, Kaiser and Adams (2007), we find that the three arbitrage strategies exhibit a lower coefficient towards the market in comparison to the other four strategies. Most of the fund strategies also display a similar relationship towards the size premium factor.

Further, we find that all fund strategies, except for the long/short equity hedge strategy, violate risk neutrality towards the market. This is inconsistent with the results of Patton (2008). We argue that, since we conduct a like-for-like analysis of the volatility of both the hedge funds and the market, while Patton (2008) use both conditional and realized volatility in his method, the different results are not surprising. In line with the reasoning of Wrampelmeyer (2012), we find that the arbitrage styles have a higher coefficient towards market volatility compared to the other strategies. We conclude that market returns, and return volatility, affect the returns and return volatility for all the examined hedge fund strategies, except long/short equity hedge.

Apart from the convertible arbitrage strategy and multi-strategy, we fail to find any significant relationship between market volatility and hedge fund returns. We see similar results when accounting for financial instability. Therefore, we find no clear evidence that most of the strategies are able to generate returns from volatile market times, which is inconsistent with the idea of Wrampelmeyer (2012).

The remainder of this paper is structured as follows. In section 2, we describe the problem at hand. In section 3, we describe the methodology that we use to examine the problem. In section 4, we present our data and the delimitations of the study. In section 5, we present the results, and in section 6 we draw conclusions on these.

II. Problem Discussion

BarclayHedge (2017) describes that generating a positive return, while keeping a low to zero correlation to the market is difficult. Furthermore, Liang (1999); Ackermann, Enally and Ravenscraft (1999); and Agarwal & Naik (2000), show that the majority of equity market neutral hedge funds fail to generate a positive alpha.

However, the equity market neutral strategy is not the only strategy which aims to hedge market risk (e.g. being market neutral). Patton (2008) describes that funds implementing strategies such as long/short equity hedge, event-driven, or fund of funds also refer to themselves as being market neutral. Patton also explains that, as of 2008, market neutral was one of the fastest growing styles within hedge funds.

If the return distribution of a hedge fund depends on market returns and its return volatility, then could the manager of that hedge fund argue for being market neutral? Patton (2008) explains that the term neutrality can be hard to pin down since funds provide limited detail on how to measure market neutrality. The traditional measure of exposure to market risk is based on correlation or "beta" as introduced in Sharpe (1964); Lintner (1964); and Mossin (1966), and tested on hedge funds by Asness, Krail, and Liew (2001). However, Fung and Hsieh (2004) describes that assessing hedge fund returns require the use of more sophisticated methods, accounting for non-linear relationships between hedge fund and market returns.

To conclude the statements above, the term market neutrality has a wide, and sometimes unclear, definition. Therefore, there is a risk that the term might be used in an imprudent manner, which can mislead investors. The aim of this paper, is therefore to examine whether the term market neutral is used in such a way.

III. Methodology

A. Fung Hsieh Seven Factor Model

To evaluate the relationship between hedge fund and market returns, we use the Fung and Hsieh (2004) seven factor model:

$$(r_t^{hf} - r_{f,t}) = \beta_0 + \beta_1(S\&P500_t - r_{f,t}) + \beta_2 Size\_premium_t + \beta_3 10Y_t + \beta_4 CredSpr_t + \beta_5 BdOpt_t + \beta_6 FXOpt_t + \beta_7 ComOpt_t$$

where r^{hf} represents the monthly return for the hedge fund index. *S&P500* represents the Standard & Poor 500 return, and r_f represents the risk-free rate. *Size premium* represents the monthly return of the Russell 2000 index subtracted by the monthly return of the S&P500. *10Y* represents the end change in the U.S Federal Reserve 10-year constant maturity yield. *CredSpr* is the difference between Moody's BAA yield and the Federal Reserve's 10-year constant maturity yield. *BdOpt* represents the return of a portfolio of look back straddles on bond futures,

FXOpt is the return of a portfolio of look back straddles on currency futures and *ComOpt* represents the return of a portfolio of look back straddles on commodity futures. The notation ***t*** implies that the variable is measured at time *t.*

The Fung and Hsieh (2004) model allows us to identify the hedge funds exposure to common sources of market risk. Positive significant betas towards the two market factors, S&P500 and Size premium, implies that the returns of the hedge funds are affected by the returns of the market.

B. Conditional Variance

Before we estimate the volatility of both hedge fund and market returns, it is important to define the concept of conditional variance, and why we consider it to be useful in our empirical research. Conditional variance is the variance of a random variable, given the value of one or more variables. It can be defined as:

$$Var(Y|X) = E\left(\left(Y - E(Y|X)\right)^2 \middle| X\right)$$

Equation I *(Spanos; 1999)*

Where $E(Y|X)$ is the conditional expectation, and best prediction, of Y given is X. In the light of our research question, volatility can also be considered as a random variable, dependent on one or more variables as described by Engle (1982). Since the return volatility of any asset is not guaranteed to be constant, and is also not observable at any given time, the underlying volatility must be estimated. In the scope of our research, we consider the conditional variance to be a more adequate measure of volatility than realized return variance. Realized variance is preferable when dealing with daily or high-frequency data, while our data sample consists of monthly return data.

C. Generalized Autoregressive Heteroscedasticity (GARCH)

Engle (1982); and Bollerslev (1986) shows that the conditional volatility of asset returns can be conditioned on lagged values of itself, and squared errors of a factor model, which is also referred to as a mean equation. This estimation works in datasets that exhibit heteroscedasticity. To illustrate the conditional variance, let r_t denote the return of an asset at time *t.* Then:

$$r_t = \mu_t + \varepsilon_t$$

where $\mu_t = E(r_t|\Omega_{t-1})$ is the conditional expectation of r_t, given the past information Ω_{t-1}. The model error ε_t is defined as $\varepsilon_t = \sigma_t z_t$, where z_t is a standard normal innovation so that $z_t \sim NID\ (0,1)$. The GARCH(p,q) variance of the asset is then defined as:

$$\sigma_t^2 = \omega + \sum_{i=1}^{p} a_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-i}^2$$

Equation II *(Bollerslev; 1986)*

A GARCH(1,1) model specifies that *p* and *q* are constrained to one, implying that the variance of the asset is conditioned on one lagged value of itself, and one lagged value of the factor model error term. The factor model used as mean equation in our GARCH(1,1) estimation of hedge fund returns is the Fung Hsieh (2004). In our GARCH(1,1) estimation of market volatility, the factor model used is the return of S&P500 in the previous month.

D. Limitations to the GARCH model

Füss, Kaiser, and Adams (2007) explain that not only the magnitude, but also the sign of the innovation, influences return volatility. The relationship between returns and return volatility is assumed to have a negative sign, which implies that decreasing asset returns leads to an increasing volatility. These asymmetric (leverage) effects is not taken account for in the GARCH(p,q) model, and implies that the return volatility could be overestimated for funds which exhibit large skewness and leptokurtosis. Although various GARCH models, including TGARCH, EGARCH, and NGARCH, have been constructed to deal with such problems, it is beyond the scope of this paper to account for asymmetric probability distributions of returns.

Another complication with the use of Fung & Hsieh (2004) as mean equation in our GARCH model is that some of the variation in hedge fund returns attributed to S&P500 will already be accounted for. This will affect our outcome in the variance equation and, thus, might bias the results of our volatility correlation. The error term used to model volatility might be less correlated with S&P500 than if we use another mean equation. However, we want to capture as much of the variation in returns as possible, to circumvent other potential problems. Since the Fung & Hsieh model is a conventional model, used to explain hedge fund returns, we chose to use the Fung & Hsieh (2004) as mean equation in our GARCH model.

E. Hypothesis

We test our null-hypothesis, that market neutral hedge funds generate returns independently from the market portfolio, by investigating five different possible relationships between hedge funds and the market.

We first test for neutrality of returns by evaluating the coefficients on S&P500 and the size-premium in the Fung & Hsieh (2004). We then use the estimated volatility for the hedge funds and the market in an OLS regression to examine if the hedge funds violate variance neutrality. We then extend our analysis on variance neutrality and examine the relationship between hedge fund returns and market volatility, again by using OLS regression. Lastly, we test for variance neutrality and market volatility impact on hedge fund returns during times of financial instability by introducing a new variable that accounts for periods high market volatility.

