



Hedge Funds' performance during the recent financial crisis

Master Thesis

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CHAPTER 1: Introduction

1.1 Motivation

The main motive behind our decision to dedicate this master thesis research to the hedge funds' analysis is that their performance has merely been explored. Comparing to mutual funds and the other asset classes, very few studies have been conducted in order to examine hedge funds' returns. Also, another tempting reason behind our decision was the secrecy and the difficulty to obtain information about their activities.

Most studies on this field have attempted to examine hedge funds' performance by correcting only one of the effects that their returns appear while they ignore the other ones. Moreover, there is a very big lack of information for their behavior during the crisis period.

Our study is going to fill in the missing information of the existing literature by correcting simultaneously for most of the symptoms of hedge funds' returns such as biases, fat tails and autocorrelation. In this way, our results are going to be much more accurate and they will better represent the real attractiveness of each hedge fund strategy. This research is going to cover the last 10 years, namely the years 2002-2012 which means that the not sufficiently investigated crisis and post crisis periods are included. This will be one of the major contributions of this study to the existing knowledge on the field.

Referring to the expectations that we have before we start our analysis; is that it will be in line with the vast majority of the existing literature; which indicates that hedge funds outperform other assets like equities and bonds while they exhibit lower standard deviation. However, there are no reported results for the most recent years, namely the crisis and the post crisis era and this is something that we are going to investigate.

Based on the results that we will obtain from the aforementioned analysis, we will be able to answer the main question of our research. Hedge funds claim that they can hedge the risk and deliver excess returns even in crisis periods. For this reason, we are going to create Optimal Risky Portfolios according to the Markowitz framework so to check if the superior hedge funds performance over the other assets has a practical implementation by adding value and by contributing to a better portfolio diversification.

1.2 Introduction to the Thesis

In this study the attractiveness of hedge funds' returns comparing to other asset classes will be examined. The main scope of the thesis is to investigate how hedge funds' performance was affected by the recent financial crisis.

To do so, hedge fund returns need first to get unsmoothed and to be corrected for biases, fat tails and autocorrelation. Then, together with the returns of other asset classes like equities and bonds they will be compared to each other, during different time periods. The time range that we are going to examine is the years from 2002-2012. This period is going to be divided into 4 sub-periods. The main ones are the years from 2002-2006, which are regarded as a Bull Market and the years from 2007-2012 which in our research will be considered as the greater crisis period or a Bear Market. However, while more or less there is consensus about when the crisis started; there are many diverse opinions about when it ended. That's why we believe that it is crucial to split the period 2007-2012 into 2 sub-periods. Namely, the era 2007-2009 which represents the years that the crisis' effects are more intense and severe and the era 2010-2012 which are the years that global economy is trying to recover. With the help of various risk measures such as Sharpe ratio, Jensen's α , Modified Sharpe Ratio and Modified VaR, the returns of each period will be compared to each other.

In this way we will be able to decide whether or not hedge funds manage to remain an attractive investment even during the crisis. Finally their correlation with bonds and equities will be examined and Optimal Risky Portfolios, based on the Markowitz framework will be created. Then, we can check if the addition of hedge funds in an asset allocation can add value and contribute to the further diversification of a portfolio.

1.3 Main research question and sub-questions

The main research question that we try to answer with this study is how hedge funds' performance was affected by the recent financial crisis. This means that we are going to examine how the crisis affected their returns and to what extent comparing to equities and bonds.

The main hypothesis that we are based on is that hedge funds claim that even in crisis periods they can hedge the risk and deliver superior returns comparing to other asset classes. Our aim is to investigate if this statement holds true or not.

In this procedure, it will be very helpful to answer also the following sub-questions:

1. To what extent does the correction of hedge funds returns for autocorrelation, biases and fat tails affect their attractiveness?
2. How does hedge fund correlation with other asset classes change during the different financial situations?
3. How does hedge fund volatility change during the examined periods? Should their excess returns over the traditional asset classes be attributed to extreme volatility or not?

By answering the above questions we will have a clearer view about how each hedge fund investment style behaves when the financial situation is changing from a Bull to a Bear Market. Finally, we will be able to assess whether or not hedge funds remain an attractive investment after the correction of their returns.

1.4 Data collection

The collection of the data related to the hedge funds performance proved to be a daunting task. Hedge funds' world is shrouded in secrecy which means that in most of the cases they avoid to make public any data related to their performance and the investment strategy that they follow. This data is available only to accredited investors who are willing to pay a large amount of money in order to have access to the detailed records of every fund.

However, there are many suppliers, who provide summarized statistics related to the performance of hedge funds. For the purpose of our study, the data that will be used has been taken from the Dow Jones Credit Suisse Hedge fund database. The advantage of this database is that it classifies hedge funds in 13, generally accepted categories according to their investment style. Also, the returns are net of fees and expenses. As a result, we are not able to examine the performance of a fund individually but only the performance of the investment strategy that a hedge fund belongs to. In our investigation, we used the monthly total returns for each one of the 13 different funds categories. Monthly returns were preferred as they are considered much more accurate than the quarter or the annual ones. Equities and bonds will be represented in our study by 3 different indexes. Concerning equities, the first index that was chosen is the S&P 500, as it is considered the best representation of the US stock market. The world stock returns will be represented by the MSCI World index. This index is an appropriate one because it includes a wide collection of stocks from all the developed markets of the world while it excludes emerging and frontier markets.

Referring to bonds, the most widely used index for research purposes is the Barclays US Agg. Bond. This is a broad base index, often used to represent investment grade bonds which are

traded in the US. The total monthly returns for the above 3 indexes have been downloaded from the Datastream of Tilburg University.

1.5 Structure of the thesis

Our study is going to be divided in 6 chapters. More analytically, **chapter 1** is a summary of the motivation and the reasons why we conduct this research as well as a description about how our study has been set up. **Chapter 2** will serve as an introduction to the world of hedge funds. The main characteristics and individualities of the hedge fund industry will be discussed. Also, each one of the 13 investment strategies that will be used in this research will be presented. Finally, we will refer to the symptoms that hedge funds returns appear such as fat tails, autocorrelation and biases.

In **chapter 3** we will start with the analysis of other investigations done in the past concerning hedge fund performance. What we are going to examine is how other researchers conducted similar studies and how their results and methodology can help us in our investigation. Also, we will compare their results with ours so to check if they are identical or not. The truth is that hedge funds' performance during the recent financial crisis has not been examined sufficiently, so it is quite interesting what our results are going to be for this merely explored period. Then, it follows the research part of the thesis. The "corrected" hedge funds' returns will be compared with the returns of S&P 500, MSCI World and Barclays US Agg. Bond. This procedure will be repeated for all the 4 periods under examination. The attractiveness of hedge funds over other asset classes will be assessed with the help of various risk measures such as the Sharpe Ratio, the Jensen's α , the Modified Sharpe ratio and the Modified VaR.

After this analysis we will be able to answer questions such as:

Do hedge funds outperform equities and bonds in crisis periods even when their returns are corrected for fat tails, biases and autocorrelation?

In **chapter 4** will take place the second part of our research. We will run time series regressions by using STATA for all the 4 periods that we examine. For each period 14 different regressions will be conducted. Each one of them will have as independent variables the 3 indexes that we have already refer to and as dependent variable, each time a different hedge fund investment style. In this way, we will be able to elaborate on how each strategy is related to other asset classes during the different financial situations. Then, based on the regression results we will

create optimal risky portfolios according to the Markowitz framework so to check whether or not the different hedge funds investment styles add value and contribute to the further diversification of a portfolio. For the portfolio optimizations we will use the solver add-in of excel.

Finally, in **chapter 5** we are going to summarize the main findings of our research and to compare them with similar researches done in the past. These researches will be the ones that were already presented in chapter 3. Also, we will discuss what this study added in the existing knowledge on the field and we will make some recommendations for further investigation that needs to be done. **Chapter 6** is going to be the references.

Chapter 2: Hedge Funds' Universe

2.1 What a hedge fund is

A hedge fund constitutes an investment program whereby the manager or partners seek absolute returns by exploiting investment opportunities while protecting principal from potential losses. They are aggressively managed portfolios and they use unconventional investment strategies such as leveraged and long/short positions. The term hedge fund can be attributed to Alfred W. Jones. By using the term "hedge" Jones wanted to show that his investment strategy was aiming to reduce risk with respect to the direction of the market by pooling investments in a mix of long and short positions. Until 1970 hedge funds specialized in only one strategy, the Long/Short Equity. However, in our days, this is not the case. Investment styles such as Global Macro, Event Driven and Managed Futures are in the spotlight (Lhabitant 2004). Most of the times they are accessible to a limited number of accredited investors because of the big initial investment that is required in order somebody to participate in them. As they are not addressed to the general public, they used to be highly unregulated something that has changed after the recent financial crisis. The way that hedge funds performed during the crisis period raised criticism and regulations in order to increase monitoring on their activities were passed. On November 11th 2010, the European Parliament voted the Alternative Investment Fund Manager (AIFM) Directive. The AIFM Directive introduces requirements for financial intermediaries engaged in the management and administration of alternative investment funds within the EU. As alternative investments they are considered the hedge funds as well as the private equity and the real estate funds. First of all, the Directive imposes duties of care and loyalty to the AIF managers. Managers need to act honestly and in the best interest of the AIF that they manage. Also they have to ensure that all investors are treated equally. In the same time the Directive ensures that the risk profile of each AIF corresponds to its size, structure and investment strategies while it imposes disclosure requirements so to

enhance transparency. Hedge fund managers support that before some years 25 \$ million were enough in order to set up a hedge fund but now they are needed around 100 \$ million because of the compliance costs. Finally, the Directive requires third party valuation at least once per year and it empowers the commission and the national authorities to set leverage requirements so to ensure stability of the financial system (Awrey 2011). However there are views that are opposed to the strict regulation of hedge funds. According to Richard J. Herrings, finance professor at Wharton and co-director of the Wharton Financial Institutions Center, regulation is incompatible with the fundamental role of hedge funds. Hedge funds have been designed and should be left to operate by maximum flexibility.

Most hedge funds could be characterized as illiquid assets as they impose a lock up period, normally for a year, to their shareholders so to avoid short investing. They are operated by a manager who is getting paid a management fee and also a performance fee relative to the fund's returns. This person, most of the times, also holds a share in the fund.

In the recent years hedge funds have experienced a great expansion. As of 2013 their AUM were estimated at 2,4 \$ trillion. Some hedge funds with the greatest AUM are the Bridgewater Associates, Pimpcos and Paulson & Co. To conclude, if we should give a definition about what a hedge fund is, we believe that the most suitable among the proposed definitions is the following:

"Hedge funds are privately organized, loosely regulated and professionally managed pools of capital not widely available to the public."

2.2 Hedge fund Investment Strategies

While in the past hedge funds used to follow only the Long/Short Equity investment style, nowadays the strategies that they use are quite diversified. For the scope of this research the data that will be used is provided by the DJCS index. According to this index, hedge funds are divided into 10 individual, generally accepted, investment styles. Throughout all our research we will keep this classification. Actually the strategies are 13 because the Event Driven style is divided into 3 sub-categories. More analytically, the 13 strategies whose returns we are going to use in this study are the following: (most of the below definitions have been taken from the book of Lhabitant 2004 "Hedge Funds: Quantitative Insights")

Global Macro

Global Macro managers tend to make leveraged and opportunistic investments in currency, bonds, equities and commodities markets.

Their portfolios are quite large in size and they rely a lot on derivatives positions. Their main goal is the high returns while they have a more liberal attitude toward risk.

Managed futures

CTA's or Managed Futures managers trade mainly future contracts on behalf of their clients. Commodity futures were among the first derivatives that were used for hedging and speculative purposes. The Managed Futures strategy can be split up in 2 sub-strategies, the systematic and the discretionary. Systematic traders base their decisions on historical performance analysis while they focus a lot on the momentum factor. On the contrary, discretionary funds rely mostly on the manager's skills in order to achieve their goals.

Long/short Equity

Long/Short Equity managers invest in equities by taking long investment and short sales positions in order to be sufficiently hedged against risk, although this is not always the case. Many times, funds that follow this investment strategy tend to hold more long than short positions something that increases significantly their correlation with the traditional markets. As a result, these funds cannot be considered convenient for diversification purposes during turbulent periods.

Dedicated Short Bias is a sub-strategy of the Long/Short Equity style which uses only short positions. This investment style historically experiences great losses during bull markets and tries to recover in crisis periods.

Emerging Markets funds, as the name indicates, invest in various asset classes like equities, bonds and commodities in emerging markets around the world. Despite of the disadvantages that these markets may have, such as the unstable political and economic environment, they are regarded by many fund managers as great investment opportunities.

Event Driven

The *Event Driven* style focuses on debt or equity from companies when they are in a specific stage of their life cycle, such as merger and acquisitions, spin off or bankruptcy procedure. This style can be divided in the following categories:

Event Driven Distressed

These funds focus on the debt of companies which are in financial difficulties. The securities of such companies are traded at substantial discount which makes them an attractive investment opportunity. Managers undertake credit and liquidity risk with the hope that these securities will appreciate in value in the future.

Risk Arbitrage

This event driven sub-strategy invests in mergers and acquisitions when a leveraged buy-out or a hostile takeover takes place. The most typical trade in this style is to go long in the company that is being acquired and short in the acquirer.

Event Driven Multi-Strategy

Multi-Strategy managers use a combination of investment techniques of the event-driven strategy in order to take advantage of the market opportunities.

Arbitrage strategies

The *Convertible Arbitrage* strategy tries to take advantage of potential mispricing between convertible bonds and the underlying equities. A common investment is to go long to the convertible bond while going short to the underlying stock.

In the same time, the *Fixed Income Arbitrage* style incorporates a wide range of practices which try to exploit pricing anomalies in the global fixed income markets. Some typical strategies of this category are the yield curve arbitrage, corporate versus treasury yields spread, cash versus futures and mortgage-backed securities arbitrage.

The *Equity Market Neutral* style is a portfolio technique that seeks to exploit pricing inefficiencies between related equity securities while in the same time neutralizing exposure to market risk. A good example of this strategy is the "pair trading", which involves highly correlated stock pairs that have deviated from their historical pricing relationship. The main characteristic of this kind of funds is their low correlation with the traditional asset classes.

Multi-strategy funds

The funds that belong to this category instead of following only one investment style, implement a wide variety of strategies in order to adapt to the changing market conditions.

2.3 Common Issues with the Hedge fund data

Hedge funds' returns suffer from many different kinds of biases and autocorrelation while in the same time they appear negative skewness and excess kurtosis which means that they do not follow the normal Gaussian distribution.

