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The higher-moment CAPM and multi-factor models: Comparing hedge funds and mutual funds

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Abstract

Since its introduction, the CAPM has been undergoing numerous attempts to increase the model's explanatory power and add additional significant factors, which play a role in describing the variation of financial assets' returns. Two of the most prominent model extensions are the four-factor model and the higher-moment CAPM. Both versions have increased the power of the model in previous studies. This thesis compares the value, size and momentum factors of the four-factor CAPM to the higher-moment CAPM, which includes the first four moments of the return distribution, variance, skewness and kurtosis. In addition to the analysis of the two approaches, two asset classes, hedge funds and mutual funds, are compared. While mutual funds are generally very transparent regarding their investments and assets under management, hedge funds are regarded as very secretive. By running GMM regressions on different indices of both fund types, the thesis determines which model extension is better suited for each index and detects preferences depending on the investment style of the fund manager.

Zusammenfassung

Seit seiner Einführung wurden zahlreiche Versuche unternommen die Erklärungskraft des Capital Asset Pricing Model (CAPM), zu deutsch Kapitalgutpreismodell, zu erhöhen und weitere signifikante Faktoren hinzuzufügen, die eine Rolle bei der Beschreibung der Variationen der Rendite von Kapitalanlagen spielen. Zwei der bekanntesten Erweiterungen des Modells sind das 'Four-factor model' und das 'Higher-moment CAPM'. Beide Versionen haben in vorangegangenen Studien die Kraft des Modells erhöht. Diese Arbeit vergleicht die drei zusätzlichen Faktoren des 'Four-factor model' (value, size, momentum) mit dem 'Higher-moment CAPM', wo die ersten vier Momente der Renditeverteilung, Varianz, Schiefe und Kurtosis, verwendet werden. Zusätzlich zu der Analyse der beiden Ansätze, werden zwei Anlageklassen, Hedgefonds und klassische Investmentfonds, verglichen. Während klassische Investmentfonds generell sehr transparent sind in Bezug auf ihre Veranlagungen und ihr verwaltetes Vermögen, werden Hedgefonds als sehr geheimnisvoll angesehen. Diese Arbeit bestimmt anhand von GMM-Regressionen auf verschiedene Indizes der beiden Anlageklassen, welches Modell besser geeignet ist für den jeweiligen Index und entdeckt Präferenzen abhängig vom Anlagestil des Fondmanagers.

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Chapter 1

Introduction

The introduction of the capital asset pricing model (CAPM) by Treynor (1961, 1962), Sharpe (1964), Lintner (1965) and Mossin (1966) was a milestone in the field of financial economics. Given a set of assumptions on investors' behaviour, market regulations and return distributions, the model attempts to explain the variation in the returns of financial assets. Since its introduction there have been numerous studies testing the applicability of the theory. While early studies on individual security returns, e.g. Douglas (1969), did not confirm the validity of the model, these initial problems were overcome by using portfolio returns, as by Black et al. (1972) or Fama and MacBeth (1973). Under the new testing method, the results were more in favour of the original model given a longer observation period of security returns. Roughly 20 years later, including more recent return data, the empirical evidence faded and the results of new studies only showed weak support for the original one-factor model, e.g. He and Ng (1994), Davis (1994) or Miles and Timmermann (1996).

Motivated by the empirical insufficiency of the CAPM in completely explaining the variation of stock returns, researchers started extending the model, thereby, often moving from a single-factor model to multi-factor models. Two of these attempts form the core part of the analysis in this thesis. Other approaches are for example models depending on the time-variation of volatility, also known as the conditional CAPM. Bollerslev et al. (1988) introduced ARCH/GARCH models, developed by Engle (1982) and Bollerslev (1986), into the field of CAPM research. In their initial paper, Bollerslev et al. (1988) conclude that the conditional model generally has a higher explanatory power than models assuming constant variance and covariance over time.

The two extension approaches, which I use, are the Carhart four-factor model and the higher-moment CAPM. The first model was developed by Carhart (1997) and is based on the Fama-French three-factor model invented by Fama and French (1992). Initially they observed that companies with certain attributes, e.g. size, tend to outperform other companies. Using this information and transforming it into model factors, Fama and French (1992) added two explanatory variables to the model. A few years later, Carhart (1997) used a similar approach and extended the three-factor model to a four-factor model. While the factor models were invented decades after the original CAPM, the first attempts at a model including other moments of the return distribution than just mean and variance were already published as soon as soon as 1973. Rubinstein (1973) assumed that investors also care about the skewness of the distribution and implemented co-skewness in his three-moment CAPM. Almost 20 years later, studies including the first four moments, e.g. Fang and Lai (1997), Bansal et al. (1993) or Dittmar (2002), provided evidence for the statistical significance of the fourth co-moment, also called co-kurtosis.