IV. Data

A. Data and Variables

As a proxy for market returns, we use monthly excess returns on S&P500, which is retrieved from the Bloomberg database. The risk-free rate used in the excess return calculation is the U.S. Federal reserve 10-year bond return, de-annualized into monthly rates. For our Size-premium factor, we use the total monthly returns of S&P500 as a proxy for large cap and the Russel 2000 index as a proxy for the small cap. For the credit spread factor, we use Moodys Baa yield minus the U.S. Federal reserve 10-year maturity. Moody's Baa yield is retrieved from Bloomberg, while the 10-year maturity yield is retrieved from Federal Reserve's historical data download program (2017). The returns of the lookback straddle portfolios are all retrieved from David Hsieh's database (2017).

B. Delimitations

We have limited our research to include seven different hedge fund strategies. According to Patton (2008), market neutral hedge funds seek to exploit apparent arbitrage opportunities without having to generate exposure to market risk. Therefore, we have chosen to limit this paper to hedge fund strategies which incorporate such investment schemes. We also include fund of funds and multi strategy hedge funds, which also have the opportunity to invest in a market neutral style. We provide the chosen strategies and their respective definitions in appendix A.

Note that we sometimes refer to the three strategies; equity market neutral, fixed income arbitrage, and convertible arbitrage as a group. In line with figure 1, we then refer to them as arbitrage styles. We limit the observation period to 237 months, spanning from July 1994 to March 2014. In line with Fung & Hsieh (2000), we choose not to include data before 1994 due to the issues with selection bias (further described in Appendix B) that exists in hedge fund databases prior to 1994.

Figure I

Hedge Fund Styles and Strategies

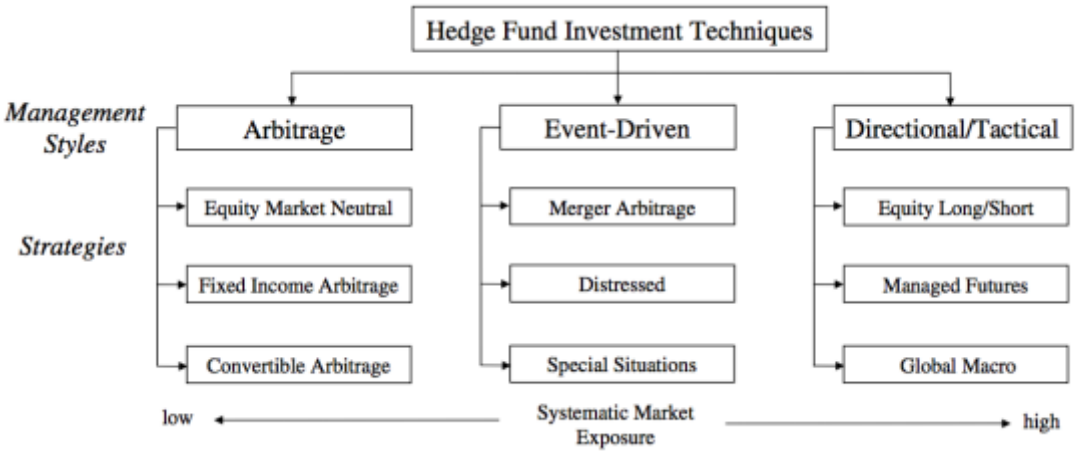


Figure 1 is retrieved from Füss, Kaiser, and Adams (2007). The figure depicts nine conventional hedge fund strategies, categorised by their respective investment style towards systematic market exposure. A quick look at the figure reveals that the arbitrage styles tend to have little/no market exposure, while event-driven and directional/tactical styles tend to be exposed to a higher degree of market risk. Multi strategy and Fund of Funds is not depicted in this figure since they have the option to invest according to multiple strategies.

C. Descriptive Statistics

Our strategy indices are constructed from a sample of 7913 hedge funds from the Lipper TASS Hedge Fund Database. We construct equally weighted indices of all the hedge funds per strategy. We choose to construct an equally weighted index, instead of a value weighted, to get statistics on how the average fund for each strategy performs, rather than a measure on how the strategy as a total performs.

In Table 1, we present summary statistics for the sample of hedge funds. We note that all strategies generate positive excess return on average, and that the average excess return span from 0.17% to 0.81% monthly. As would be expected from the results of Brooks and Kat

(2002), compared to equity markets, all hedge fund strategies exhibit a relatively low standard deviation in the light of their mean return.

Further, we examine the distribution of returns by testing for skewness and kurtosis in the return data. Bo doing so, it is possible to explain why the hedge funds can generate excess returns in parity with the market, without having an equally high standard deviation. Most the indices exhibit negative skewness lower than the market. Also, all hedge funds exhibit significant positive kurtosis in excess of the market. Thus, making large negative returns more likely than what would be under a normal distribution since the fat tail of the return distribution is located left of the mean.

The argument that hedge fund returns are not normally distributed is further supported by the Jarque and Bera (1980 test for normality. For all the listed strategies in Table 1, we can reject that returns are normally distributed.

Table 2 displays correlation factors between the hedge fund indices and the S&P500 index. As would be expected from the results of Brooks and Kat (2002), the fund of funds and the multi strategy funds exhibits a high correlation towards each other. This result is likely since both strategies engage in a wide variety of investment strategies, and should, on average, have highly correlated returns. Further, the event-driven strategy also displays a high correlation towards these two strategies. Brooks and Kat also explain that, event-driven strategies may have similar constituents, or constituents with similar time series of returns, as for fund of funds and multi strategy hedge funds. However, in contrast to their results, the convertible arbitrage strategy also exhibits a high correlation to fund of funds and multi strategy hedge fund indices.

For the long/short equity hedge, event-driven, funds of funds, and multi strategy indices, correlation towards the S&P500 is higher than 50%, which could mean that they are more exposed to systematic market risk than the other strategies. The equity market neutral strategy exhibits the lowest correlation to the other strategies as well as to the S&P500, and only the correlations towards the other arbitrage styles are statistically significant.

In figure 2, we plot the dynamic correlation between respective hedge fund index and the S&P500. An interesting remark is that some strategies exhibit a non-constant correlation towards the market over time. For example, the equity market neutral strategy decreases its correlation to the market during the early and late 2000's. This relationship also holds for the convertible arbitrage and event-driven strategy, however, to a smaller degree.

Table I

Return Properties of Hedge Fund Indices

Table 1 presents descriptive statistics for the observed hedge fund strategies. Mean monthly excess return, standard deviation, and minimum/maximum return are presented in percentage form. The Jarque-Bera normality test is asymptotically distributed as a central χ^2 with two degrees of freedom under the null hypothesis with 5% at critical value 5. 99. * = p < 0.05. ** = p < 0.01

	Mean Monthly Return	Monthly Standard Deviation	Skewness	Kurtosis	Jarque-Bera	Minimum Monthly Return	Maximum Monthly Return	No. Funds	Avg. Life Span (Months)
Equity Market Neutral	0.57	2.46	12.3696**	177.7991**	9.80**	-3.37	35.81	466	60
Long/Short Equity Hedge	0.81	2.70	0.0160	4.6128**	25.70**	-8.97	10.30	2698	68
Fixed Income Arbitrage	0.35	1.05	-2.6424**	18.2955**	2586.00**	-6.60	2.85	277	69
Convertible Arbitrage	0.34	2.04	-3.1926**	27.9411**	6545.00**	-16.58	6.96	241	70
Event-Driven	0.55	1.68	-1.4781**	8.2532**	358.80**	-8.15	5.28	654	72
Fund of Funds	0.17	1.59	-0.6378**	5.9204**	100.30**	-6.46	5.66	2834	74
Multi Strategy	0.40	1.41	-0.8634**	5.2558**	79.70**	-5.89	3.86	743	63
S&P500	0.34	4.40	-0.7067**	4.0683**	31.00**	-0.1726	10.57	-	-