For this reason, before we start our research, the returns of the different hedge fund strategies need to be corrected so as the conclusions that we are going to come up with, to be as more accurate as possible. Without the appropriate modifications, hedge funds will appear to be extremely attractive comparing to the traditional asset classes while they will exhibit much lower volatility than their real one.

2.3.1 Biases

It has been proved that hedge funds' data can suffer from various biases which can distort greatly the real picture concerning their returns. These biases stem either from the way that a hedge fund database is constructed or from the fact that many managers report the returns of their funds by themselves, which can create a kind of "window dressing". For the scope of this research, the returns that were used have not been corrected for any of the biases that will be mentioned below. The reason is that in order to calculate the level of a bias it is needed a much more detailed data than the one that we had in our disposition. However, it is important to refer to the main biases and to present the results of past researches done on this field.

Self selection bias

While mutual funds are obliged to disclose data about their performance, hedge funds because of their private character are not required to do so. As a result, it is normal that poorly performing funds have no reason to make public any data related to their performance. This situation can create a bias as the characteristics of the reporting funds may differ from the ones

of the non reporting ones. In the same time, there are also funds that perform really well but they do not wish to report their activities to a database. Most possibly, they already have available the assets that they need so there is no reason to regularly report to a third party. According to Fung-Hsieh (2000) the effect of the self selection bias cannot be easily quantified but overall its level can be considered as negligible comparing to other biases.

Database / sample selection bias

The selection of the database can also be a source of performance bias. The reason is that all databases are incomplete as they cover only funds that meet specific criteria. In order a hedge fund to be included in the DJCS database it needs to meet the following characteristics:

1. To have a minimum of one year track record
2. To have an audited financial statement
3. To have at least USD 50 mln in AUM
4. To meet the reporting requirements

Survivorship bias

Survivorship bias is possibly the most prominent among the biases that can be encountered in a hedge fund performance analysis. The existence of this kind of bias can be attributed to the fact that some funds are excluded from performance databases because they no longer exist. Most databases started collecting data only during the last 2 decades. Consequently, historical returns are conditioned by survival and may be overstated while historical risk may be understated. This happens because the data of the funds that disappear for performance reasons during these years has been dropped from the databases (Lhabitant 2004). A very interesting survival analysis was conducted by Gregoriou (2002). By examining the Zurich Capital Market database from 1990 to 2001, Gregoriou calculated that the median life of a hedge fund is 5,5 years and that the most long-lived funds tend to be large in size, with high returns and low leverage. In another research, Brooks and Kat (2001) stated that 30% of the newly established funds do not survive the first three years because of poor performance. The level of the survivorship bias varies depending on the database and the way that it is constructed. As a result, Fung-Hsieh (2000b, 2001b) estimate the annual survivorship bias of the Tass database at 3% while Ackerman (1999) states that for the HFR index it is only 0.16%.

The DJCS database that was used for the purpose of this research in order to minimize the survivorship bias, does not remove funds from the index until they are fully liquidated or fail to

meet the financial reporting requirements. For this reason, no adjustments in our data for survivorship bias will be done.

Backfill bias

Another important source of bias is the backfill one. It occurs when funds joining a given database are allowed to backfill their historical returns even though they were not part of the database in the previous years (Llabitant2004). The backfill bias is estimated to be around 1,4% annually according to Fung-Hsieh (2000b, 2001b). The DJCS database as well as other hedge fund databases, state that they do not allow data to be backfilled. As a result, we are not going to make any correction to our data for this kind of bias.

2.3.2 Autocorrelation

Except of the biases another important effect that we encounter during a hedge fund returns' analysis is that of the autocorrelation. Autocorrelation systematically leads standard deviation to be biased downwards, so an asset appears to be less volatile and more attractive than it really is.

In the below tables are presented the autocorrelation coefficients for the first 5 orders, as well as their statistical significance for each one of the 13 hedge fund investment strategies during all the periods that are examined. In order to measure the level of autocorrelation we used the corrgram command in STATA. Then, with the help of the Ljung-Box test we compared the Q statistic with the chi-square distribution so to decide upon the statistical significance of the coefficients. The appropriate number of lags was chosen based on the Schwert formula:

$$= [12 \times (\frac{t}{100})^{\frac{1}{4}}]$$

Tables 1-2: Autocorrelation function until lag 5 and Ljung-Box Q statistic at lag 11 for all the hedge funds strategies. The * reveals the statistical significance of the coefficients at the 10%, 5%, and 1% confidence levels.

| 2002-2006 | ACF(1) | ACF(2) | ACF(3) | ACF(4) | ACF(5) | LB-Q(11) |
|-----------------------------|---------------|---------------|---------------|---------------|---------------|-----------------|
| ALL HEDGE FUND INDEX | 0.2515** | -0.008 | -0.0627 | -0.0385 | -0.1864 | 12.09 |
| CONVERTIBLE ARBITRAGE | 0.4437*** | 0.1312*** | 0.0376*** | 0.0467*** | 0.0115** | 14.162 |
| DEDICATED SHORT BIAS | 0.2009 | 0.0744 | 0.0743 | -0.3263** | -0.0211 | 16.046 |
| EMERGING MARKETS | 0.1821 | 0.0373 | -0.0066 | -0.1616 | -0.1769 | 10.976 |
| EQUITY MARKET NEUTRAL | 0.1496 | 0.0057 | -0.0101 | -0.0200 | -0.1704 | 8.4863 |
| EVENT DRIVEN | 0.3632*** | 0.1686*** | 0.0042** | -0.0271** | -0.0444 | 14.306 |
| EVENT DRIVEN DISTRESSED | 0.3926*** | 0.2418*** | 0.1353*** | 0.023*** | -0.0023** | 21.559** |
| EVENT DRIVEN MULTI-STRATEGY | 0.2593** | 0.0996* | -0.113 | -0.1116 | -0.1059 | 10.55 |
| EVENT DRIVEN RISK-ARBITRAGE | 0.3534*** | 0.0764** | -0.0530** | -0.0779 | 0.0615 | 17.231* |
| FIXED INCOME ARBITRAGE | 0.3538*** | -0.2149*** | -0.1463*** | -0.0615** | -0.1227** | 23.957** |
| GLOBAL MACRO | 0.0364 | -0.2254 | 0.1614 | 0.1140 | -0.1207 | 14.865 |
| LONG/SHORT EQUITY | 0.2659** | 0.0359** | -0.05 | -0.1117 | -0.1605 | 10.845 |
| MANAGED FUTURES | 0.1753 | -0.0935 | -0.1695 | -0.1902 | -0.1784 | 14.202 |
| MULTI STRATEGY | 0.3302*** | 0.0016** | -0.1279** | -0.0963 | -0.1356 | 10.708 |

| 2007-2012 | ACF(1) | ACF(2) | ACF(3) | ACF(4) | ACF(5) | LB-Q(11) |
|-----------------------------|---------------|---------------|---------------|---------------|---------------|-----------------|
| ALL HEDGE FUND INDEX | 0.4068*** | 0.242*** | 0.1829*** | 0.0862*** | -0.0485*** | 27.188*** |
| CONVERTIBLE ARBITRAGE | 0.5506*** | 0.2547*** | 0.1584*** | 0.0473*** | -0.0079*** | 38.245*** |
| DEDICATED SHORT BIAS | 0.0204 | -0.1096 | 0.015 | 0.0813 | -0.0557 | 7.3909 |
| EMERGING MARKETS | 0.3391*** | 0.1669*** | 0.2151*** | 0.0808*** | -0.0679*** | 21.503*** |
| EQUITY MARKET NEUTRAL | 0.0254 | -0.0003 | 0.1408 | -0.0197 | -0.0593 | 3.4749 |
| EVENT DRIVEN | 0.3859*** | 0.2497*** | 0.2732*** | 0.0694*** | -0.0409*** | 27.309*** |
| EVENT DRIVEN DISTRESSED | 0.5367*** | 0.3416*** | 0.3381*** | 0.1354*** | -0.0296*** | 47.323*** |
| EVENT DRIVEN MULTI-STRATEGY | 0.3006*** | 0.2073*** | 0.2314*** | 0.0369*** | -0.0326** | 18.333* |
| EVENT DRIVEN RISK-ARBITRAGE | 0.3029*** | 0.0078** | -0.0169* | -0.0617 | -0.0211 | 13.613 |
| FIXED INCOME ARBITRAGE | 0.5796*** | 0.2636*** | 0.1564*** | 0.0703*** | -0.07*** | 38.579*** |
| GLOBAL MACRO | 0.2128* | 0.0183 | -0.0434 | 0.0998 | 0.08 | 8.3346 |
| LONG/SHORT EQUITY | 0.2542* | 0.1134* | 0.0917* | -0.0331 | -0.1053 | 11.967 |
| MANAGED FUTURES | -0.0697 | -0.2082 | -0.2741** | 0.2501*** | 0.079** | 17.244* |
| MULTI STRATEGY | 0.5414*** | 0.3099*** | 0.1901*** | 0.0516*** | -0.0229*** | 39.435*** |

Tables 3-4: Autocorrelation function until lag 5 and Ljung-Box Q statistic at lag 9 for all the hedge funds strategies. The * reveals the statistical significance of the coefficients at the 10%, 5%, and 1% confidence levels.

| 2007-2009 | ACF(1) | ACF(2) | ACF(3) | ACF(4) | ACF(5) | LB-Q(9) |
|-----------------------------|---------------|---------------|---------------|---------------|---------------|----------------|
| ALL HEDGE FUND INDEX | 0.5182*** | 0.3646*** | 0.1631*** | 0.1765*** | -0.0194*** | 21.315*** |
| CONVERTIBLE ARBITRAGE | 0.5764*** | 0.2863*** | 0.1549*** | 0.0451*** | -0.0059*** | -19.783** |
| DEDICATED SHORT BIAS | 0.0204 | -0.2342 | -0.0408 | 0.3789 | -0.0009* | 16.609* |
| EMERGING MARKETS | 0.4857*** | 0.3208*** | 0.2101*** | 0.1943*** | 0.0343*** | 21.115** |
| EQUITY MARKET NEUTRAL | 0.0265 | -0.0007 | 0.1285 | -0.0253 | -0.0609 | 2.2756 |
| EVENT DRIVEN | 0.466*** | 0.4054*** | 0.259*** | 0.2133*** | 0.0638*** | 21.965*** |
| EVENT DRIVEN DISTRESSED | 0.6507*** | 0.4948*** | 0.3716*** | 0.2428*** | 0.0382*** | 40.488*** |
| EVENT DRIVEN MULTI-STRATEGY | 0.3211** | 0.3373** | 0.1616** | 0.1764** | 0.0764** | 11.987 |
| EVENT DRIVEN RISK-ARBITRAGE | 0.4779*** | 0.074** | -0.0383** | -0.0264* | 0.0598* | 13.154 |
| FIXED INCOME ARBITRAGE | 0.5829*** | 0.2395*** | 0.1108*** | 0.027*** | -0.1355*** | 20.042** |
| GLOBAL MACRO | 0.3098* | 0.0337 | -0.0406 | 0.109 | 0.0553 | 6.5985 |
| LONG/SHORT EQUITY | 0.3904** | 0.2684** | 0.0524** | 0.0982* | -0.0487 | 11.009 |
| MANAGED FUTURES | 0.0565 | -0.3535* | -0.2727** | 0.2581** | 0.131** | 26.101*** |
| MULTI STRATEGY | 0.6197*** | 0.3857*** | 0.1633*** | 0.0878*** | 0.0106*** | 24.628*** |

| 2010-2012 | ACF(1) | ACF(2) | ACF(3) | ACF(4) | ACF(5) | LB-Q(9) |
|-----------------------------|---------------|---------------|---------------|---------------|---------------|----------------|
| ALL HEDGE FUND INDEX | 0.121 | -0.0751 | 0.2029 | -0.1967 | -0.147 | 8.0438 |
| CONVERTIBLE ARBITRAGE | 0.2488 | -0.1071 | 0.0809 | -0.0653 | -0.0964 | 9.3428 |
| DEDICATED SHORT BIAS | 0.0016 | -0.007 | 0.0179 | -0.2728 | -0.091 | 5.0855 |
| EMERGING MARKETS | -0.0042 | -0.1917 | 0.2071 | -0.1883 | -0.2739 | 9.833 |
| EQUITY MARKET NEUTRAL | -0.1453 | -0.1681 | 0.2275 | -0.1112 | -0.264 | 14.176 |
| EVENT DRIVEN | 0.277* | 0.0504 | 0.2563 | -0.1696 | -0.1563 | 12.822 |
| EVENT DRIVEN DISTRESSED | 0.2638* | -0.0088 | 0.1924 | -0.2329 | -0.2048 | 14.45 |
| EVENT DRIVEN MULTI-STRATEGY | 0.2755* | 0.0751 | 0.274 | -0.1442 | -0.1225 | 12.542 |
| EVENT DRIVEN RISK-ARBITRAGE | -0.0201 | -0.1445 | -0.0184 | -0.1563 | -0.1624 | 4.7401 |
| FIXED INCOME ARBITRAGE | 0.0696 | 0.0277 | 0.3379 | -0.1567 | 0.0827 | 8.8929 |
| GLOBAL MACRO | -0.1987 | -0.0566 | -0.0951 | 0.1087 | 0.0325 | 5.2572 |
| LONG/SHORT EQUITY | 0.0831 | -0.0878 | 0.1062 | -0.1983 | -0.1384 | 4.8691 |
| MANAGED FUTURES | -0.2846 | 0.0288 | -0.2756* | 0.2501* | -0.0446 | 12.27 |
| MULTI STRATEGY | 0.1721 | -0.0693 | 0.2204 | -0.2174 | -0.1802 | 12.558 |

With a first look at the tables it is easy to make 2 observations. The first thing that we notice is that autocorrelation differs greatly among the examined periods. During the periods which represent the financial crisis, which in our research are the years 2007-2012 and 2007-2009, autocorrelation coefficients seem to be relatively high and statistically significant. On the contrary, during the Bull Market of 2002-2006, it is quite lower while in the period 2010-2012, which is the period that the global economy starts recovering from the crisis, autocorrelation does not exist.

The second thing that we notice is that serial correlation varies also among the different hedge fund investment strategies. On the one hand, strategies like Dedicated Short Bias, Global Macro and Equity Market Neutral have zero autocorrelation. On the other hand, all the Event Driven, the Convertible and Fixed Income Arbitrage as well as the Multi-Strategy investment styles experience high autocorrelation, no matter the period under examination.

For the vast majority of the investment strategies autocorrelation exists and it is also statistically significant so it is necessary that we make the appropriate modifications in our data. The "smoothed" observed returns need to be corrected and to get replaced with "unsmoothed" ones. In this procedure, we are going to borrow a return unsmoothing method from the real estate finance literature. The reason is that because of the smoothing in appraisals and the infrequent valuations of properties, the returns of the real estate indices suffer from quite similar problems as the hedge fund indexes do.