Table II

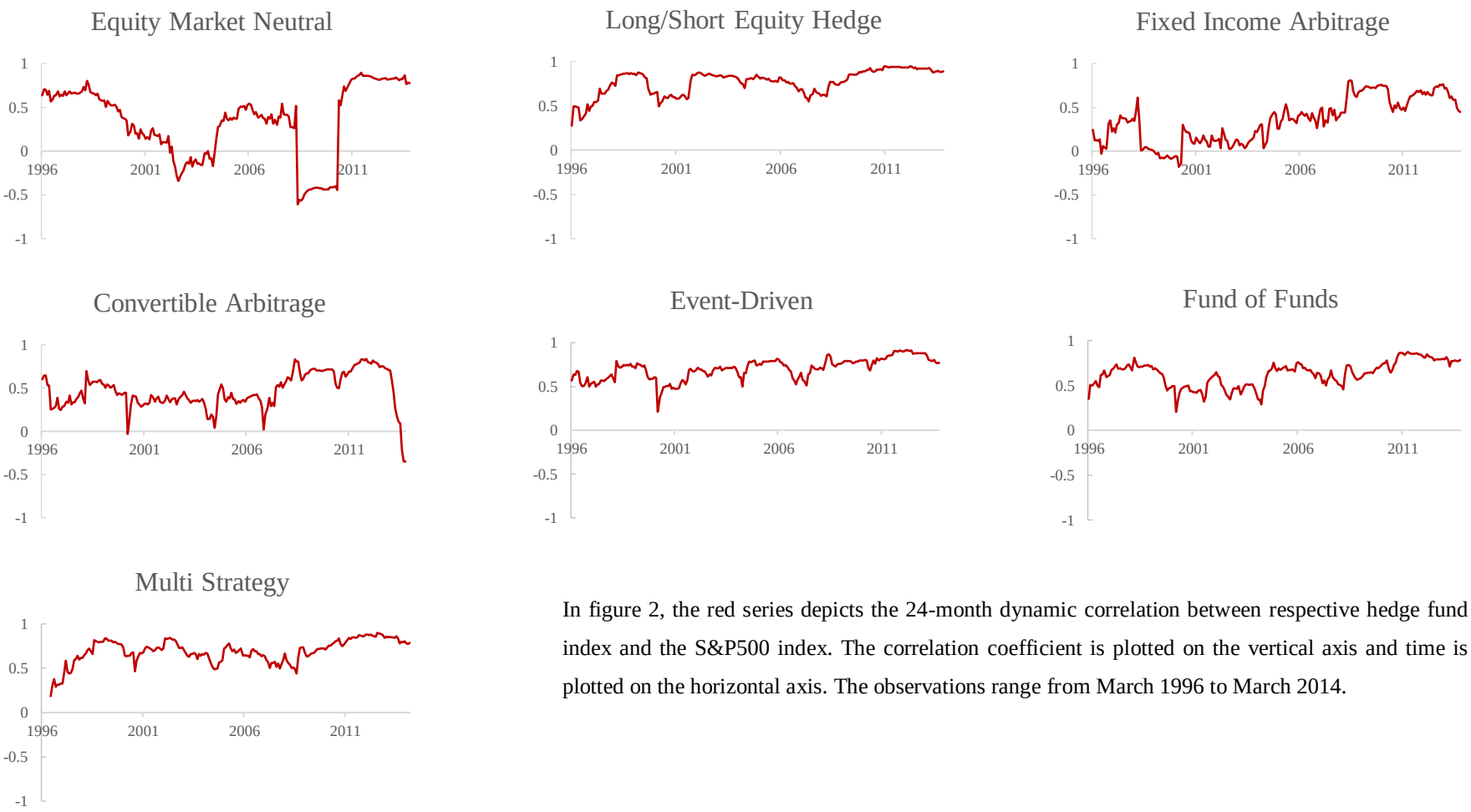
Hedge Fund Correlation of Returns

Table 2 displays correlation factors, and its respective significance level, for the average monthly return between hedge fund indices and the S&P500 index between July 1994 and March 2014. * = $p < 0.05$. ** = $p < 0.01$.

	Equity Market Neutral	Long /Short Equity Hedge	Fixed Income Arbitrage	Convertible Arbitrage	Event-Driven	Fund of Funds	Multi Strategy	S&P 500
Equity Market Neutral	**1.0000**							
Long/Short Equity Hedge	0.0143	**1.0000**						
Fixed Income Arbitrage	-0.2502**	0.4332**	**1.0000**					
Convertible Arbitrage	-0.3533**	0.5639**	0.7199**	**1.0000**				
Event-Driven	-0.0753	0.8078**	0.6022**	0.7259**	**1.0000**			
Fund of Funds	-0.0181	0.8405**	0.5368**	0.6253**	0.8309**	**1.0000**		
Multi Strategy	-0.0622	0.8106**	0.4951**	0.6685**	0.8181**	0.8671**	**1.0000**	
S&P 500	-0.0888	0.7352**	0.3536**	0.4740**	0.7055**	0.5901**	0.6439**	**1.0000**

Figure II

24-Month Dynamic Return Correlation



In figure 2, the red series depicts the 24-month dynamic correlation between respective hedge fund index and the S&P500 index. The correlation coefficient is plotted on the vertical axis and time is plotted on the horizontal axis. The observations range from March 1996 to March 2014.

V. Results

This section presents the results from the tests described in section three. All tests are executed in Stata. Thereafter, each test is assigned its own section, including a description of the corresponding results.

A. Neutrality of Returns

The test for market neutrality of returns is conducted using the Fung and Hsieh (2004) seven factor model. We test for significance of the two market factors: S&P500 and Size-premium.

Inconsistent with our expected results, the results from the initial regression show that all hedge fund strategies have a positive, significant coefficient towards the S&P500. Except for the fixed income arbitrage strategy, this also holds true for the size-premium factor. Previous literature has emphasized the difficulty in generating abnormal returns while staying neutral to the market, and we find support for this argument in our results.

Like the classification of exposure to market risk exposure made presented by Füss, Kaiser, and Adams (2007), long/short equity hedge, event-driven, fund of funds, and multi strategy all exhibit higher coefficients towards the S&P500 and a higher R^2 than the arbitrage strategies.

Due to the low R^2 and coefficients on S&P500 for the arbitrage styles, especially equity market neutral and fixed income arbitrage, it is perhaps a too strong statement to conclude that they fail to stay market neutral. However, we can still see that the S&P500 has some impact on their returns.

Long/short equity hedge exhibits the highest coefficient and R^2 of all strategies. Given that they generally have a long bias, this is not surprising. Event-driven also exhibits a high R^2 and a high coefficient towards the S&P500. We argue that this should be the fact, since the number of corporate events rise in bull-markets, and therefore event-driven funds should therefore have a larger possibility to generate returns during good market times. Fund of funds and multi strategy can invest in a variety of styles, and should on aggregate exhibit statistics that are similar to that of the average hedge fund. Therefore, it is not surprising that their coefficients and R^2 are lower that long/short equity hedge and event-driven, but higher than the rest of the strategies.

Table III

Regression of Indices on Seven Hedge Fund Risk Factors

Table 3 displays coefficients and z-scores (in brackets) from the initial regression where the excess returns of each hedge fund index are regressed on the seven risk factors introduced by Fung and Hsieh (2004). The equally weighted index returns are monthly averages from our hedge fund sample, consisting of 7913 individual hedge funds. * = p < 0.05. ** = p < 0.01.

Excess Return	Equity Market Neutral	Long/Short Equity Hedge	Fixed Income Arbitrage	Convertible Arbitrage	Event-Driven	Funds of Funds	Multi Strategy
SP500	0.0361**	0.3871**	0.0376**	0.1155**	0.2294**	0.1843**	0.1933**
	(5.89)	(38.88)	(4.52)	(12.35)	(18.97)	(11.17)	(13.72)
Size premium	0.0203**	0.2315**	0.0130	0.0694**	0.1597**	0.1290**	0.1076**
	(4.33)	(16.13)	(1.12)	(5.61)	(9.71)	(6.85)	(7.64)
10Y	0.0952	-0.2001	-0.7581**	0.5451**	0.3746*	-0.3331	-0.0656
	(1.08)	(-1.62)	(-7.80)	(3.48)	(2.05)	(-1.63)	(-0.35)
CredSpr	0.2605**	-0.1697**	-0.2456**	0.1384*	-0.2340**	-0.1333	-0.0486
	(5.61)	(-2.65)	(-5.33)	(2.01)	(-3.36)	(-1.65)	(-0.58)
BdOpt	-0.0039*	-0.0090**	-0.0093	-0.0112**	-0.0159**	-0.0086*	-0.0009
	(-2.36)	(-3.54)	(-5.51)	(-4.46)	(-4.22)	(-2.34)	(-0.29)
FXOpt	0.0147**	0.0115**	0.0003	-0.0010	0.0044	0.0122**	0.0016
	(10.91)	(6.16)	(0.15)	(-0.31)	(1.41)	(3.92)	(0.54)
ComOpt	0.0074**	-0.0017	-0.0054*	-0.0030	-0.0122**	0.0025	-0.0019
	(4.31)	(-0.60)	(-2.48)	(-0.90)	(-3.12)	(0.65)	(-0.5)
Intercept	-0.0023**	0.0067**	0.0088**	0.0018	0.0099**	0.0034	0.0038*
	(-1.92)	(4.05)	(8.09)	(1.01)	(5.61)	(1.93)	(2.04)
Adj. R^2	0.04	0.67	0.11	0.26	0.66	0.44	0.47
Observations	237	237	237	237	237	237	237

The model however, provides a lower R^2 than what would be expected from the results of Fung and Hsieh (2004). For the long/short equity hedge, event-driven, fund of funds, and multi strategy funds, we receive a fairly accurate description of how returns are generated, but for the other strategies we observe much lower a R^2 than what we expected. One explanation for this might be our longer time-period. Also, the industry, or at least certain strategies, might have evolved significantly since the introduction of the Fung & Hsieh (2004), and it might therefore be difficult to fit a linear regression during this time of progress. However, it should be noted that the Fung Hsieh (2004) model is not an asset pricing model, but a model used to detect styles. Therefore, a low R^2 does not necessarily harm the validity of the results.

B. Variance Equation

In Table 4, we present the GARCH(1,1) estimate of the variance equation, using the Fung and Hsieh (2004) as mean equation. As presented in Table 4, both the ARCH and GARCH parameters are significant for all the mentioned strategies. We find strong evidence for heteroscedasticity in our residual from the Fung & Hsieh (2004). Therefore, as shown by Engle (1982) and Bollerslev (1986), we can use the GARCH(1,1) to estimate the volatility of hedge fund returns.

Table IV

GARCH(1,1) Coefficients

Table 4 displays coefficients and z-statistics (in brackets) from the GARCH(1,1) model. * = p < 0.05. ** = p < 0.01.

σ^2_{HF}	Equity Market Neutral	Long/Short Equity Hedge	Fixed Income Arbitrage	Convertible Arbitrage	Event-Driven	Funds of Funds	Multi Strategy
ARCH L1	0.3493** (54.17)	0.3015** (10.68)	0.2100** (10.29)	0.2391** (10.88)	0.0630** (4.64)	0.1405** (5.14)	0.1340** (7.54)
GARCH L1	0.6507** (100.91)	0.6985** (24.76)	0.7900** (38.72)	0.7609** (34.63)	0.9370** (68.96)	0.8595** (31.46)	0.8660** (48.75)
Observations	237	237	237	237	237	237	237

C. Variance Neutrality

To examine the relationship of the conditional variance between the hedge funds and the market, we run an OLS regression on the conditional variance of the hedge funds by using the conditional variance of the market as the explanatory variable so that:

$$\sigma^2_{hfi,t} = \beta_0 + \beta_1 \sigma^2_{market,t} + u_t$$

Patton (2008) finds no evidence against risk neutrality. We find evidence that all strategies, except long/short equity hedge, fail to stay risk-neutral from the market. Although we only use one explanatory variable, the model exhibit an adjusted R^2 higher than 30% for four out of seven strategies. The difference between Patton (2008), and our results, might arise from our use of method. Since we use the same method to estimate the conditional variance for both the hedge funds and the market, while Patton use a method in which both conditional and realized variances is included, it is not surprising that we find a different result than Patton (2008).

Table V

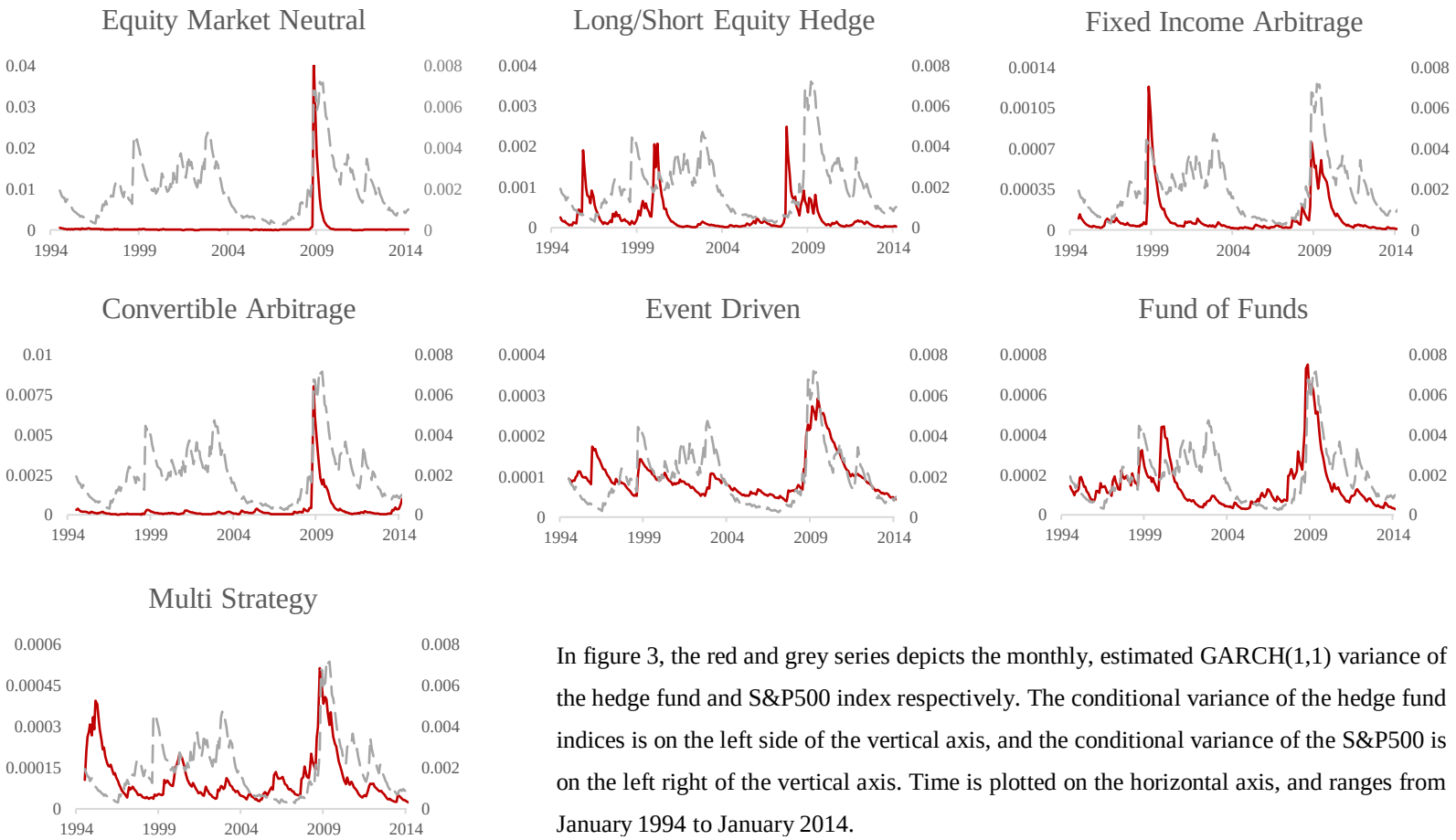
Regression of Conditional Variances

Table 5 displays coefficients and t-statistics (in brackets) from the regression where the estimated, conditional variance of each hedge fund index is regressed on the estimated, conditional variance of the S&P500. * = p < 0.05. ** = p < 0.01.