The main idea is to "unsmooth" the observed returns in order to create a totally new set of returns which will be more volatile and accurate. There are many ways to "unsmooth" data. In this research we will use the basic formula that was first proposed by Geltner (1991) and also successfully used by Brooks and Kat (2001) and Kat-Lu (2002).

The formula is the following:

$$r^*(t) = \frac{1}{(1-a)} r(t) - \frac{a}{(1-a)} r(t-1)$$

where r_t^* and r_t are the unsmoothed and the observed return time series respectively, while r_{t-1} is the lagged by one period observed return. "a" is the autocorrelation coefficient at lag 1. According to the aforementioned formula, the return series r_t^* will have the same mean with r_t and near zero first order autocorrelation. Also, the standard deviation of r_t^* will be higher than that of r_t if "a" is positive while it will be lower if "a" is negative. The truth is that this methodology corrects for the AR(1) process and only removes the first order autocorrelation while many hedge fund indices have also high second order autocorrelation that is not going to be removed. Nevertheless, this method has been used widely in hedge fund analysis in the past and is considered sufficient for the scope of this study.

A possible explanation for the existence of high autocorrelation in the hedge fund data is because of the difficulty for the hedge fund managers to obtain up-to-date valuation of their positions in illiquid and complex securities. As a result, they have to use in their calculations the last reported prices or an estimate of the current market value. This procedure can create lags in the evolution of their returns (Brooks-Kat 2002).

From now on for all the calculations that will be conducted in this research, we will use the corrected for autocorrelation, "unsmoothed" returns. In order to better understand the effect of serial correlation in the level of the volatility of our data it would be useful to compare the standard deviation for the 13 hedge fund strategies before and after the correction.

Table 5: Observed and Unsmoothed Standard Deviation for the Bull market period 2002-2006

| 2002-2006 | Observed Std. Deviation | Unsmoothed Std. Deviation | Percentage change |
|-----------------------------|--------------------------------|----------------------------------|--------------------------|
| DEDICATED SHORT BIAS | 0.0397 | 0.0489 | 23.25% |
| MANAGED FUTURES | 0.0350 | 0.0421 | 20.30% |
| MSCI WORLD | 0.0340 | 0.0340 | |
| S&P 500 | 0.0327 | 0.0327 | |
| EMERGING MARKETS | 0.0215 | 0.0254 | 18.27% |
| LONG/SHORT EQUITY | 0.0158 | 0.0209 | 32.45% |
| EVENT DRIVEN DISTRESSED | 0.0134 | 0.0204 | 52.25% |
| CONVERTIBLE ARBITRAGE | 0.0120 | 0.0194 | 62.31% |
| EVENT DRIVEN | 0.0118 | 0.0174 | 47.45% |
| EVENT DRIVEN MULTI-STRATEGY | 0.0123 | 0.0161 | 31.47% |
| EVENT DRIVEN RISK-ARBITRAGE | 0.0092 | 0.0134 | 45.80% |
| ALL HEDGE FUND INDEX | 0.0103 | 0.0134 | 30.23% |
| MULTI STRATEGY | 0.0089 | 0.0124 | 39.49% |
| FIXED INCOME ARBITRAGE | 0.0079 | 0.0116 | 46.06% |
| GLOBAL MACRO | 0.0101 | 0.0104 | 2.63% |
| EQUITY MARKET NEUTRAL | 0.0055 | 0.0063 | 15.35% |
| BARCLAYS US AGG BOND | 0.0050 | 0.0050 | |

Table 6: Observed and Unsmoothed Standard Deviation for the greater crisis period 2007-2012

| 2007-2012 | Observed Std. Deviation | Unsmoothed Std. Deviation | Percentage change |
|-----------------------------|--------------------------------|----------------------------------|--------------------------|
| MSCI WORLD | 0.0635 | 0.0635 | |
| S&P 500 | 0.0606 | 0.0606 | |
| CONVERTIBLE ARBITRAGE | 0.0291 | 0.0540 | 85.54% |
| EQUITY MARKET NEUTRAL | 0.0503 | 0.0516 | 2.57% |
| DEDICATED SHORT BIAS | 0.0481 | 0.0491 | 2.06% |
| FIXED INCOME ARBITRAGE | 0.0245 | 0.0476 | 93.87% |
| EMERGING MARKETS | 0.0327 | 0.0466 | 42.42% |
| MULTI STRATEGY | 0.0202 | 0.0368 | 82.56% |
| EVENT DRIVEN DISTRESSED | 0.0197 | 0.0357 | 81.07% |
| LONG/SHORT EQUITY | 0.0265 | 0.0344 | 29.58% |
| EVENT DRIVEN MULTI-STRATEGY | 0.0237 | 0.0323 | 36.07% |
| EVENT DRIVEN | 0.0215 | 0.0322 | 49.74% |
| ALL HEDGE FUND INDEX | 0.0199 | 0.0306 | 53.65% |
| MANAGED FUTURES | 0.0326 | 0.0304 | -6.68% |
| GLOBAL MACRO | 0.0181 | 0.0225 | 24.07% |
| EVENT DRIVEN RISK-ARBITRAGE | 0.0118 | 0.0161 | 36.62% |
| BARCLAYS US AGG BOND | 0.0066 | 0.0066 | |

Table 7: Observed and Unsmoothed Standard Deviation for the “core” of the crisis period 2007-2009

| 2007-2009 | Observed Std. Deviation | Unsmoothed Std. Deviation | Percentage change |
|-----------------------------|--------------------------------|----------------------------------|--------------------------|
| CONVERTIBLE ARBITRAGE | 0.0395 | 0.0760 | 92.33% |
| MSCI WORLD | 0.0735 | 0.0735 | |
| EQUITY MARKET NEUTRAL | 0.0695 | 0.0714 | 2.68% |
| S&P 500 | 0.0706 | 0.0706 | |
| EMERGING MARKETS | 0.0391 | 0.0666 | 70.26% |
| FIXED INCOME ARBITRAGE | 0.0338 | 0.0659 | 94.71% |
| MULTI STRATEGY | 0.0257 | 0.0525 | 104.56% |
| DEDICATED SHORT BIAS | 0.0493 | 0.0504 | 2.06% |
| EVENT DRIVEN DISTRESSED | 0.0227 | 0.0483 | 112.62% |
| LONG/SHORT EQUITY | 0.0286 | 0.0431 | 50.71% |
| ALL HEDGE FUND INDEX | 0.0239 | 0.0423 | 76.77% |
| EVENT DRIVEN | 0.0226 | 0.0370 | 64.22% |
| MANAGED FUTURES | 0.0339 | 0.0359 | 5.72% |
| EVENT DRIVEN MULTI-STRATEGY | 0.0237 | 0.0329 | 38.88% |
| GLOBAL MACRO | 0.0233 | 0.0321 | 37.49% |
| EVENT DRIVEN RISK-ARBITRAGE | 0.0132 | 0.0222 | 68.25% |
| BARCLAYS US AGG BOND | 0.0076 | 0.0076 | |

Table 8: Observed and Unsmoothed Standard Deviation for the post-crisis period 2010-2012

| 2010-2012 | Observed Std. Deviation | Unsmoothed Std. Deviation | Percentage change |
|-----------------------------|--------------------------------|----------------------------------|--------------------------|
| MSCI WORLD | 0.0521 | 0.0521 | |
| S&P 500 | 0.0488 | 0.0488 | |
| DEDICATED SHORT BIAS | 0.0470 | 0.0477 | 1.49% |
| EVENT DRIVEN MULTI-STRATEGY | 0.0240 | 0.0323 | 34.42% |
| EVENT DRIVEN | 0.0207 | 0.0278 | 34.20% |
| LONG/SHORT EQUITY | 0.0247 | 0.0270 | 9.41% |
| EMERGING MARKETS | 0.0253 | 0.0255 | 0.72% |
| MANAGED FUTURES | 0.0316 | 0.0233 | -26.23% |
| EVENT DRIVEN DISTRESSED | 0.0163 | 0.0214 | 30.95% |
| ALL HEDGE FUND INDEX | 0.0151 | 0.0171 | 13.81% |
| CONVERTIBLE ARBITRAGE | 0.0123 | 0.0161 | 30.51% |
| MULTI STRATEGY | 0.0125 | 0.0150 | 20.70% |
| EQUITY MARKET NEUTRAL | 0.0160 | 0.0140 | -12.36% |
| EVENT DRIVEN RISK-ARBITRAGE | 0.0102 | 0.0102 | -0.62% |
| GLOBAL MACRO | 0.0110 | 0.0091 | -17.24% |
| FIXED INCOME ARBITRAGE | 0.0064 | 0.0065 | 2.20% |
| BARCLAYS US AGG BOND | 0.0050 | 0.0050 | |

In the above tables is presented the level of the standard deviation before and after the data correction, as well as the level of its percentage change. The results have been sorted by the Unsmoothed Standard Deviation. What we observe is that the standard deviation rises significantly in all periods, independently of the financial situation. This means that hedge funds in reality are much more volatile that they appear to be so they lose a big part of their attractiveness. As we expected the percentage increase is bigger during the crisis period while during the years that the economy is trying to recover (2010-2012) the increase is relatively smaller. A second point that we should focus on is that investment styles such as the Event Driven and Multi-Strategy that exhibited high autocorrelation, they also exhibit the highest increase in their standard deviation. On the contrary, strategies with low autocorrelation have also lower fluctuations in their volatilities.

A paradox that we should refer to is that for the era 2010-2012, after the correction for autocorrelation, the standard deviation of Global Macro, Equity Market Neutral and Managed Futures, is decreasing. This happens because their first order autocorrelation coefficient is negative. However, the most important conclusion that can be derived from the above tables is that the vast majority of the hedge fund strategies, even after the adjustments exhibit lower volatility than the equity indices S&P 500 and MSCI World no matter what the state of the economy is. These results are consistent with past researches (Stulz 2007) as well as with annual reports such as the one from KPMG (2012). In the same time, bonds have the lowest volatility during all periods, without big fluctuations in their prices, even when the state of the economy is changing. It needs to be mentioned that no corrections have been done to the standard deviations of the S&P 500, the MSCI World and the Barclays US Agg. Bond Indexes.

2.3.3 Skewness & Kurtosis

When somebody conducts an analysis concerning hedge funds' returns, apart from the aforementioned problems of biases and autocorrelation, he needs also to have in mind that his data may also exhibit third and fourth moments. When returns are normally distributed, mean and standard deviation are sufficient so to describe the performance of a fund. However, in the case that they do not follow the normal Gaussian distribution it is necessary to take into account the level of skewness and kurtosis. It has been proved that hedge funds' returns are negatively skewed and that they also exhibit excess kurtosis. An easy way to measure the level of fat tails in our data is to use the Jarque-Bera test. The general formula of this tool is:

$$JB = n \left[\frac{S^2}{6} + \frac{(K-3)^2}{24} \right]$$

n = number of observations

S = skewness

K = Kurtosis

In a perfectly normal distribution S = 0 and K = 3 so JB = 0. The more the score of the JB test deviates from 6, the more conclusive the indication that the returns do not follow the normal distribution. The below tables demonstrate the level of skewness, kurtosis and the JB score for all the hedge fund strategies as well as for the aggregate hedge fund index. All calculations have been conducted on the corrected for autocorrelation data.

Table 9: Skewness – Kurtosis - Jarque Bera Test for all the examined periods.

| | 2002-2006 | | | 2007-2012 | | |
|-----------------------------|------------------|-----------------|--------------------|------------------|-----------------|--------------------|
| | Skewness | Kurtosis | Jarque-Bera | Skewness | Kurtosis | Jarque-Bera |
| ALL HEDGE FUND INDEX | -0.3333 | -0.0562 | 24.4618 | -0.6182 | 0.7616 | 19.6172 |
| CONVERTIBLE ARBITRAGE | -0.9403 | 2.3411 | 9.9267 | -1.6918 | 8.6031 | 128.5295 |
| DEDICATED SHORT BIAS | 0.2834 | -0.2484 | 27.1830 | 0.3245 | -0.1628 | 31.2742 |
| EMERGING MARKETS | -1.0218 | 1.5196 | 15.9204 | -0.7991 | 1.4238 | 15.1163 |
| EQUITY MARKET NEUTRAL | 0.8157 | 0.4678 | 22.6832 | -7.3556 | 59.0976 | 10090.0641 |
| EVENT DRIVEN | -0.7484 | 1.4099 | 11.9211 | -0.5621 | 0.6864 | 19.8492 |
| EVENT DRIVEN DISTRESSED | -0.6271 | 3.2817 | 4.1306 | -0.6814 | 0.9973 | 17.6043 |
| EVENT DRIVEN MULTI-STRATEGY | -0.7321 | 2.2272 | 6.8522 | -0.5240 | 0.5211 | 21.7291 |
| EVENT DRIVEN RISK-ARBITRAGE | 0.0643 | 2.0215 | 2.4351 | -0.1371 | 0.5954 | 17.5713 |
| FIXED INCOME ARBITRAGE | -0.6408 | 0.6318 | 18.1268 | -2.4097 | 11.7417 | 298.9317 |
| GLOBAL MACRO | 0.1790 | -0.2282 | 26.3743 | -0.8220 | 2.4370 | 9.0597 |
| LONG/SHORT EQUITY | -0.5009 | -0.1455 | 27.2447 | -0.3927 | 0.1982 | 25.4002 |
| MANAGED FUTURES | -0.0921 | -0.6112 | 32.6860 | 0.0350 | -1.1431 | 51.5114 |
| MULTI STRATEGY | -0.1219 | -0.3528 | 28.2522 | -0.8224 | 2.9499 | 8.1238 |

| | 2007-2009 | | | 2010-2012 | | |
|-----------------------------|------------------|-----------------|--------------------|------------------|-----------------|--------------------|
| | Skewness | Kurtosis | Jarque-Bera | Skewness | Kurtosis | Jarque-Bera |
| ALL HEDGE FUND INDEX | -0.6926 | 0.4589 | 12.5638 | -0.2948 | 0.0359 | 13.7003 |
| CONVERTIBLE ARBITRAGE | -1.3617 | 4.8436 | 16.2234 | -0.5368 | 0.3681 | 12.1190 |
| DEDICATED SHORT BIAS | 0.3771 | -0.3313 | 17.4997 | 0.3159 | 0.0249 | 13.8755 |
| EMERGING MARKETS | -0.6882 | 0.3718 | 13.2028 | -0.9243 | 1.5748 | 8.1724 |
| EQUITY MARKET NEUTRAL | -5.6235 | 32.7983 | 1521.6509 | -0.1403 | 0.2445 | 11.5076 |
| EVENT DRIVEN | -0.8978 | 0.6723 | 12.9638 | -0.4616 | 0.8305 | 8.3388 |
| EVENT DRIVEN DISTRESSED | -0.8536 | 0.9261 | 10.8239 | -0.8078 | 1.2396 | 8.5637 |
| EVENT DRIVEN MULTI-STRATEGY | -0.8149 | 0.5506 | 12.9841 | -0.3286 | 0.6773 | 8.7404 |
| EVENT DRIVEN RISK-ARBITRAGE | -0.0620 | 1.7211 | 2.4766 | -0.0037 | -0.6672 | 20.1725 |
| FIXED INCOME ARBITRAGE | -1.7251 | 5.3871 | 26.4033 | -0.4617 | 0.0613 | 14.2328 |
| GLOBAL MACRO | -0.7606 | 1.1074 | 8.8438 | 0.2070 | -0.5844 | 19.5293 |
| LONG/SHORT EQUITY | -0.6538 | 0.0224 | 15.8641 | -0.2920 | 0.0680 | 13.4071 |
| MANAGED FUTURES | -0.0005 | -1.1534 | 25.8762 | -0.0908 | -0.9942 | 23.9801 |
| MULTI STRATEGY | -0.8363 | 2.3646 | 4.8025 | -0.5595 | 0.1791 | 13.8147 |