σ^2_{HF}	Equity Market Neutral	Long/Short Equity Hedge	Fixed Income Arbitrage	Convertible Arbitrage	Event-Driven	Funds of Funds	Multi Strategy
$\sigma^2_{S\&P500}$	1.1189** (7.85)	0.0088 (0.51)	0.0732** (12.46)	0.3449** (11.13)	0.0245** (14.52)	0.0540** (11.61)	0.0249** (6.5)
Intercept	-0.0016** (4.61)	0.0002** (5.80)	0.0000** (-3.13)	-0.0004** (-4.79)	0.0001** (12.21)	0.0000** (3.54)	0.0001** (6.37)
Adj. R^2	0.20	0.00	0.40	0.34	0.47	0.36	0.15
Observations	237	237	237	237	237	237	237

Figure III

Volatility Paths for Hedge Fund Indices and S&P500



In figure 3, the red and grey series depicts the monthly, estimated GARCH(1,1) variance of the hedge fund and S&P500 index respectively. The conditional variance of the hedge fund indices is on the left side of the vertical axis, and the conditional variance of the S&P500 is on the left right of the vertical axis. Time is plotted on the horizontal axis, and ranges from January 1994 to January 2014.

As presented in table 5, the three arbitrage styles display the highest coefficient towards the market, all significant. Therefore, we find evidence that hedge funds strategies, which aims to profit from statistical mispricing, should exhibit a volatility correlation with the market. This is in line with expected results, and the reasoning of Wrampelmeyer (2012). However, our results are contradictory with the results of Patton (2008) and the style classification, shown in figure 1, by Füss, Kaiser and Adams (2007), that implies that these three strategies should exhibit the lowest variance correlation with the market. The analysis of Füss, Kaiser and Adams (2007) however, is based on returns and not volatility, which might be one reason for the difference.

The most surprising result is that long/short equity hedge exhibits an adjusted R^2 lower than 1% and insignificant coefficient towards the S&P500. One explanation for this might be the use of Fung & Hsieh (2004) as mean model in our estimation of conditional variance. The returns of long/short equity hedge are, to a large extent, explained by the Fung & Hsieh (2004) model, especially the S&P500 factor. Therefore, the error terms used to estimate conditional variance are affected by this, and the true correlation between S&P500 volatility and volatility of long/short equity hedge hedge funds might already be incorporated in our first regression.

To summarize, we can conclude that six out of seven strategies fail to stay risk neutral.

D. The Effect of Volatility on Returns

In this section, we extend our analysis from the previous section to examine whether hedge fund returns are dependent on market volatility. We also control for the volatility of the hedge fund returns. We use the conditional variances estimated with the GARCH (1,1) model to run an OLS regression on the hedge fund returns. We use the conditional variance of the market and the hedge funds as the explanatory variable such that:

$$(r_t^{hf} - r_{f,t}) = \beta_0 + \beta_1 \sigma_{hf,t}^2 + \beta_2 \sigma_{market,t}^2 + u_t$$

In comparison to the conditional variance of hedge funds, hedge fund returns prove to be more difficult to model by using the conditional variance of the market. Only the strategies convertible arbitrage and multi strategy exhibit a significant beta towards the conditional variance of the S&P500, and all strategies display an adjusted R^2 lower than 10%. The conditional variance of the hedge funds, and the market alone, appear to be insufficient as explanatory variables for hedge fund returns.

Table VI

Regression of Returns on Conditional Variances

Table 6 displays coefficients and t-statistics (in brackets) from the regression where the excess returns of each hedge fund index are regressed on the estimated, conditional variance of the S&P500. We control for the estimated conditional variance of the hedge fund indices. * = p < 0.05. ** = p < 0.01.

Excess Return	Equity Market Neutral	Long/Short Equity Hedge	Fixed Income Arbitrage	Convertible Arbitrage	Event-Driven	Funds of Funds	Multi Strategy
$\sigma^2_{\text{Hedge fund}}$	-0.7563 (-1.49)	3.3657 (0.73)	7.0039 (1.35)	-6.2084** (-3.38)	41.1067 (1.41)	-22.4403* (-2.25)	-32.36** (-3.05)
$\sigma^2_{\text{S\&P500}}$	0.6202 (0.50)	0.4681 (0.38)	0.0181 (0.03)	5.4906** (5.09)	-0.6581 (-0.63)	0.6996 (0.78)	1.6526* (2.45)
Intercept	0.0050 (1.76)	0.0063* (1.97)	0.0028* (2.41)	-0.0054* (-2.41)	0.0028 (1.18)	0.0036* (2.00)	0.0042* (2.57)
Adj. R^2	0.00	0.00	0.00	0.09	0.00	0.02	0.04
Observations	237	237	237	237	237	237	237

As presented in Table 6, only the convertible arbitrage and the multi strategy funds exhibit a significant relationship between their returns and the market volatility. For the equity market neutral and fixed income arbitrage strategy, we see an adjusted R^2 lower than 1% and insignificant coefficients towards the conditional variance of the S&P500. Therefore, we fail to find evidence in support for both our expected result, and the reasoning of Wrampelmeyer (2012) that these funds should be able to profit from mispricing during volatile times. However, we find evidence that the convertible arbitrage funds manage to fulfil this reasoning with a significant, positive coefficient towards the market volatility. The convertible arbitrage strategy is therefore the only strategy of the three that shows evidence that they fulfil this expectation, to generate return from mispricing during volatile times.

One result worth noting is the extreme, and significant, coefficients for return on its own volatility for convertible arbitrage, fund of funds and multi strategy. Event-driven also exhibit an extreme, although insignificant, coefficient towards its own conditional variance. However, these coefficients are not that surprising, given the high R^2 in the mean equation used to estimate conditional variance. A large portion of the change in returns for these strategies will already be explained by the Fung & Hsieh (2004) model, and the error term used to estimate conditional

variance will be low relative to the change in return. Therefore, the extreme coefficients for these strategies arise from the low value of conditional variance, rather from an extreme impact of volatility on returns.

E. Variance Neutrality During Times of Financial Instability

To examine variance neutrality during times of financial instability, we introduce two new variables which are included in the last OLS regressions.

$$Financial\ Crisis = A\ dummy\ varible\ taking\ the\ value\ 1\ , if\ the\ observation\ is\ made\ during\ times\ of\ financial\ instability.$$

$$Financial\ Interaction = (Financial\ Crisis * \sigma^2_{market})$$

Where times of financial crisis are defined as July 1997 to October 1998; February 2000 to September 2002; March 2007 to December 2008; and March 2010 to February 2012, thus capturing the effect of the Asian financial contagion [Washington Post, (1999)], the dot-com bubble [Whitefoot, (2017)], the subprime crisis [BBC, (2009)], and the European sovereign debt crisis [BBC, (2012)].

The interaction term $Financial\ Interaction$ allows us to examine if the marginal effect of increasing market volatility is higher in times of financial instability, compared to normal market conditions We run a modified version of the previous variance neutrality regression so that:

$$\sigma^2_{hf,t} = \beta_0 + \beta_1 \sigma^2_{market,t} + \beta_2 Financial\ Crisis_t + \beta_3 Financial\ Interaction_t + u_t$$

We test for significance of the financial interaction term to see whether the relationship between hedge fund and market volatility is different during times of crisis.

Our results show that, during times of financial instability, variance neutrality differ between the examined hedge fund strategies. We find significant evidence that the correlation of volatility for equity market neutral, convertible arbitrage, and multi strategy funds and the market volatility is higher during times of crisis. Long/short equity hedge and fixed income arbitrage, display opposite results.

Adjusted R^2 for all strategies increase when we account for financial instability, and the interaction term is significant for five out of seven strategies. This implies that the volatility of these hedge funds can be further explained by market volatility in times of crisis, and that we can reject the idea that this relationship is not affected by times of crisis for all strategies except event-driven and fund of funds. These results are unfavourable for hedge fund investors, since times of financial instability are when a market neutral investment style should be demanded the most.

Table VII

Regression of Conditional Variances During Times of Financial Instability

Table 7 displays coefficients and t-statistics (in brackets) from the regression where the estimated, conditional variance of each hedge fund index is regressed on the estimated, conditional variance of the S&P500. We control for financial instability by adding the dummy variable *Financial Crisis*, and the interaction term *Interaction*.
* = p < 0.05. ** = p < 0.01.

σ^2_{HF}	Equity Market Neutral	Long/Short Equity Hedge	Fixed Income Arbitrage	Convertible Arbitrage	Event-Driven	Funds of Funds	Multi Strategy
$\sigma^2_{S\&P500}$	0.1111 (0.56)	0.0491 (1.85)	0.1133** (14.01)	-0.1802** (-4.07)	0.0311*' (12.61)	0.0574** (7.98)	0.0190** (3.27)
Financial Crisis	-0.0047** (-6.41)	0.0002* (2.12)	0.0000 (-0.31)	-0.0010** (-6.08)	0.0000 (-1.51)	0.0000 (0.02)	-0.0001** (-3.29)
Interaction	2.1118** (7.47)	-0.0881** (-2.33)	-0.0493** (-4.27)	0.3857** (6.10)	-0.0060 (-1.70)	-0.0044 (-0.43)	0.0200* (2.42)
Intercept	-0.000 (-0.09)	0.0002** (3.52)	-0.0001** (4.4400)	-0.0001 (-0.72)	0.0000** (10.35)	0.0000** (2.76)	0.0001** (6.97)
Adj. R^2	0.35	0.01	0.52	0.44	0.52	0.36	0.18
Observations	237	237	237	237	237	237	237

Equity market neutral is the only strategy that exhibit different results in term of its coefficient on the S&P500 volatility, which has lost its significance. This provide evidence that the risk of equity market neutral funds has a positive significant relationship towards market risk during times of crisis, but no such evidence is found during normal market times. Also, equity market neutral has an extreme coefficient towards market volatility. This result could

arise from managers holding deep out of the money put options, that they chose the exercise at the start of the crisis.

Convertible arbitrage and fixed income arbitrage exhibits opposite results. For the convertible arbitrage strategy, the financial interaction term is positive and significant, and the coefficient on S&P500 volatility switches sign from the previous regression. This provides evidence that during normal market times, convertible arbitrage volatility is negatively correlated with market volatility, but during times of crisis they fail to stay so. Fixed income arbitrage shows the opposite. They manage to weaken their risk relationship towards the market risk during times of crisis, but fail to keep that during normal market times. The long/short equity hedge strategy display a similar behaviour as fixed income arbitrage.

F. The Effect of Volatility on Returns during Times of Financial Instability

In this section, we use the dummy and interaction term introduced in the previous section. To examine whether there is an extra effect on hedge fund returns during times of instability, we run a modified version of the regression in section D, so that:

$$\left(\mathrm{r}_{\mathrm{t}}^{\mathrm{hf}} - r_{f,t}\right) = \beta_0 + \beta_1 \sigma_{hf,t}^2 + \beta_2 \sigma_{market,t}^2 + \beta_3 Financial\ Crisis_t + \beta_4 Financial\ Interaction_t + u_t$$

Only one strategy, convertible arbitrage, exhibit a significant beta towards the interaction term. We fail to find any evidence that the returns of the equity market neutral strategy would be correlated with the market volatility, even during times of financial instability. Interestingly, equity market neutral is the only strategy that does not provide a negative, significant coefficient towards the financial crisis dummy. Therefore, we find no evidence that these funds performed any worse during market instability, than during any other time-period. All other strategies show evidence of worse performance during these periods.

Convertible arbitrage is the only strategy that shows significantly different correlation with market volatility during times of crisis. This provides evidence against market neutrality, but the results are still favourable for the strategy since it proves they manage to generate returns from increasing market volatility. Convertible arbitrage is the only strategy that exhibit significant evidence for the argument that they use volatility to generate returns.

Table VIII

Regression of Returns on Conditional Variances During Times of Financial Instability

Table 5 displays coefficients and t-statistics (in brackets) from the regression where the excess returns of each hedge fund index are regressed on estimated, conditional variance of the S&P500. We control for the estimated conditional variance of the hedge funds themselves and for financial instability by adding the dummy variable *Financial Crisis*, and the interaction term *Interaction*. * = p < 0.05. ** = p < 0.01.

Excess Return	Equity Market Neutral	Long/Short Equity Hedge	Fixed Income Arbitrage	Convertible Arbitrage	Event-Driven	Funds of Funds	Multi Strategy
$\sigma^2_{\text{Hedge fund}}$	-0.8925 (-1.57)	4.5019 (1.02)	2.0796 (0.36)	-9.4752** (-5.12)	-12.3907 (-0.43)	-24.0076* (-2.52)	-42.4791** (-4.16)
$\sigma^2_{\text{S\&P500}}$	0.0523 (0.03)	2.0529 (1.14)	0.5979 (0.62)	5.6225** (4.34)	2.5163 (1.79)	1.6800 (1.42)	2.5989** (2.81)
Financial Crisis	-0.0032 (-0.47)	-0.0242** (-3.64)	-0.0064** (-2.45)	-0.0278** (-5.59)	-0.0156** (-3.88)	-0.0136** (-3.52)	-0.0142** (-4.17)
Interaction	1.49 (0.55)	2.2855 (0.89)	0.8670 (0.82)	6.2037** (3.23)	0.4056 (0.26)	1.2837 (0.86)	1.6487 (1.26)
Intercept	0.0058 (1.79)	0.0097** (2.80)	0.0037** (2.63)	-0.0004 (-0.18)	0.0073** (2.94)	0.0036** (2.83)	0.0072** (3.80)
Adj. R^2	-0.01	0.09	0.03	0.22	0.13	0.10	0.15
Observations	237	237	237	237	237	237	237

VI. Robustness Check

In this section, we test the robustness of our results from the previous section. The results can be seen in Appendix C. We use another proxy for hedge fund returns, namely the Credit Suisse Hedge Fund indices, instead of our own constructed indices. The only exception is for the fund of funds strategy, for which we use Hedge Funds Research Fund of Fund index, since Credit Suisse does not provide an index for this strategy. The main difference with our study is that Credit Suisse and Hedge Fund Research's indices are value weighted instead of equally weighted, which provides a different view on the market neutrality of the market neutral

strategies. We test the robustness of our results from all sections using this data. For return neutrality, we see similar results for most of the hedge fund strategies. Except for the fixed income arbitrage strategy, all strategies maintain a significant coefficient towards the S&P500. Since fixed income arbitrage is an arbitrage strategy, this is not surprising. Equity market neutral exhibit an insignificant coefficient on size premium, while all other strategies exhibit similar results as in section five. To summarize, we conclude that the results for return neutrality are highly similar when using a value-weighted index as a proxy for hedge fund returns.

For variance neutrality, all strategies show a significant, positive coefficient towards market volatility. This means that the only strategy that exhibits different results, compared with our results, is the long/short equity hedge strategy. We can conclude that our results seem to be robust.

In the section for variance impact on hedge funds returns, we find that all arbitrage strategies exhibit significant coefficients towards market volatility. Equity market neutral has a negative coefficient, while convertible arbitrage and fixed income arbitrage both have a positive coefficient. This implies that equity market neutral does the exact opposite of what their supposed to, while fixed income arbitrage and convertible arbitrage provide evidence that they fulfil their purpose of generating returns from market volatility. For all other strategies, we see similar results as in section five.

When accounting for financial instability, most of our results are similar. The major difference is the result for the arbitrage styles, which all three exhibit different results than in the results sections. Equity market neutral returns show a significant, negative coefficient towards the financial interaction term meaning that we provide evidence that equity market neutral hedge funds do the exact opposite of what is expected from them. Convertible arbitrage and fixed income returns show a significant positive coefficient towards market volatility, but fail to do so for the interaction term. This implies that they manage to generate returns from market volatility, and that the relationship does no significantly change during times of crisis. Also, event-driven hedge funds exhibit different results regarding both variance neutrality and volatility impact of returns. In the robustness check, managers of event-driven hedge funds manage to lower their risk correlation towards the market during times of crisis, and to generate returns from increasing market volatility. This is a favourable result for the event-driven funds, and is contrary to what we find in the results section.

To conclude, our results in the robustness check are highly similar for most strategies, with small differences in mostly the arbitrage styles.

VII. Conclusion

The term "market neutral" is used to describe hedge funds which implement trading strategies with the purpose to mitigate market risk. The popular belief is that such hedge funds can generate returns, regardless of the market environment. In this paper, we provide significant evidence against this belief. Not only do we find that all the examined hedge fund strategies exhibit positive return relation, but also a positive volatility relation to the S&P500, apart from the long/short equity hedge funds. However, for most of the strategies, we fail to find evidence that increased market volatility would lead to increased hedge fund returns. Only the convertible arbitrage and multi strategy funds prove to generate positive returns from increased market volatility.