What we observe is that all investment styles except of the Dedicated Short Bias are negatively skewed. They also appear excess kurtosis which in most of the cases is positive, especially during the crisis period. As a result the JB scores are much higher than the level of 6 which means that our data does not follow the normal distribution. For a risk-averse investor, negative skewness combined with excess kurtosis are not desirable because they indicate a probability of great losses. Jarque-Bera test statistic strongly indicates the existence of non-normality in hedge fund's returns. Apart from the Event Driven Strategies in the Bull Market period (2002-2006), for all the other investment styles we safely conclude that they are not normally distributed. This phenomenon becomes more intense during the Bear Market. In this period, the Equity Market Neutral strategy has a JB score of 10.090 which is extremely large but can be attributed to the very high level of kurtosis. The fact that hedge funds' returns are not normally distributed is very important and will be proved quite helpful for the research part of our investigation. This means that, when we will try to evaluate hedge funds' performance, we will use risk measures like the Modified Sharpe Ratio and the Modified VaR which take into account the level of skewness and kurtosis, so our results are going to be more realistic and representative of the actual hedge fund returns.

Chapter 3: Hedge Funds' performance

3.1 Studies on Hedge Funds' performance

Despite the continuously increasing interest on their activities, very few performance studies have been conducted on hedge funds returns comparing to other investment tools like equities, bonds and mutual funds. In the same time they are even less the studies which have examined hedge fund performance in the recent years and more specifically from the financial crisis and onwards. This lack of literature can be attributed to the limited access to individual funds data.

Before we start with our investigation, it would be quite interesting and helpful to take a look to the existing literature which tried to examine hedge fund returns comparing to other asset classes. A first attempt in this way was done by Ackermann (1999). By examining a very large sample of data, from 1988-1995, he reaches to the conclusion that hedge funds outperform mutual funds but not equities and bonds while in the same time they are more volatile. In this study Ackermann compared hedge funds' monthly returns with the returns of various indexes like S&P 500, MSCI World and EAFE, as well as with the Lehman Agg. Bond Index. The first 3 indexes represent equities while the last one represents bonds. This is the same methodology with the one that we are also going to use in our analysis. As a performance measure he used the Shape Ratio, which in the case of hedge fund analysis is not the most suitable risk measure, as it assumes normality while it does not account for skewness and kurtosis. More recent studies exhibit significant differences in the performance of the hedge funds after the year 2000 and reach to completely different results than the ones of Ackermann.

More specifically Lhabitant (2004) after examining more than 6000 hedge funds concludes that they substantially outperform other asset classes and especially equities while they exhibit much lower volatility. Also, Eling (2005) incorporates in hedge fund analysis the use of the Modified Sharpe Ratio (MSR), which also takes into account the higher moments in the return distribution. His results indicate that hedge fund strategies have higher MSR than equities and bonds while in general they have low correlation with other asset classes. Nevertheless, when their returns are corrected for biases, autocorrelation and fat tails only few strategies (Equity Market Neutral) remain attractive and deliver excess returns comparing to the market indexes. Later researches (Stulz 2007) and annual reports (KPMG 2012) come to reinforce partially the aforementioned studies. Both suggest that from 1994-2000 hedge funds underperformed equities (S&P 500), as Ackermann suggests, but after 2000 they consistently outperform equities and they exhibit lower standard deviation (Eling, Lhabitant). Finally, a quite recent report on hedge fund performance was conducted by Pictet Alternative Investment in 2010. By using the Dow Jones Credit Suisse database, it suggests that DJCS Aggregate Hedge Fund Index outperformed equities (MSCI World) during all the financial crisis periods from 1994-2009, namely the Asian Crisis (1987), the Russian crisis (1998), the Technology bubble (2000-2001) and finally the recent financial crisis (2007-2009). Pictet's report covers only the era until the middle of 2009 when the financial crisis was not yet over. Our study examines hedge fund performance until the end of 2012 which is a barely explored period. Consequently, our results can contribute to the existing literature with additional information also for the post crisis era (2010-2012).

In the same time, many other studies focused on the correlation of hedge funds with other asset classes. Lhabitant (2004,2006) found evidences that hedge fund strategies have shown low to medium correlation with traditional assets like equities and bonds while Brooks-Kat (2001) support that while correlation with bonds is low or even negative, on the contrary it is quite high with equities. Even the above results do not manage to reach to a consensus, many studies like the ones of Liang (1999), Agarwal-Naik (2000) and Amin-Kat (2001) tend to conclude that correlation between hedge funds and other assets, in most of the cases, is low. That's why according to Fung-Hsieh (1997) and Schneeweis-Spurgin (1997), the addition of hedge funds in a portfolio can significantly improve its risk-return profile and contribute to a better diversification and asset allocation. It remains to be proved, if the research part of our study in the next two chapters, will reach to the same conclusions.

3.2 Risk measure selection

What can somebody easily understand, is that many past researches do not manage to reach to a consensus and they report conflicting results concerning the performance of the hedge funds' strategies. Some of the main reasons for these discrepancies are the size, the quality and the methodology of the database that is used. Each database has different standards in order to include a fund or not. As a result, databases with stricter entrance criteria are very possible to give different results comparing to the less strict ones. Also, some of them correct only for some of the biases such as survivorship and back fill bias while they are net of fees and expenses. Apparently, these differences in methodology affect also the performance of the reported funds. Another possible explanation for the great differences among the current studies is the fact that they examine different periods in time. When the financial situation changes, this also affects hedge fund performance as well as their correlation with other assets. In the same time, in the vast majority of the

existing papers, hedge fund returns are corrected only for one of the effects that they appear but not for all of them simultaneously. Even if there is consensus that hedge funds returns suffer from serial correlation, biases and higher order moments, only few researchers attempted to correct their data for all these problems. As a result, these profound differences in the methodology lead sometimes to diverse conclusions.

However, the most important reason that many studies cannot reach to identical results about the hedge fund performance is that they use a different risk measure in order to conduct their analysis. The issue of the performance indicator in the hedge fund industry is a source of controversial literature. The explanation for this complexity is that hedge funds cover a wide range of strategies which have a different risk return profile. For this reason, different risk measures reach to different performance evaluation. Based on the existing literature, we decided to conduct our study, by using 4 different risk indicators, which will let us create a more complete and accurate approach on hedge funds' returns during the 4 different periods that we are going to examine. Namely, in our calculations we will use the Sharpe Ratio, the Modified Sharpe Ratio, the Modified VaR and the Jensen's alpha. Of course there are also many other performance measures like the Treynor and Sortino ratios or the more sophisticated omega ratio. None risk measure is perfect. Each one has advantages and disadvantages depending on the situation. More specifically, the newly introduced omega ratio (Keating-Shadwick 2002) is considered as a very good indicator for a hedge fund performance analysis as it captures all the moments of the return distribution. It is represented by the ratio of the gain with respect to a threshold and the loss with respect to the same threshold. As it requires complex calculations and in order to keep this study as simple as possible we decided not to make use of it.

Regarding to the risk measures that we are going to work with, the first one will be the Sharpe Ratio which was first introduced in 1966 by William F. Sharpe. Its formula is the following:

$$SR = \frac{E(R_p) - r_f}{\sigma_p}$$

Where :

$E(R_p)$: expected portfolio returns

r_f : risk free rate

σ_p : portfolio standard deviation

Sharpe ratio assumes normality in the return distribution so higher moments are not taken into account, while in the same time it penalizes volatility. If autocorrelation exists then the SR can be overstated even by 65%, according to Lo (2002). In our study we deal with this problem by correcting our data for autocorrelation. It is easy for somebody to understand that Sharpe Ratio is not the ideal risk measure for alternative investments like the hedge funds. The only reason that we will use it is just for comparison purposes with other risk measures which take into account the higher order moments. In this way, we will be able to understand to

what extent the negative skewness combined with the excess kurtosis affect the returns of the different hedge fund strategies. For this purpose, we are going to use the Modified Value at Risk (MVaR) and the Modified Sharpe Ratio. Because VaR assumes normality and also suffers from the same problems with Sharpe Ratio, in our research we will use the VaR with the Cornish-Fisher expansion which is otherwise called the Modified VaR. MVaR like value-at-risk represents the greatest expected loss over the holding period at the given confidence level but it also accounts for skewness and kurtosis. It can be derived from the following formula:

$$\mathbf{MVaR} = \mu - Z \sigma$$

Where:

μ : mean

σ : standard deviation

$$Z = (Z_c + \frac{1}{6}(Z_c^2 - 1)S + \frac{1}{24}(Z_c^3 - 3Z_c)K - \frac{1}{36}(2Z_c^3 - 5Z_c)S^2)$$

S: skewness

K: kurtosis

Zc: the quantile of the distribution

VaR as well as MVAR have been widely used in the past for hedge fund analysis studies. The most prominent among them are the ones from Jorion (2000), Gupta-Liang (2005), Agarwal-Naik (2004) and Gokcan-Liang (2007).

Nevertheless, MVAR is not perfect. Even if it quite more suitable than the classic VaR for this kind of analysis, it fails to explain sufficiently illiquid assets as many of the hedge funds are. However, keeping this in mind and based on the great appreciation toward this risk measure in the existing literature, we believe that it is suitable for the purpose of our study. Together with MVAR we will also use the Modified Sharpe Ratio. As its name reveals, MSR is an adjustment of the classic Sharpe Ratio, so to count also for higher moments.

Its formula is:

$$\mathbf{MSR} = \frac{E(r_p) - r_f}{MVaR}$$

Where:

$E(R_p)$: expected portfolio returns

r_f : risk free rate

MVaR: Modified VaR as defined above

The last one of the 4 risk measures that we will work with is the Jensen's α (1968) which is obtained via a regression on:

$$R_p - r_f = \alpha_p + \beta_p (R_m - r_f) + \varepsilon_p$$

Where:

R_p : portfolio return

r_f : risk free rate

β_p : beta of the portfolio

R_m : market return

It reveals the excess return of an asset or a portfolio over a predefined benchmark. The biggest problem that we should cope with in this case is the choice of the index that we should use as a benchmark. The reason is that hedge funds invest in many different asset classes while using quite diversified strategies, so no index can be perfectly compared and represent adequately all the investment styles. Overall, we conclude that the most appropriate index for this purpose would be the S&P 500. S&P is one of the most reputable and widely used indexes for research purposes and has already been used as a benchmark for hedge funds' performance analysis in many cases in the past. Some of these studies are Ackermann (1999), Liang (1999), Amin-Kat (2002) and Stulz (2007).

3.3 Hedge funds' performance analysis

Based on the aforementioned 4 risk measures, we will try to conduct a performance analysis for the 13 different hedge fund strategies as well as for equities and bonds. The main question that we try to answer is whether hedge funds manage to outperform other asset classes, like equities and bonds, during the crisis period, when their returns have been corrected for the effects of biases, serial correlation and fat tails. The 2 main periods that will be compared are the years 2002-2006 which represent the Bull market and the years 2007-2012 which denote the greater crisis era. However, it is quite difficult to define exactly when the end of the crisis was. For this reason, we believe that it is crucial to split the crisis period into two sub-periods. The first one will be the 2007-2009 which are the years that the effects of the crisis on the economy are more intense and severe. The second period will be the years 2010-2012 which is the time that the global economy starts recovering. According to our research, the performance of all assets differs significantly between these two periods, so it would be wrong to not separate them but to examine them as one unique era. All calculations have been conducted on the corrected for autocorrelation, monthly returns. As a result, all risk measures are expressed on a monthly basis. For the calculations related to the Jensen's α , S&P 500 was set as a benchmark. The Modified VaR has been computed on the 95% confidence level.

The below tables present the performance evaluation for all the asset classes that are examined in this study, during the Bull and the Bear markets respectively. The results have been sorted based on the performance of each hedge fund strategy for each one of the different risk indicators.

Table 10: Evaluation of hedge fund performance for the Bull Market period 2002-2006.

| 2002-2006 | Sharpe Ratio | | Modified Sharpe Ratio | | Modified VaR | | Jensen's a |
|-----------------------------|--------------|-----------------------------|-----------------------|-----------------------------|--------------|-----------------------------|------------|
| GLOBAL MACRO | 0.7781 | GLOBAL MACRO | 0.3029 | BARCLAYS US AGG BOND | 0.0035 | EMERGING MARKETS | 0.0097 |
| EQUITY MARKET NEUTRAL | 0.6665 | EQUITY MARKET NEUTRAL | 0.2806 | EQUITY MARKET NEUTRAL | 0.0150 | GLOBAL MACRO | 0.0080 |
| MULTI STRATEGY | 0.5070 | MULTI STRATEGY | 0.2153 | EVENT DRIVEN RISK-ARBITRAGE | 0.0249 | EVENT DRIVEN DISTRESSED | 0.0071 |
| EMERGING MARKETS | 0.4468 | ALL HEDGE FUND INDEX | 0.1902 | FIXED INCOME ARBITRAGE | 0.0258 | MANAGED FUTURES | 0.0062 |
| ALL HEDGE FUND INDEX | 0.4435 | EMERGING MARKETS | 0.1853 | GLOBAL MACRO | 0.0267 | EVENT DRIVEN | 0.0061 |
| EVENT DRIVEN MULTI-STRATEGY | 0.4268 | EVENT DRIVEN DISTRESSED | 0.1835 | MULTI STRATEGY | 0.0291 | EVENT DRIVEN MULTI-STRATEGY | 0.0058 |
| EVENT DRIVEN | 0.4222 | EVENT DRIVEN MULTI-STRATEGY | 0.1817 | ALL HEDGE FUND INDEX | 0.0312 | MULTI STRATEGY | 0.0056 |
| EVENT DRIVEN DISTRESSED | 0.4154 | EVENT DRIVEN | 0.1792 | EVENT DRIVEN MULTI-STRATEGY | 0.0379 | ALL HEDGE FUND INDEX | 0.0051 |
| LONG/SHORT EQUITY | 0.2969 | LONG/SHORT EQUITY | 0.1363 | CONVERTIBLE ARBITRAGE | 0.0410 | LONG/SHORT EQUITY | 0.0048 |
| FIXED INCOME ARBITRAGE | 0.2492 | FIXED INCOME ARBITRAGE | 0.1118 | EVENT DRIVEN | 0.0410 | EQUITY MARKET NEUTRAL | 0.0042 |
| MSCI WORLD | 0.2033 | MSCI WORLD | 0.0968 | LONG/SHORT EQUITY | 0.0455 | MSCI WORLD | 0.0035 |
| CONVERTIBLE ARBITRAGE | 0.1566 | MANAGED FUTURES | 0.0755 | EVENT DRIVEN DISTRESSED | 0.0461 | FIXED INCOME ARBITRAGE | 0.0029 |
| MANAGED FUTURES | 0.1414 | CONVERTIBLE ARBITRAGE | 0.0743 | EMERGING MARKETS | 0.0613 | CONVERTIBLE ARBITRAGE | 0.0027 |
| EVENT DRIVEN RISK-ARBITRAGE | 0.1172 | EVENT DRIVEN RISK-ARBITRAGE | 0.0633 | S&P 500 | 0.0644 | EVENT DRIVEN RISK-ARBITRAGE | 0.0008 |
| S&P 500 | 0.1084 | S&P 500 | 0.0551 | MSCI WORLD | 0.0715 | BARCLAYS US AGG BOND | -0.0011 |
| DEDICATED SHORT BIAS | -0.0964 | DEDICATED SHORT BIAS | -0.0638 | DEDICATED SHORT BIAS | 0.0740 | DEDICATED SHORT BIAS | -0.0011 |
| BARCLAYS US AGG BOND | -0.2387 | BARCLAYS US AGG BOND | -0.3451 | MANAGED FUTURES | 0.0787 | S&P 500 | |

Table 11: Evaluation of hedge fund performance for the greater crisis period 2007-2012

| 2007-2012 | Sharpe Ratio | | Modified Sharpe Ratio | | Modified VaR | | Jensen's a |
|-----------------------------|--------------|-----------------------------|-----------------------|-----------------------------|--------------|-----------------------------|------------|
| GLOBAL MACRO | 0.2538 | GLOBAL MACRO | 0.1205 | BARCLAYS US AGG BOND | 0.0075 | GLOBAL MACRO | 0.0055 |
| EVENT DRIVEN RISK-ARBITRAGE | 0.1575 | EVENT DRIVEN RISK-ARBITRAGE | 0.0839 | EVENT DRIVEN RISK-ARBITRAGE | 0.0303 | MANAGED FUTURES | 0.0027 |
| EVENT DRIVEN MULTI-STRATEGY | 0.0983 | EVENT DRIVEN MULTI-STRATEGY | 0.0517 | GLOBAL MACRO | 0.0473 | EVENT DRIVEN MULTI-STRATEGY | 0.0023 |
| EVENT DRIVEN | 0.0867 | MANAGED FUTURES | 0.0474 | MANAGED FUTURES | 0.0538 | EVENT DRIVEN RISK-ARBITRAGE | 0.0021 |
| MANAGED FUTURES | 0.0838 | BARCLAYS US AGG BOND | 0.0464 | ALL HEDGE FUND INDEX | 0.0583 | CONVERTIBLE ARBITRAGE | 0.0021 |
| ALL HEDGE FUND INDEX | 0.0837 | EVENT DRIVEN | 0.0457 | EVENT DRIVEN | 0.0610 | MULTI STRATEGY | 0.0019 |
| MULTI STRATEGY | 0.0801 | ALL HEDGE FUND INDEX | 0.0439 | EVENT DRIVEN MULTI-STRATEGY | 0.0613 | EVENT DRIVEN | 0.0019 |
| EVENT DRIVEN DISTRESSED | 0.0648 | MULTI STRATEGY | 0.0420 | LONG/SHORT EQUITY | 0.0630 | ALL HEDGE FUND INDEX | 0.0016 |
| EMERGING MARKETS | 0.0595 | EVENT DRIVEN DISTRESSED | 0.0342 | EVENT DRIVEN DISTRESSED | 0.0677 | FIXED INCOME ARBITRAGE | 0.0014 |
| LONG/SHORT EQUITY | 0.0581 | LONG/SHORT EQUITY | 0.0317 | DEDICATED SHORT BIAS | 0.0700 | EMERGING MARKETS | 0.0014 |
| CONVERTIBLE ARBITRAGE | 0.0571 | EMERGING MARKETS | 0.0312 | MULTI STRATEGY | 0.0702 | EVENT DRIVEN DISTRESSED | 0.0012 |
| BARCLAYS US AGG BOND | 0.0533 | CONVERTIBLE ARBITRAGE | 0.0290 | EQUITY MARKET NEUTRAL | 0.0756 | LONG/SHORT EQUITY | 0.0009 |
| FIXED INCOME ARBITRAGE | 0.0503 | S&P 500 | 0.0265 | EMERGING MARKETS | 0.0890 | BARCLAYS US AGG BOND | 0.0004 |
| S&P 500 | 0.0485 | FIXED INCOME ARBITRAGE | 0.0245 | FIXED INCOME ARBITRAGE | 0.0976 | MSCI WORLD | -0.0009 |
| MSCI WORLD | 0.0328 | MSCI WORLD | 0.0182 | CONVERTIBLE ARBITRAGE | 0.1064 | EQUITY MARKET NEUTRAL | -0.0051 |
| EQUITY MARKET NEUTRAL | -0.0753 | EQUITY MARKET NEUTRAL | -0.0513 | S&P 500 | 0.1108 | DEDICATED SHORT BIAS | -0.0054 |
| DEDICATED SHORT BIAS | -0.1442 | DEDICATED SHORT BIAS | -0.1012 | MSCI WORLD | 0.1146 | S&P 500 | |

Many interesting conclusions can be derived from the analysis of these tables. First of all, we observe that the vast majority of the different hedge fund investment styles, as well as the Aggregate Hedge Fund index, substantially outperform both equity indexes and of course bonds, in both periods.

More analytically, during the pre-crisis era (2002-2006) all risk indicators reveal superior returns for the hedge fund strategies with the Global Macro style to be the best performing among them. Moreover, the Barclays US Agg. Bond index seems to have the worst performance. This is something that we expected if we consider the low returns that bonds offer. In the same time, between the two equity indexes, MSCI World outperforms S&P 500. By comparing the results of the SR and the MSR we see that hedge funds' returns, independently of strategies, lose a very big part of their attractiveness when negative skewness and excess kurtosis are taken into account. In some cases, the returns of the MSR are even less than half, comparing to those of the SR for the same investment styles. Nevertheless, the classifications of the strategies reveals that even SR is not an appropriate risk measure to assess hedge fund performance, finally it gives identical results with the MSR, not quantitatively but at least qualitatively.

Furthermore, by examining the MVaR the general picture does not change a lot. Bonds have the lowest MVaR that is quite normal considering their nature. Also, S&P 500 and MSCI World again do not manage to outperform most hedge fund strategies except of the Dedicated Short Bias and the Managed Futures. Finally, most hedge funds deliver excess returns comparing to the S&P 500 which has been set as a benchmark.

Referring to the greater crisis period (2007-2012) the situation doesn't change dramatically regarding the hedge fund outperformance over the traditional asset classes. However, there are some significant differences with the pre-crisis period. First of all, as we expected, almost all assets deliver much lower returns comparing to the Bull Market era. However, this is not the case for the bonds which during the crisis perform better than equities and also better than many hedge fund strategies. Global Macro remains the best performing strategy but this time it is followed by the Event Driven styles while the Dedicated Short Bias is ranking last in all the performance evaluation tests. MSR gives again much lower returns than the classic SR but this time the differences are not that big like they were in the period (2002-2006). This means that the effects of skewness and kurtosis during the crisis still exist but are not so severe and intense like in the pre-crisis era. Moreover, hedge funds remain less risky, considering their MVAR scores, while they still give excess returns over the S&P 500. Until now, the main hypothesis in our research which is whether or not hedge funds outperformed equities and bonds during the financial crisis period, holds true. These results are compatible with the existing literature in which we have already referred to. Namely Lhabitant (2004) and Stulz (2007) reach to similar conclusions. Also Pictet's annual report (2012) suggested that DJCS index outperformed MSCI

World and S&P 500 in all crises from 1994 to 2009. Our results come to reinforce the existing knowledge on the field. In the same time, we proved that hedge funds lose a very big part of their attractiveness in both periods, when we examine the combined effects on their performance from autocorrelation, biases and higher order moments. This is something that was firstly introduced by Eling (2009).

However, as we have already explained, it is quite difficult to define when the financial crisis ended. For this reason we believe that it would be quite interesting to further examine this era by splitting it into two sub-periods, namely the years 2007-2009 and 2010-2012. The reason that we do that is that both periods exhibit significant differences in many fields of analysis, so a further and in-depth investigation would help us to better evaluate and understand the effect of the crisis on hedge funds' returns behavior.

The below tables present the results for the aforementioned 2 periods for all the 4 risk measures that we used.

Table 12: Evaluation of hedge fund performance for the “core” of the crisis period 2007-2009

| 2007-2009 | Sharpe Ratio | | Modified Sharpe Ratio | | Modified VaR | | Jensen's a |
|-----------------------------|--------------|-----------------------------|-----------------------|-----------------------------|--------------|-----------------------------|------------|
| BARCLAYS US AGG BOND | 0.1559 | BARCLAYS US AGG BOND | 0.1404 | BARCLAYS US AGG BOND | 0.0084 | GLOBAL MACRO | 0.0048 |
| GLOBAL MACRO | 0.1406 | EVENT DRIVEN RISK-ARBITRAGE | 0.0744 | EVENT DRIVEN RISK-ARBITRAGE | 0.0408 | EVENT DRIVEN MULTI-STRATEGY | 0.0040 |
| EVENT DRIVEN RISK-ARBITRAGE | 0.1366 | GLOBAL MACRO | 0.0697 | MANAGED FUTURES | 0.0646 | EVENT DRIVEN RISK-ARBITRAGE | 0.0035 |
| EVENT DRIVEN MULTI-STRATEGY | 0.0972 | MANAGED FUTURES | 0.0498 | GLOBAL MACRO | 0.0647 | EMERGING MARKETS | 0.0030 |
| MANAGED FUTURES | 0.0898 | EVENT DRIVEN MULTI-STRATEGY | 0.0486 | EVENT DRIVEN MULTI-STRATEGY | 0.0658 | EVENT DRIVEN | 0.0030 |
| EVENT DRIVEN | 0.0540 | EVENT DRIVEN | 0.0274 | EVENT DRIVEN | 0.0729 | MANAGED FUTURES | 0.0030 |
| LONG/SHORT EQUITY | 0.0261 | LONG/SHORT EQUITY | 0.0138 | DEDICATED SHORT BIAS | 0.0763 | LONG/SHORT EQUITY | 0.0024 |
| EMERGING MARKETS | 0.0194 | EMERGING MARKETS | 0.0104 | ALL HEDGE FUND INDEX | 0.0793 | CONVERTIBLE ARBITRAGE | 0.0024 |
| CONVERTIBLE ARBITRAGE | 0.0145 | CONVERTIBLE ARBITRAGE | 0.0075 | LONG/SHORT EQUITY | 0.0813 | ALL HEDGE FUND INDEX | 0.0018 |
| ALL HEDGE FUND INDEX | 0.0130 | ALL HEDGE FUND INDEX | 0.0069 | EVENT DRIVEN DISTRESSED | 0.0915 | EVENT DRIVEN DISTRESSED | 0.0018 |
| EVENT DRIVEN DISTRESSED | 0.0048 | EVENT DRIVEN DISTRESSED | 0.0025 | MULTI STRATEGY | 0.0970 | BARCLAYS US AGG BOND | 0.0011 |
| MULTI STRATEGY | -0.0047 | MULTI STRATEGY | -0.0025 | S&P 500 | 0.1203 | MULTI STRATEGY | 0.0011 |
| FIXED INCOME ARBITRAGE | -0.0406 | FIXED INCOME ARBITRAGE | -0.0208 | EMERGING MARKETS | 0.1245 | MSCI WORLD | 0.0007 |
| MSCI WORLD | -0.0441 | MSCI WORLD | -0.0256 | MSCI WORLD | 0.1264 | FIXED INCOME ARBITRAGE | -0.0011 |
| S&P 500 | -0.0556 | S&P 500 | -0.0326 | FIXED INCOME ARBITRAGE | 0.1287 | DEDICATED SHORT BIAS | -0.0046 |
| DEDICATED SHORT BIAS | -0.0590 | DEDICATED SHORT BIAS | -0.0389 | EQUITY MARKET NEUTRAL | 0.1343 | EQUITY MARKET NEUTRAL | -0.0073 |
| EQUITY MARKET NEUTRAL | -0.1279 | EQUITY MARKET NEUTRAL | -0.0679 | CONVERTIBLE ARBITRAGE | 0.1471 | S&P 500 | |