During a financial crisis, i.e. when a hedge towards market risk should be demanded at most, most fund strategies still exhibit a positive risk relation toward the S&P500. However, we find significant evidence that the long/short equity hedge and fixed income arbitrage strategies manages to lower their risk exposure towards the market during these times. All other strategies either increase their risk relation or stay constant towards the S&P500 during times of financial instability.

Our study indicates that market neutral hedge funds are indeed exposed to market risk, and that most of these fund strategies fail to convert this exposure into positive returns. Therefore, we provide evidence that the term "market neutrality" is used in a non-prudent manner, and that the diversification benefits of these investments may not be as great as investors tend to believe. To mitigate this problem, investors must analyse the historical relationship to the market, and determine what sort of market neutrality that is desired.

It is hard to determine which strategy that best fulfils the aim of generating returns regardless of the market environment. However, the results in this paper implies that convertible arbitrage is the only strategy which efficiently converts increased market volatility into returns, both during normal and abnormal market conditions. Although the strategy exhibit a significant positive relationship towards both the return and returns volatility of the S&P500, it is of the outmost interest of an investor to generate returns during volatile times. The multi strategy funds are also successful in generating returns from increased market volatility. However, when accounting for periods of financial instability, we find no significant evidence that they manage to capitalise further on the additional volatility that is caused by the abnormal market conditions.

The results in this paper contributes to existing empirical research in several aspects. To start with, we analyse market neutral hedge funds and their risk and return relationship towards the market during a long period, including a wide aspect of market conditions. The results are up-to-date, whereas earlier empirical research have spanned from 1999 to 2008. Thus, we can include data from the financial crisis of 2007 to 2009, as well as the sovereign debt crisis of Europe in 2010. To our knowledge, this paper is also the first to conduct a like-for-like analysis of the variance neutrality of market neutral hedge funds.

However, the results leave unanswered questions. One interesting extension to this paper is to analyse the risk and return relationship on individual hedge funds, rather than indices. By doing so, it would be possible to understand if market neutrality is violated on a non-aggregate level. Another interesting extension to this paper would be to go further into the question on how the market neutral hedge funds perform during times of financial instability, and evaluate individual hedge funds in this aspect.

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IX. Appendix

A. Definitions of Hedge Fund Strategies

The following definitions are copied from Hedge Fund Research's "Hedge Fund Strategy Classifications" available on their website (see references).

Equity Market Neutral: Strategies employ sophisticated quantitative techniques of analyzing price data to ascertain information about future price movement and relationships between securities, select securities for purchase and sale. These can include both Factor-based and Statistical Arbitrage/Trading strategies. Factor-based investment strategies include strategies in which the investment thesis is predicated on the systematic analysis of common relationships between securities. Statistical Arbitrage/Trading strategies consist of strategies in which the investment thesis is predicated on exploiting pricing anomalies which may occur as a function of expected mean reversion inherent in security prices.

Convertible Arbitrage: Includes strategies in which the investment thesis is predicated on realization of a spread between related instruments in which one or multiple components of the spread is a convertible fixed income instrument. Strategies employ an investment process designed to isolate attractive opportunities between the price of a convertible security and the price of a non-convertible security, typically of the same issuer. Convertible arbitrage positions maintain characteristic sensitivities to credit quality the issuer, implied and realized volatility of the underlying instruments, levels of interest rates and the valuation of the issuer's equity, among other more general market and idiosyncratic sensitivities.

Event-Driven: Maintain positions in companies currently or prospectively involved in corporate transactions of a wide variety including but not limited to mergers, restructurings, financial distress, tender offers, shareholder buybacks, debt exchanges, security issuance or other capital structure adjustments. Security types can range from most senior in the capital structure to most junior or subordinated, and frequently involve additional derivative securities. Event-driven exposure includes a combination of sensitivities to equity markets, credit markets and idiosyncratic, company specific developments.

Fund of Funds: Invest with multiple managers through funds or managed accounts. The strategy designs a diversified portfolio of managers with the objective of significantly lowering the risk (volatility) of investing with an individual manager. The Fund of Funds manager has discretion in choosing which strategies to invest in for the portfolio. A manager may allocate funds to numerous managers within a single strategy, or with numerous managers in multiple strategies. The minimum investment in a Fund of Funds may be lower than an investment in an individual hedge fund or managed account. The investor has the advantage of diversification among managers and styles with significantly less capital than investing with separate managers.

The following definitions are copied from Credit Suisse's "AllHedge Indices" available on their website (see references).

Long/Short Equity Hedge: Typically invest in both long and short sides of equity markets, generally focusing on diversifying or hedging across particular sectors, regions or market capitalizations. Managers typically have the flexibility to shift from value to growth; small to medium to large capitalization stocks; and net long to net short. Managers can also trade equity futures and options as well as equity related securities and debt or build portfolios that are more concentrated than traditional long-only equity funds.

Fixed Income Arbitrage: Typically attempt to generate profits by exploiting inefficiencies and price anomalies between related fixed income securities. Fixed income arbitrage funds seek to limit volatility by hedging out exposure to the market and interest rate risk. Strategies may include leveraging long and short positions in similar fixed income securities that are related either mathematically or economically. The sector includes credit yield curve relative value trading involving interest rate swaps, government securities and futures; volatility trading involving options; and mortgage-backed securities arbitrage (the mortgage-backed market is primarily U.S.-based and over-the-counter).

Multi Strategy: Are characterized by their ability to allocate capital based on perceived opportunities among several hedge fund strategies. Through the diversification of capital, managers seek to deliver consistently positive returns regardless of the directional movement in equity, interest rate or currency markets. The added diversification benefits may reduce the risk profile and help to smooth returns, reduce volatility and decrease asset-class and single-strategy risks. Strategies adopted in a multi-strategy fund may include, but are not limited to, convertible bond arbitrage, long/short equity hedge, statistical arbitrage and merger arbitrage.

B. Problems/Biases in the dataset

As explained by Kidd (2013), all hedge fund indices bear the risk of being biased due to weighting, and construction methodologies. Therefore, we explain which possible biases that our hedge fund indices are subject to.

i. Self-selection Bias

Hedge funds, which are lightly regulated in terms of reporting standards, have a choice whether to report their returns or not. As explained by Fung and Hsieh (2004), hedge funds prefer to disclose their returns only when they are favourable to attract new investors. Thus, the return data might become skewed. The returns of the hedge funds that are publicly available might therefore not be a representative sample of all existing hedge funds.

ii. Smooth Pricing Bias

Hedge funds invest in a large variety of illiquid and OTC-traded securities. Therefore, the price movements of these instruments bear a risk of being smoothened out, since they are not traded at a daily frequency. Therefore, the realized volatility of these instruments might suffer from a downward bias, leading to a possible underestimation of the hedge funds true volatility.

iii. Implications of Fee Structure

Most hedge funds follow a fee structure which includes a fixed fee of 1-2%, and an incentive fee of up to 20%, given that a high-water mark is reached. Such a fee structure implies that, during times of high performance, the observed return volatility might be downward biased since the hedge fund returns are presented net of fees in our data set.

C. Outputs from Robustness Check

Outputs from the robustness check is provided in table 9 through 14 in the following pages.

Table IX

Robustness Check: Regression of Indices on Seven Hedge Fund Risk Factors

Table 9 displays coefficients and z-scores (in brackets) from the initial regression where the excess returns of each hedge fund index are regressed on the seven risk factors introduced by Fung and Hsieh (2004). * = p < 0.05. ** = p < 0.01.