Table 13: Evaluation of hedge funds' performance for the post-crisis period 2010-2012

| 2010-2012 | Sharpe Ratio | | Modified Sharpe Ratio | | Modified VaR | | Jensen's a |
|-----------------------------|--------------|-----------------------------|-----------------------|-----------------------------|--------------|-----------------------------|------------|
| FIXED INCOME ARBITRAGE | 0.9831 | FIXED INCOME ARBITRAGE | 0.3435 | BARCLAYS US AGG BOND | 0.0093 | FIXED INCOME ARBITRAGE | 0.0058 |
| GLOBAL MACRO | 0.6268 | GLOBAL MACRO | 0.2725 | FIXED INCOME ARBITRAGE | 0.0186 | GLOBAL MACRO | 0.0056 |
| MULTI STRATEGY | 0.3566 | MULTI STRATEGY | 0.1623 | EVENT DRIVEN RISK-ARBITRAGE | 0.0187 | ALL HEDGE FUND INDEX | 0.0033 |
| CONVERTIBLE ARBITRAGE | 0.2857 | CONVERTIBLE ARBITRAGE | 0.1352 | GLOBAL MACRO | 0.0210 | MULTI STRATEGY | 0.0031 |
| ALL HEDGE FUND INDEX | 0.1947 | ALL HEDGE FUND INDEX | 0.0992 | EQUITY MARKET NEUTRAL | 0.0248 | CONVERTIBLE ARBITRAGE | 0.0026 |
| S&P 500 | 0.1866 | S&P 500 | 0.0947 | MULTI STRATEGY | 0.0331 | MANAGED FUTURES | 0.0018 |
| EVENT DRIVEN DISTRESSED | 0.1684 | EVENT DRIVEN DISTRESSED | 0.0826 | ALL HEDGE FUND INDEX | 0.0336 | EVENT DRIVEN DISTRESSED | 0.0005 |
| EMERGING MARKETS | 0.1461 | EMERGING MARKETS | 0.0719 | CONVERTIBLE ARBITRAGE | 0.0340 | EMERGING MARKETS | 0.0002 |
| MSCI WORLD | 0.1287 | MSCI WORLD | 0.0676 | MANAGED FUTURES | 0.0419 | EVENT DRIVEN RISK-ARBITRAGE | -0.0002 |
| EVENT DRIVEN RISK-ARBITRAGE | 0.1113 | EVENT DRIVEN RISK-ARBITRAGE | 0.0605 | EVENT DRIVEN DISTRESSED | 0.0435 | EVENT DRIVEN | -0.0013 |
| LONG/SHORT EQUITY | 0.1012 | LONG/SHORT EQUITY | 0.0546 | LONG/SHORT EQUITY | 0.0500 | EQUITY MARKET NEUTRAL | -0.0013 |
| EVENT DRIVEN | 0.0987 | EVENT DRIVEN | 0.0525 | EMERGING MARKETS | 0.0518 | BARCLAYS US AGG BOND | -0.0013 |
| MANAGED FUTURES | 0.0772 | MANAGED FUTURES | 0.0430 | EVENT DRIVEN | 0.0522 | LONG/SHORT EQUITY | -0.0016 |
| EVENT DRIVEN MULTI-STRATEGY | 0.0748 | EVENT DRIVEN MULTI-STRATEGY | 0.0411 | EVENT DRIVEN MULTI-STRATEGY | 0.0588 | EVENT DRIVEN MULTI-STRATEGY | -0.0022 |
| EQUITY MARKET NEUTRAL | 0.0448 | EQUITY MARKET NEUTRAL | 0.0252 | DEDICATED SHORT BIAS | 0.0624 | MSCI WORLD | -0.0025 |
| BARCLAYS US AGG BOND | -0.2364 | BARCLAYS US AGG BOND | -0.1261 | S&P 500 | 0.0962 | DEDICATED SHORT BIAS | -0.0046 |
| DEDICATED SHORT BIAS | -0.2579 | DEDICATED SHORT BIAS | -0.1969 | MSCI WORLD | 0.0992 | S&P 500 | |

The years 2007-2009 could be characterized as the "core" of the crisis, with the returns of all asset classes to be shrinking even more, comparing to the previously examined, greater crisis period (2007-2012). Many hedge fund strategies as well as both equity indexes experience negative returns, while bonds rank first in almost all the risk indicators. Global Macro and Event Driven Risk Arbitrage are the best performing investment styles. On the contrary, Equity Market Neutral which was delivering superior returns during the Bull Market is now experiencing losses and ranks last among all the investment categories. Modified Sharpe Ratio indicates again big differences in returns relatively to the classic Sharpe Ratio which means that skewness and kurtosis still exist during this period. Also, the results based on the MVAR and Jensen's alpha do not deviate a lot from the picture that we have already created based on the MSR. The main conclusion is that most hedge fund strategies remain less risky than equities while they manage to deliver excess returns comparing to the S&P 500.

To conclude, we observe that if we isolate the core of the crisis era, hedge funds constantly outperform equities but not bonds. Bonds, during this period manage to deliver superior returns over all the assets that are examined, something that is a significant deviation from the results that we acquired by investigating the period 2007-2012. As far as we are concerned, this is the first time that the comparison of the "corrected" hedge fund returns with equities and bonds during the crisis period reports a superior bond performance over the hedge fund strategies. This is going to be major contribution of this study to the existing literature.

The same or even more interesting results are obtained when we examine the post-crisis era (2010-2012) or otherwise the period that the global economy is trying to recover from the shock of the crisis. The first observation is that the returns of all the assets except that of the bonds explode comparing to the years 2007-2009. Fixed Income Arbitrage and Multi Strategy are now the best performing styles while in the years 2007-2009 they had negative returns. Also, this is the first time that MSCI World but mainly the S&P 500, are observed to outperform most of the hedge fund strategies. This observation is compatible with the Goldman Sachs annual report (2012) which indicates that hedge funds missed a big part of the Bull Market in the post-crisis era. According to the same report, many hedge fund managers were quite conservative and risk averse during that period. This happened because of the great losses that they had suffered in the previous years (2007-2009) when S&P 500 index experienced a loss of 57%. Also, the monetary policy of the Federal Reserves managed to "confuse" the funds which invest mainly based on their estimations on the political and financial situation. By printing money, FED put the markets in an upward trend while the macroeconomic analysis in which the hedge funds were based on indicated the opposite. The superior performance of equities over hedge funds in the post crisis period is a very important contribution of this research to the existing literature. This is one of the few times that these years are isolated, so to be examined in-depth and as a standalone era. Also, this is the first period (2010-2012) after the year 2000 that equities manage to report excess returns over most of the hedge fund strategies. Sharpe Ratio, Modified Sharpe Ratio and alpha indicator reach to identical results. Most hedge funds do not outperform equities and fail to deliver positive alphas. The quantitative difference in the reported results between the 2 Sharpe Ratio is getting even bigger, so we conclude that the presence of fat tails is increasing. Moreover, MVAR indicates that equities remain riskier than all the other asset classes and bonds experience negative returns while during the previous 3 years they were the best performing asset.

In conclusion it is proved that the separation of the greater crisis period (2007-2012) into two sub-periods was a wise choice. The results that we obtain for each period are very diverse to each other and contribute to the better understanding and analysis of hedge fund performance in the different states of the economy.

Some general remarks, after the analysis of all the 4 periods are that hedge funds' strategies outperform both equities and bonds during the Bull Market as well as in the years 2007-2012. However, when we examine the core years of the crisis, namely 2007-2009, they underperform bonds.

Chapter 4: Regression analysis and Optimal Risky Portfolio Creation

In this chapter it will be conducted the second research part of our study. More analytically, we will examine how the various hedge fund strategies relate with equities and bonds. The methodology that we are going to use is the same with the one of the previous chapter. Initially, it will be investigated the dependency of each investment style to the other asset classes during the two main periods namely the pre-crisis, Bull Market era (2002-2006) and the greater crisis period (2007-2012). Then, the crisis era will be split again into two sub-periods, the 2007-2009 and the 2010-2012 in order to examine if there are significant changes between the core years of the crisis and the years that the economy is recovering. Based on the above results we will be able to decide whether or not the addition of hedge funds in a portfolio allocation can contribute to a better diversification. Then we will create Optimal Risky Portfolios by using the Markowitz framework so to check how the results that we have already obtained from the regression analysis can be implemented in practice.

4.1 Regression analysis

For the first part of our investigation, we will conduct 14 time series regressions, for each one of the 4 different periods, by using STATA. Each regression will have as independent variables the S&P 500, the MSCI World and the Barclays US Agg Bond Index while as dependent variable, each time will be used a different hedge fund investment style. In this way, we will be able to elaborate on how each strategy interacts with the other asset classes in the different states of the economy. The existing literature on the field, such as Liang (1999), Agarwal-Naik (2000) and Amin-Kat (2001) has mainly investigated the correlation between the hedge funds with the other assets. What we are going to do is to regress the returns of the different hedge fund strategies, one strategy each time, with the returns of the 3 indexes which represent a different asset class. In this way, we will be able to elaborate on how each strategy interacts with the other asset classes when the situation of the economy is changing, as well as their combined effects. Of course, regression results cannot be interpreted in the same way with those of a correlation analysis, so our findings are not directly comparable with the aforementioned studies. However, a regression can represent in a better way and to give more detailed information for the explanatory power and the dependency level among the variables. The below tables present the regression results for the periods 2002-2006 and 2007-2012.

The values in brackets indicate the t-statistic of each variable.

Tables 14-15: Time series regressions for the periods 2002-2006 and 2007-2012. The values in the brackets indicate the t-statistics of each variable.

| <i>Regression 2002-2006</i> | ALL HEDGE FUND INDEX | CONVERTIBLE ARBITRAGE | DEDICATED SHORT BIAS | EMERGING MARKETS | EQUITY MARKET NEUTRAL | EVENT DRIVEN | EVENT DRIVEN DISTRESSED | EVENT DRIVEN MULTI-STRATEGY | EVENT DRIVEN RISK-ARBITRAGE | FIXED INCOME ARBITRAGE | GLOBAL MACRO | LONG/SHORT EQUITY | MANAGED FUTURES | MULTI STRATEGY |
|-----------------------------|-------------------------|--------------------------|-------------------------|---------------------|--------------------------|--------------------|----------------------------|--------------------------------|--------------------------------|---------------------------|-------------------|----------------------|--------------------|--------------------|
| S&P 500 | -0.3908 [-3.44] | -0.2808 [-1.17] | -0.1302 [-0.28] | -0.4054 [-1.73] | -0.2439 [-3.11] | -0.0616 [-0.39] | -0.0130 [-0.06] | -0.1015 [-0.67] | -0.2025 [-1.48] | -0.4065 [-2.79] | -0.2878 [-2.2] | -0.5568 [-3.42] | -1.1568 [-2.17] | -0.2737 [-2.33] |
| MSCI WORLD | 0.6522 [5.94] | 0.4368 [1.88] | -0.9011 [-2.02] | 0.9229 [4.08] | 0.2312 [3.05] | 0.4516 [2.99] | 0.4322 [2.22] | 0.4430 [3.01] | 0.4446 [3.37] | 0.3873 [2.75] | 0.3227 [2.55] | 1.0025 [6.47] | 1.1600 [2.25] | 0.5025 [4.42] |
| BARCLAYS US AGG BOND | 0.6881 [2.98] | 1.1854 [2.42] | -0.9011 [0.17] | 0.6208 [1.3] | -0.0510 [-0.32] | 0.8693 [2.74] | 1.0188 [2.49] | 0.7477 [2.41] | 0.1356 [0.49] | -0.1478 [-0.5] | 0.4092 [1.54] | 0.7557 [2.28] | 1.9153 [1.77] | 0.7453 [3.11] |
| INTERCEPT | 0.0037 [3.06] | 0.0018 0.68 | 0.0059 1.19 | 0.0069 [2.74] | 0.0055 [6.56] | 0.0050 [2.96] | 0.0059 [2.71] | 0.0049 [2.99] | 0.0006 0.43 | 0.0038 [2.43] | 0.0085 [6.02] | 0.0017 1 | 0.0025 0.44 | 0.0047 [3.73] |

| <i>Regression 2007-2012</i> | ALL HEDGE FUND INDEX | CONVERTIBLE ARBITRAGE | DEDICATED SHORT BIAS | EMERGING MARKETS | EQUITY MARKET NEUTRAL | EVENT DRIVEN | EVENT DRIVEN DISTRESSED | EVENT DRIVEN MULTI-STRATEGY | EVENT DRIVEN RISK-ARBITRAGE | FIXED INCOME ARBITRAGE | GLOBAL MACRO | LONG/SHORT EQUITY | MANAGED FUTURES | MULTI STRATEGY |
|-----------------------------|-------------------------|--------------------------|-------------------------|---------------------|--------------------------|--------------------|----------------------------|--------------------------------|--------------------------------|---------------------------|-------------------|----------------------|--------------------|--------------------|
| S&P 500 | -0.7202 [-3.67] | -1.3054 [-2.87] | -0.1429 [-0.41] | -1.4066 [-4.98] | 0.8961 [2] | -0.5965 [-2.62] | -0.4538 [-1.83] | -0.6705 [-2.86] | -0.4111 [-3.51] | -1.0246 [-2.58] | -0.5588 [-2.7] | -0.8688 [-4.44] | -0.6305 [-2.13] | -0.6972 [-2.63] |
| MSCI WORLD | 1.0176 [5.43] | 1.6047 [3.7] | -0.4088 [-1.23] | 1.8373 [6.81] | -0.4736 [-1.11] | 0.8966 [4.12] | 0.8193 [3.45] | 0.9501 [4.24] | 0.5415 [4.84] | 1.3195 [3.47] | 0.6083 [3.07] | 1.2279 [6.56] | 0.5679 [2.03] | 1.0301 [4.07] |
| BARCLAYS US AGG BOND | 0.3361 [0.92] | 0.9679 [1.14] | 0.1943 [0.3] | 0.7143 [1.36] | -0.0521 [-0.06] | -0.0515 [-0.12] | 0.0814 [0.18] | -0.0604 [-0.14] | 0.2276 [1.04] | -0.0140 [-0.02] | 0.2132 [0.55] | 0.3412 [0.94] | 0.1403 [0.26] | 0.9414 [1.91] |
| INTERCEPT | 0.0027 [1.13] | 0.0030 [0.54] | -0.0048 [-1.12] | 0.0027 [0.78] | -0.0050 [-0.91] | 0.0033 [1.18] | 0.0024 [0.77] | 0.0038 [1.32] | 0.0031 [2.12] | 0.0032 [0.66] | 0.0066 [2.59] | 0.0021 [0.88] | 0.0039 [1.08] | 0.0023 [0.71] |

Regarding the first period under examination, namely the Bull Market era (2002-2006), we observe that all strategies relate negatively with the S&P 500. Based on the coefficients that we acquire from the regression we see that the level of dependency is not that strong while in many cases the results are statistically insignificant on the 5% confidence level. Managed Futures is the strategy which appears the highest dependency with the S&P 500 during this period. In the same time, interaction with the MSCI World is always positive, a little bit stronger than that with the S&P and also statistically significant. The difference in the signs of the coefficients between the 2 equity indexes can be attributed to the discrepancies in their composition and structure. S&P includes only 500 prominent US stocks while MSCI is comprised by stocks from 24 developed markets around the world. It seems more possible that most hedge fund strategies relate in a positive and stronger way with the world stock markets that they do with the US one. The regression results for this period also reveal a positive relation of hedge funds with bonds. This means that when the economy is in a good state, the movements in the bond market can explain up to a certain level changes in the hedge funds returns. To conclude, for the years 2002-2006 hedge funds appear a semi-strong and positive interaction with the World Stock as well as with the US bond markets while their dependency to the S&P 500 is negative but relatively weak. In correlation terms we could say that in the pre-crisis era, most possibly, there is a positive but not strong correlation with MSCI World. On the contrary, correlation with S&P 500 and Barclays US Agg is negative and positive respectively, but as many of the results are statistically insignificant we assume that it is low.

Referring to the second table which presents the regression results for the crisis period, we observe that relationship between hedge funds and S&P remains negative, but this time it is stronger and also statistically significant. Convertible Arbitrage and Emerging Markets are the strategies with the highest level of dependency. Regressions' results also indicate a strong and positive relation of hedge funds with the MSCI World. Many strategies such as the Convertible Arbitrage, the Emerging Market and the Fixed Income Arbitrage appear high levels of dependency to this index. The difference in the signs between the 2 equity indexes' interaction with hedge funds can be attributed to the same reason that we have already explained above. The coefficients of the Barclays index are all statistically insignificant so no further analysis is needed. If we try to interpret these results in correlation terms, so to compare them with the existing literature, we could say that during the crisis there is a semi-strong, negative correlation with the US equity market (S&P 500) while correlation with the world stock market is high and positive. During these years it seems that there is no correlation between hedge funds and bonds.

By comparing the above 2 periods we can conclude that correlation with equities during the crisis increases, even not always in the same way. In the same time correlation with bonds in the first period is low while during the greater crisis period it doesn't exist.

Following the methodology that we used in chapter 3, we are going to divide again the crisis era into 2 periods, the 2007-2009 and 2010-2012 whose results are presented in the below tables.

Tables 16-17: Time series regressions for the periods 2007-2009 and 2010-2012. The values in the brackets indicate the t-statistics of each variable.

| <i>Regression 2007-2009</i> | ALL HEDGE FUND INDEX | CONVERTIBLE ARBITRAGE | DEDICATED SHORT BIAS | EMERGING MARKETS | EQUITY MARKET NEUTRAL | EVENT DRIVEN | EVENT DRIVEN DISTRESSED | EVENT DRIVEN MULTI-STRATEGY | EVENT DRIVEN RISK-ARBITRAGE | FIXED INCOME ARBITRAGE | GLOBAL MACRO | LONG/SHORT EQUITY | MANAGED FUTURES | MULTI STRATEGY |
|-----------------------------|-------------------------|--------------------------|-------------------------|---------------------|--------------------------|--------------------|----------------------------|--------------------------------|--------------------------------|---------------------------|--------------------|----------------------|--------------------|--------------------|
| S&P 500 | -1.2374 [-3.37] | -2.0545 [-2.37] | 0.1228 [0.23] | -2.6623 [-4.8] | 1.5273 [1.85] | -0.9836 [-2.65] | -0.9366 [-2.01] | -0.9686 [-2.9] | -0.6052 [-2.48] | -1.8454 [-2.71] | -0.9232 [-2.45] | -1.5602 [-4.47] | -0.5206 [-1.1] | -1.2909 [-2.48] |
| MSCI WORLD | 1.5617 [4.4] | 2.3690 [2.83] | -0.5240 [-1] | 3.0752 [5.8] | -1.0180 [-1.28] | 1.2272 [3.43] | 1.3253 [2.95] | 1.1591 [3.59] | 0.7164 [3.05] | 2.2349 [3.41] | 1.0028 [2.75] | 1.8630 [5.53] | 0.4474 [0.98] | 1.6416 [3.27] |
| BARCLAYS US AGG BOND | 1.2843 [1.97] | 2.0014 [1.3] | 0.1215 [0.13] | 1.8225 [1.87] | 0.3124 [0.21] | 0.4765 [0.72] | 1.1461 [1.38] | 0.2718 [0.46] | 0.5292 [1.22] | 1.1233 [0.93] | 1.0474 [1.56] | 0.6804 [1.1] | 0.2627 [0.31] | 2.2971 [2.49] |
| INTERCEPT | -0.0017 [-0.34] | -0.0037 [-0.31] | -0.0023 [-0.3] | -0.0033 [-0.44] | -0.0065 [-0.57] | 0.0020 [0.39] | -0.0013 [-0.21] | 0.0037 [0.8] | 0.0029 [0.87] | -0.0048 [-0.51] | 0.0027 [0.52] | 0.0003 [0.06] | 0.0036 [0.55] | -0.0053 [-0.74] |

| <i>Regression 2010-2012</i> | ALL HEDGE FUND INDEX | CONVERTIBLE ARBITRAGE | DEDICATED SHORT BIAS | EMERGING MARKETS | EQUITY MARKET NEUTRAL | EVENT DRIVEN | EVENT DRIVEN DISTRESSED | EVENT DRIVEN MULTI-STRATEGY | EVENT DRIVEN RISK-ARBITRAGE | FIXED INCOME ARBITRAGE | GLOBAL MACRO | LONG/SHORT EQUITY | MANAGED FUTURES | MULTI STRATEGY |
|-----------------------------|-------------------------|--------------------------|-------------------------|---------------------|--------------------------|--------------------|----------------------------|--------------------------------|--------------------------------|---------------------------|--------------------|----------------------|--------------------|--------------------|
| S&P 500 | 0.1397 [0.51] | -0.2208 [-1.29] | -0.7596 [-2.19] | -0.2937 [-1.3] | -0.1388 [-1.02] | -0.0576 [-0.24] | 0.0085 [0.04] | -0.0837 [-0.3] | -0.1646 [-1.86] | -0.1200 [-1.38] | -0.1599 [-1.17] | 0.0208 [0.12] | -0.5082 [-1.46] | -0.0637 [-0.52] |
| MSCI WORLD | -0.1207 [-0.47] | 0.4273 [2.66] | -0.1097 [-0.34] | 0.6717 [3.19] | 0.3406 [2.67] | 0.4991 [2.22] | 0.3307 [1.82] | 0.5914 [2.23] | 0.3098 [3.74] | 0.1780 [2.2] | 0.1729 [1.35] | 0.4543 [2.8] | 0.5056 [1.55] | 0.3059 [2.68] |
| BARCLAYS US AGG BOND | -0.4905 [-0.81] | -0.4258 [-1.12] | 2.0697 [2.7] | -0.7191 [-1.44] | -0.1022 [-0.34] | -1.1986 [-2.25] | -0.7427 [-1.73] | -1.5537 [-2.48] | -0.3931 [-2.01] | 0.0235 [0.12] | -0.5277 [-1.74] | -1.4084 [-3.67] | -1.2130 [-1.58] | -0.5846 [-2.16] |
| INTERCEPT | 0.0032 [1.05] | 0.0040 [2.08] | -0.0029 [-0.74] | 0.0017 [0.68] | -0.0002 [-0.16] | -0.0003 [-0.13] | 0.0012 [0.55] | -0.0012 [-0.36] | 0.0010 [0.98] | 0.0068 [6.88] | 0.0066 [4.25] | -0.0005 [-0.24] | 0.0032 [0.82] | 0.0041 [2.99] |

What we observe is an even stronger and again negative relationship between the hedge funds' returns and the returns of the S&P 500. The vast majority of these results are statistically significant at the 5% confidence level. The same strong dependency, but this time positive, exists between all the strategies and the MSCI World index. It looks like, when the crisis is at its peak, the interaction between the equity indexes and the hedge funds styles significantly increases. The biggest dependency levels are the ones of the Convertible Arbitrage and the Emerging Markets. However, it doesn't happen the same with the bonds as almost all the coefficients are far from being significant. In correlation terms we could say that it is quite high with equities while there is no correlation with bonds. Finally, for the post-crisis period (2010-2012) the dependency level among hedge funds and the other assets disappears. More analytically, there is only a low level of interaction with the returns of the MSCI World while regarding to the S&P the regression results that we obtain are not statistically significant. Quite interesting is the analysis for the bonds as sometimes it is observed negative relationship, but in most cases it is neither strong nor significant.

To conclude, based on the regression analysis for the 4 periods we observe that for the pre-crisis (2002-2006) and the post-crisis (2010-2012) years, the interaction between hedge fund returns and the returns of the other asset classes either it is relatively small (Bull market) or it almost doesn't exist (post-crisis). Nevertheless, it doesn't happen the same during the crisis. Especially for the years 2007-2009 there is a quite strong dependency to the equities returns. In general terms, our results are identical with the existing literature, which suggests low correlation of hedge funds with equities and bonds. The only significant difference is that during crisis correlation with equities is strong, and more specifically negative with S&P 500 and positive with the MSCI World

4.2 Asset allocation - Optimal Risky Portfolio Creation

In the last part of our research, we are going to investigate if the addition of hedge funds in a portfolio contributes to a better diversification and a more efficient asset allocation. To do so, we will create Optimal Risky Portfolios based on the Markowitz framework, by using the Solver function in excel. In this way we will be able to decide how the regression results which reveal the level of dependency among the assets can be applied in practice. In other words, by examining the constitution of the risky portfolios during the different periods, we can observe how the superior hedge fund returns and their low interaction with other assets that we have already proved can be interpreted in terms of a portfolio allocation.

The Modern Portfolio Theory (MPT) was introduced by Harry Markowitz in 1952. It is a theory of finance that attempts to maximize the portfolio's returns while in the same time to minimize the level of risk by carefully choosing the proportion of assets in the portfolio allocation. According to this theory, diversification in investing can lower the risk of a portfolio comparing to an individual asset for a certain level of expected returns. Portfolio's returns are calculated as a weighted combination of assets' returns while risk is defined as the returns' standard deviation. Moreover, the two main hypotheses of the MPT are that investors are rational and the markets efficient. These two assumptions have been questioned recently by the behavioral economics.

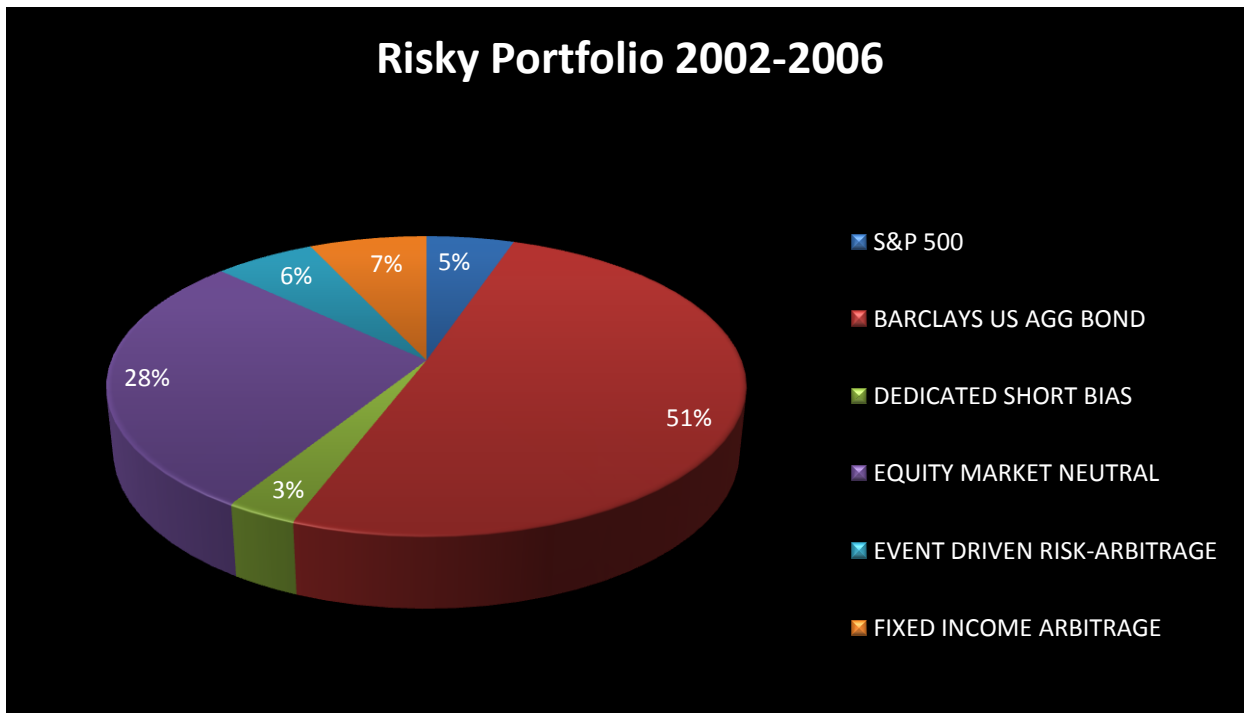
For the scope of our research we will create only the Optimal Risky Portfolios for each period and not the Optimal Complete Portfolios. This means that we are not going to have any allocation to the risk free asset and we will not need to make any assumptions for the risk aversion level (A) of the investor.

For one more time, we will follow the methodology that we used so far in our analysis. Initially, we will create the Optimal Portfolios for the years 2002-2006 and 2007-2012. Then we will split the crisis years into 2 sub-periods, namely the 2007-2009 and the 2010-2012.

Below is presented the constitution of the Risky Portfolios for the first two periods.