Excess Return	Equity Market Neutral	Long/Short Equity Hedge	Fixed Income Arbitrage	Convertible Arbitrage	Event-Driven	Funds of Funds	Multi Strategy
SP500	0.2265**	0.4074**	0.0071	0.1134**	0.2327**	0.1975**	0.1095**
	(25,54)	(23,84)	(1,26)	(14,49)	(15,53)	(14,14)	(8,98)
SCLC	0.0121	0.2085**	0.0087	0.0647**	0.1357**	0.1247**	0.0564**
	(1,17)	(12,37)	(1,08)	(4,44)	(5,12)	(7.39)	(4,05)
10Y	-0.9904**	-0.2732	0.8329**	0.5077**	0.5755*	-0.2439	0.0338
	(-7,46)	(0,35)	(9,33)	(3,64)	(2,03)	(-1,32)	(0,17)
CredSpr	-1.1454**	-0.1265	0.1403**	-0.0178	-0.1020	-0.1143	0.1225
	(-25,87)	(-1,27)	(3,48)	(-0,26)	(-1,13)	(-1,64)	(1,58)
BdOpt	0.0139**	-0.0110*	-0.0022	-0.0020	-0.0290**	-0.0078*	-0.0124**
	(4,44)	(-2,43)	(-1,39)	(-0,95)	(-7,75)	(-2,47)	(-4,19)
FXOpt	-0.0079**	0.0078*	-0.0080**	-0.0001	0.0064	0.0109**	0.0064*
	(-3,77)	(2,12)	(-5,16)	(-0,04)	(1,67)	(1,67)	(2,46)
ComOpt	-0.0041	-0.0006	0.0115**	-0.0033	-0.0023	0.0012	-0.0030
	(-1,40)	(-0,16)	(7,90)	(-1,09)	(-0,42)	(0,36)	(-0,81)
Intercept	0.0233	0.0041	-0.0005	0.0045**	0.0052*	0.0026	0.0002
	(22,07)	1,88)	(-0,51)	(2,94)	(2,55)	(1.70)	(0,12)
R^2	0,12	0.59	0.03	0.17	0.54	0.46	0.18
Observations	237	237	237	237	237	237	237

Table X

Robustness Check: GARCH (1,1) Coefficients

Table 10 displays coefficients and z-statistics (in brackets) from the GARCH (1,1) model. * = p < 0.05. ** = p < 0.01.

σ^2_{HF}	Equity Market Neutral	Long/Short Equity Hedge	Fixed Income Arbitrage	Convertible Arbitrage	Event-Driven	Funds of Funds	Multi Strategy
ARCH L1	0.4551** (14,16)	0.2189** (5,97)	0.3211** (15,05)	0.2435** (11,29)	0.0757** (4,54)	0.1721** (6,57)	0.1664** (7,07)
GARCH L1	0.5449** (16,96)	0.7811** (21,28)	0.6789** (31,82)	0.7565** (35,09)	0.9243** (55,42)	0.8279** (31,60)	0.8336** (35,40)
Observations	237	237	237	237	237	237	237

Table XI

Robustness Check: Regression of Conditional Variances

Table 11 displays coefficients and t-statistics (in brackets) from the regression where the estimated, conditional variance of each hedge fund index is regressed on estimated, conditional variance of the S&P500. * = p < 0.05. ** = p < 0.01.

σ^2_{HF}	Equity Market Neutral	Long/Short Equity Hedge	Fixed Income Arbitrage	Convertible Arbitrage	Event-Driven	Funds of Funds	Multi Strategy
$\sigma^2_{S\&P500}$	1.3303** (7,02)	0.1056** (5,20)	0.3128** (9,97)	0.2982** (12,63)	0.0397** (16,51)	0.0674** (10,73)	0.1108** (12,81)
Intercept	-0.0018** (-3,97)	0.0001** (2,38)	-0.0004** (-4,80)	-0.0003** (-4,71)	0.0001** (11,86)	0.0000** (1,55)	0.0000** (-1,97)
Adj. R^2	0.17	0.10	0.30	0.40	0.54	0.33	0.41
Observations	237	237	237	237	237	237	237

Table XII

Robustness Check:
Regression of Returns on Conditional Variances

Table 12 displays coefficients and t-statistics (in brackets) from the regression where the excess returns of each hedge fund index are regressed on estimated, conditional variance of the S&P500. We control for the estimated conditional variance of the hedge funds themselves. * = p < 0.05. ** = p < 0.01.

Excess Return	Equity Market Neutral	Long/Short Equity Hedge	Fixed Income Arbitrage	Convertible Arbitrage	Event-Driven	Funds of Funds	Multi Strategy
$\sigma^2_{\text{Hedge fund}}$	0.3377 (0,77)	-4.8098 (-1,20)	-6.3230** (-4,41)	-8.6014** (-3,75)	-2.0060 (-0,09)	-13.8446 (-1,77)	-13.5988** (-2,78)
$\sigma^2_{\text{S\&P500}}$	-4.5485** (-4,55)	0.9972 (0,76)	2.4027** (2,93)	5.1964** (4,84)	-0.0109 (-0,01)	0.3495 (0,38)	1.6867* (2,00)
Intercept	0.0098** (3,03)	0.0044 (1,44)	-0.0020 (-1,15)	-0.0047* (-2,20)	0.0046 (1,87)	0.0026 (1,40)	0.0022 (1,37)
Adj. R^2	0,04	0.00	0.07	0.09	-0.01	0.01	0.04
Observations	237	237	237	237	237	237	237

Table XIII

Robustness Check:
Regression of Conditional Variances During Times of Financial Instability

Table 13 displays coefficients and t-statistics (in brackets) from the regression where the estimated, conditional variance of each hedge fund index is regressed on estimated, conditional variance of the S&P500. We control for financial instability by adding the dummy variable *Financial Crisis*, and the interaction term *Interaction*.
* = p < 0.05. ** = p < 0.01.

σ^2_{HF}	Equity Market Neutral	Long/Short Equity Hedge	Fixed Income Arbitrage	Convertible Arbitrage	Event-Driven	Funds of Funds	Multi Strategy
$\sigma^2_{\text{S\&P500}}$	0.1131 (0,38)	0.1692** (4,98)	0.1533** (3,04)	0.2137** (5,59)	0.0633** (17,87)	0.0859** (8,21)	0.1015** (7,31)
Financial Crisis	-0.0050** (--4,88)	0.0001 (0,93)	-0.0008** (-4,69)	-0.0006** (-4,53)	0.0000* (2,42)	0.0000 (-0,28)	-0.0002** (-4,67)

Interaction	2.2988** (5,67)	-0.0923* (-2,01)	0.3285** (4,83)	0.2038** (3,95)	-0.0323** (-6,76)	-0.0193 (-1,37)	0.0507** (2,70)
Intercept	0.0000 (-0,02)	0.0001 (0,85)	-0.0001 (-1,09)	-0.0001 (-1,43)	0.0000** (7,37)	0.0000 (0,65)	0.0000 (0,29)
Adj. R^2	0,27	0.11	0.35	0.45	0.65	0.34	0.18
Observations	237	237	237	237	237	237	237

Table XIV

Robustness Check: Regression of Conditional Variances During Times of Financial Instability

Table 14 displays coefficients and t-statistics (in brackets) from the regression where the excess returns of each hedge fund index are regressed on estimated, conditional variance of the S&P500. We control for the estimated conditional variance of the hedge funds themselves and for financial instability by adding the dummy variable *Financial Crisis*, and the interaction term *Interaction*. * = $p < 0.05$. ** = $p < 0.01$.

Excess Return	**Equity Market Neutral**	**Long/Short Equity Hedge**	**Fixed Income Arbitrage**	**Convertible Arbitrage**	**Event-Driven**	**Funds of Funds**	**Multi Strategy**
$\sigma^2_{\text{Hedge fund}}$	0.8440 (1,83)	-5.9648 (-1,51)	-6.8601** (-4,72)	-11.2724** (-5,00)	-40.1893 (-1,72)	-19.5822* (-2,58)	-19.9036** (-4,01)
$\sigma^2_{\text{S\&P500}}$	0.2057 (0,10)	3.4598 (1,61)	4.0747** (3,58)	6.4326** (4,60)	4.0022* (2,06)	2.4788 (1,81)	3.3140** (2,84)
Financial Crisis	0.0188* (2,49)	-0.0172* (-2,46)	-0.0102* (-2,56)	-0.0210** (-4,48)	-0.0150** (-3,43)	-0.0131** (-3,16)	-0.0118** (-3,13)
Interaction	-9.6218** (-3,16)	0.4237 (0,15)	0.1194 (0,08)	3.2877 (1,80)	-0.1523 (-0,08)	0.3592 (0,22)	1.0593 (0,74)
Intercept	0.0032 (0,84)	0.0062 (1,67)	-0.0014 (-0,68)	-0.0017 (-0,72)	0.0083** (3,29)	0.0039 (1,81)	0.0035 (1,83)
Adj. R^2	0,07	0.06	0.14	0.19	0.11	0.10	0.15
Observations	237	237	237	237	237	237	237