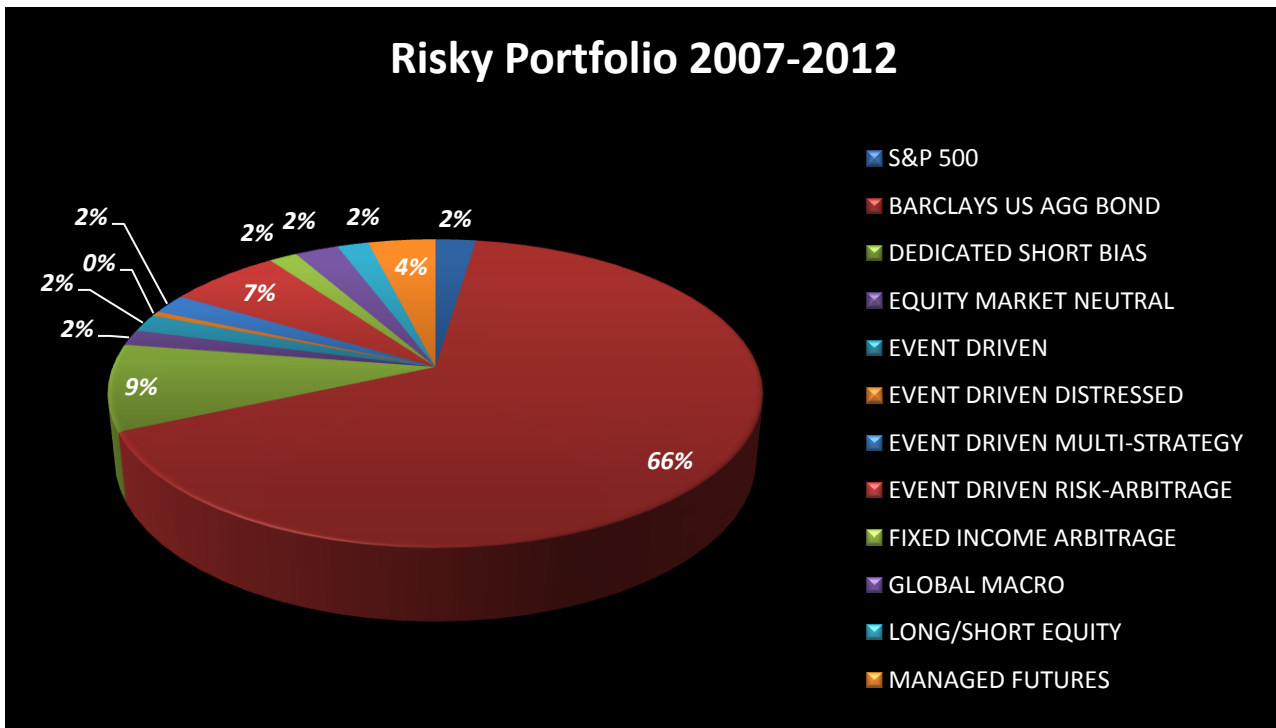
| Optimal Risky Portfolio 2002-2006 | Weights |
|--|---------|
| <i>S&P 500</i> | 5.22% |
| <i>BARCLAYS US AGG BOND</i> | 50.59% |
| <i>DEDICATED SHORT BIAS</i> | 3.11% |
| <i>EQUITY MARKET NEUTRAL</i> | 28.09% |
| <i>EVENT DRIVEN RISK-ARBITRAGE</i> | 5.98% |
| <i>FIXED INCOME ARBITRAGE</i> | 7.00% |
| | 100.00% |

| Period 2002-2006 | |
|---------------------------|---------|
| Portfolio variance | 0.00001 |
| Portfolio SD | 0.00328 |
| Portfolio Mean | 0.00291 |
| Sharpe Ratio | 0.27656 |
| Rf | 0.00200 |



| Optimal Risky Portfolio 2007-2012 | Weights |
|--|---------|
| S&P 500 | 2.35% |
| BARCLAYS US AGG BOND | 66.03% |
| DEDICATED SHORT BIAS | 9.06% |
| EQUITY MARKET NEUTRAL | 1.65% |
| EVENT DRIVEN | 1.87% |
| EVENT DRIVEN DISTRESSED | 0.49% |
| EVENT DRIVEN MULTI-STRATEGY | 2.09% |
| EVENT DRIVEN RISK-ARBITRAGE | 6.55% |
| FIXED INCOME ARBITRAGE | 1.63% |
| GLOBAL MACRO | 2.54% |
| LONG/SHORT EQUITY | 1.82% |
| MANAGED FUTURES | 3.92% |
| | 100.00% |

| Period 2007-2012 | |
|---------------------------|----------|
| Portfolio variance | 1.00004 |
| Portfolio SD | 1.00002 |
| Portfolio Mean | 0.00101 |
| Sharpe Ratio | -0.00699 |
| Rf | 0.00800 |



Referring to the pre-crisis era (2002-2006), the Risky Portfolio is comprised by 51% allocation to bonds, 28% to the Equity Market Neutral strategy, 5% in US equities (S&P 500) and 16% in other hedge fund investment styles. In this period there is no allocation to the MSCI World. This is something that we expected because of the very high relationship of the world equities with hedge funds. As far as hedge funds outperform the MSCI index, its presence in an Optimal Risky Portfolio neither contributes to the further diversification nor adds value to the portfolio, so it is exempted from our asset allocation. On the contrary, interaction of hedge funds with bonds exists but it is relatively low. That's why 50% of our allocation is to bonds.

For the years 2007-2012, our allocation in bonds increases even more as there is almost no dependency between their returns and the returns of the hedge funds. Also, the representation of the S&P 500 is only 2% while MSCI still does not offer any diversification advantage. The reason is that both equity indexes highly interact with all the hedge fund investment styles. Moreover, the allocation in hedge funds is 31% with Dedicated Short Bias (9%) and Event Driven Risk Arbitrage (6%) to be the strategies that prevail. Comparing to the Bull Market period there is a decline in the hedge fund allocation from 44% to 31%. This means that during these years, hedge fund strategies lose a part of their diversification power because of their higher interaction, mainly with equities.

In order to better examine the crisis era we will split it into two different periods. Below is presented the asset allocation of the Optimal Risky Portfolios for the years 2007-2009 and 2010-2012 as well as their graphical representation.

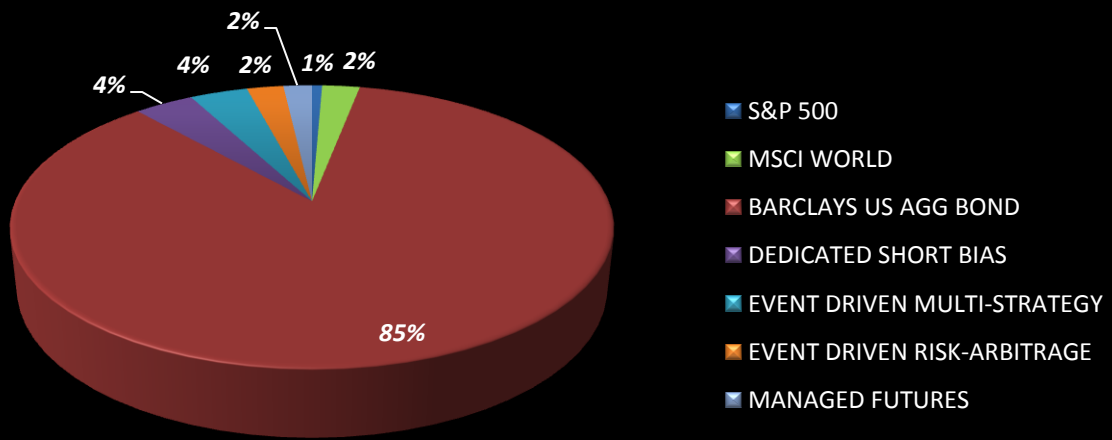
| Optimal Risky Portfolio 2007-2009 | Weights |
|--|---------|
| <i>S&P 500</i> | 0.65% |
| <i>MSCI WORLD</i> | 2.40% |
| <i>BARCLAYS US AGG BOND</i> | 85.33% |
| <i>DEDICATED SHORT BIAS</i> | 3.78% |
| <i>EVENT DRIVEN MULTI-STRATEGY</i> | 3.68% |
| <i>EVENT DRIVEN RISK-ARBITRAGE</i> | 2.34% |
| <i>MANAGED FUTURES</i> | 1.82% |
| | 100.00% |

| Period 2007-2009 | |
|---------------------------|---------|
| Portfolio variance | 0.00005 |
| Portfolio SD | 0.00677 |
| Portfolio Mean | 0.00264 |
| Sharpe Ratio | 0.15326 |
| Rf | 0.00160 |

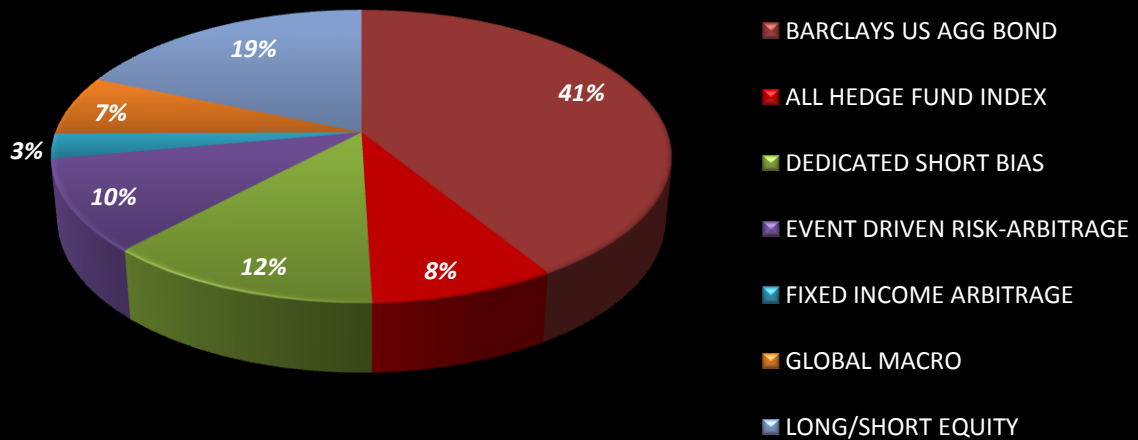
| Optimal Risky Portfolio 2010-2012 | Weights |
|--|---------|
| <i>BARCLAYS US AGG BOND</i> | 41.19% |
| <i>ALL HEDGE FUND INDEX</i> | 8.34% |
| <i>DEDICATED SHORT BIAS</i> | 12.44% |
| <i>EVENT DRIVEN RISK-ARBITRAGE</i> | 10.14% |
| <i>FIXED INCOME ARBITRAGE</i> | 2.73% |
| <i>GLOBAL MACRO</i> | 6.60% |
| <i>LONG/SHORT EQUITY</i> | 18.55% |
| | 100.00% |

| Period 2010-2012 | |
|---------------------------|----------|
| Portfolio variance | 0.00001 |
| Portfolio SD | 0.00264 |
| Portfolio Mean | 0.00014 |
| Sharpe Ratio | -0.21243 |
| Rf | 0.00070 |

Risky Portfolio 2007-2009



Risky Portfolio 2010-2012



In the first period (2007-2009), when the effects of the financial crisis on the economy are more intense and severe, we observe that the vast majority of our allocation (85%) will be to bonds. In the same time, the allocation to equities is limited to 3% in total, while to hedge funds only to 11%. The extremely high allocation to bonds during this era can be attributed to the fact that bonds performed quite well and delivered higher returns comparing to equities and hedge funds. Moreover they are not correlated at all with any of the other asset classes. On the contrary, the level of dependency between equities and hedge funds is relatively high, that's how it can be explained their little representation in our portfolio. During the core years of the crisis, even many hedge fund strategies manage to deliver positive returns; their high interaction with equities doesn't permit to them to contribute to the further diversification of a portfolio.

Finally, the picture for the allocation of the years 2010-2012 greatly changes. The percentage of bonds in our portfolio is limited to 40% while the allocation to hedge funds is the highest so far in our research as it rises to 58%. The strategies that prevail are the Long-Short Equity and the Dedicated Short Bias with an allocation of 19% and 12,5% respectively. Investment styles like Global Macro and Event-Driven Risk Arbitrage also have an important share in the constitution of the Optimal Risky portfolio.

In conclusion in the post crisis period, hedge funds can offer great diversification advantages, which are even higher than the ones of the pre-crisis, Bull Market era.

Chapter 5: Conclusions

In this study, we attempted to investigate how the performance of the different hedge fund strategies was affected by the recent financial crisis. To do so, after that we corrected hedge funds returns for the effects of autocorrelation, biases and fat tails, we evaluated their performance by using various risk measures like Sharpe ratio, Jensen's α as well as Modified Sharpe Ratio and VaR. Based on the above risk measures, we compared hedge fund returns with the returns of equities and bonds, which in our research were represented by the indexes S&P 500, MSCI World and Barclays US Agg. Bond. We repeated this procedure for 4 different periods. Our purpose was to isolate the crisis era so to be able to calculate more accurately the effects of the financial crisis on hedge funds returns.

We documented that hedge funds lose a very big part of their attractiveness when their returns are corrected for serial correlation and fat tails. However, even after these corrections they exhibit lower standard deviation than equities. Moreover, most of the hedge fund strategies with the exception of the Dedicated Short Bias, deliver higher returns than equities and bonds during the years 2002-2006 and 2007-2012. Nevertheless, when the greater crisis era is split into the "core" crisis years (2007-2009) and the years that the economy is recovering (2010-2012), the picture partially changes. During the crisis period, hedge funds still outperform equities but not bonds. This is the first time that bonds are observed to deliver higher returns than hedge funds. The best performing strategies in this period are the Global Macro and the Event-Driven Risk Arbitrage while Dedicated Short Bias is still the worst performing investment style. Things greatly change in the post crisis period (2010-2012). According to the limited reported results for this period, hedge funds appear to lose a very big part of the Bull Market that followed the financial crisis. Our study comes to reinforce these results. Many hedge fund strategies did better than bonds but failed to outperform equities. Fixed Income Arbitrage and Dedicated Short Bias were the best and worst performing strategies respectively.

Regarding to the level of dependency among the returns of the different asset classes our results reveal a low interaction of hedge fund returns with the ones of equities and bonds in the pre-crisis and post-crisis periods. However, during the years of the financial crisis, correlation with equities is quite strong, especially for the Convertible Arbitrage and the Emerging Markets strategies. Finally, we observed that the addition of hedge funds in an asset allocation can contribute to the further portfolio, diversification, for the years 2002-2006 and 2010-2012. However, this is not the case during the "core" years of the crisis (2007-2009) where hedge fund strategies fail to add value to an Optimal Risky Portfolio.

To conclude, we could say that in general, hedge funds perform much better than equities and bonds while they exhibit lower standard deviation. Nevertheless, if we would like to focus solely on the crisis era which is the main field of interest of this study, we observe that this is not the case. Even if they manage to outperform equities, their high correlation with them during that period takes away any diversification power that they have. This means that in practice, their superior returns so subsequently their addition in an asset allocation; cannot be interpreted in a better portfolio performance.

The major contribution of our research to the existing literature is that we attempted to assess the attractiveness of the hedge funds returns during two barely explored periods, the crisis and the post crisis years. Evidences, like the outperformance of bonds as well as the high correlation of hedge fund strategies with equities during the years 2007-2009 are reported for first time and can be the basis for a further investigation in the future. Moreover, our results gain in credibility and accuracy as we accounted and corrected for many of the effects that can be observed on hedge fund returns. Until now, most studies were trying to resolve only one of the aforementioned effects. Finally, this is also one of the first times that equities are reported to deliver superior returns comparing to most of the hedge funds investment styles in a specific period, namely the Bull Market that succeeded the crisis era.

Our study is subjected to some limitations which can also be perceived as recommendations for future research. The first important limitation is that historically it has been proved that the selection of the database for the hedge funds returns is a very important determinant for the quality of the reported results. Different databases many times give different results. In our research we used data from the DJCS which is considered to be among the best databases. However it would be interesting to examine if a similar analysis would be conducted on returns taken from other databases would reach to the same conclusions with our study.

The second restriction is that we had access to very limited information as hedge funds do not reveal almost anything about their activities. Nevertheless, in case that somebody has access to a more detailed data, it would be very useful to investigate how hedge funds' performance is affected by factors like the age, the size (AUM) and the region that a fund invest in. A last recommendation is a deeper research on the reasons that the Dedicated Short Bias strategy persistently delivers the lowest returns in all the states of the economy and also why some managers still chose to invest in this strategy.

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