Most studies testing the CAPM model use portfolios, which are specifically built for this purpose. In my thesis, I will compare two asset classes, mutual funds and hedge funds. Both types of funds are portfolios of various financial assets, but the differences are their investment style and portfolio composition. On the one hand, mutual funds are generally more conservative and tend to follow market indices. On the other hand, hedge funds pursue a variety of different strategies which aim at outperforming the market and taking on more risk than other types of investment. Therefore, I will compare the performance of the two models for the two types of funds and analyse whether one model generally has more explanatory power than the other or which model is better suited for each fund type.

The remainder of this paper is set out as follows. Chapter 2 gives an overview of the basic CAPM. Chapters 3 and 4 describe the two fund types analysed. Afterwards chapter 5 explains the derivation and economic interpretation of the four-factor model and the higher-moment CAPM. Chapter 6 starts the empirical analysis by describing the data set and the testing methodology. Chapters 7 and 8 present the results and a summary of the most important findings. At the end, chapter 9 contains a conclusion of the model performance, as well as the explanatory power for each fund type.

Chapter 2

CAPM

As stated in the introduction, the CAPM was separately invented by Treynor (1961, 1962), Sharpe (1964), Lintner (1965) and Mossin (1966). The model provides a risk-based explanation for the returns of financial assets. As this thesis investigates and analyses two extensions of this model, chapter 2.1 will give an introduction to the basic derivation including the model assumptions and the testing of the model, and chapter 2.2 will present the most prominent criticism of the classic model.

2.1 Basics and derivation

The CAPM describes the return of a financial asset as a combination of the return on a risk-free asset and a risk-adjusted market return. The following derivation is based on the groundwork of Treynor (1961, 1962), Sharpe (1964), Lintner (1965) and Mossin (1966). The whole model contains the following assumptions, which Lintner (1965) lists in his study:

- Investors are risk-averse utility-maximizers.
- Markets are perfect, there are no taxes or other regulatory restrictions.
- Assets are perfectly divisible and marketable.
- Investors are price takers having the same information and the same expectations about returns.
- Asset returns follow a normal distribution.

Sharpe (1964) uses the idea of a portfolio composed of the market portfolio and an additional asset i to derive the CAPM. The starting points are the portfolio's return and standard deviation as illustrated in equation 2.1.

$$
\begin{aligned}
E(\tilde{R}_p) &= aE(\tilde{R}_i) + (1-a)E(\tilde{R}_m) \\
\sigma(\tilde{R}_p) &= \sqrt{a^2\sigma_i^2 + (1-a)^2\sigma_m^2 + 2a(1-a)\sigma_{im}}
\end{aligned}
\tag{2.1}
$$

where $E(\tilde{R}_p)$ is the expected return of the investor's portfolio, a is the percentage invested in asset i, $E(\tilde{R}_m)$ is the expected return of the market portfolio, $\sigma(\tilde{R}_p)$ is the standard deviation of the investor's portfolio and σ_{im} is the covariance between the return of the market portfolio and the return of asset i.

Equation 2.2 shows the first derivatives of the portfolio's return and standard deviation, while equation 2.3 evaluates both at zero.

$$
\begin{aligned}
\frac{\delta E(\tilde{R}_p)}{\delta a} &= E(\tilde{R}_i) - E(\tilde{R}_m) \\
\frac{\delta \sigma(\tilde{R}_p)}{\delta a} &= \frac{1}{2}[a^2\sigma_i^2 + (1-a)^2\sigma_m^2 + 2a(1-a)\sigma_{im}]^{-\frac{1}{2}} \\
&\quad * (2a\sigma_i^2 - 2\sigma_m^2 + 2a\sigma_m^2 + 2\sigma_{im} - 4a\sigma_{im})
\end{aligned}
\tag{2.2}
$$

$$
\begin{aligned}
\left.\frac{\delta E(\tilde{R}_p)}{\delta a}\right|_{a=0} &= E(\tilde{R}_i) - E(\tilde{R}_m) \\
\left.\frac{\delta \sigma(\tilde{R}_p)}{\delta a}\right|_{a=0} &= \frac{1}{2}(\sigma_m^2)^{-\frac{1}{2}}(-2\sigma_m^2 + 2\sigma im) \\
&= \frac{\sigma_{im} - \sigma_m^2}{\sigma_m}
\end{aligned}
\tag{2.3}
$$

The assumption of $a = 0$ is based on the idea, that in equilibrium all investors will hold the market portfolio and there is no excess demand for asset i. The possible combinations of portfolio m and asset i form an opportunity set. The slope of this curve is the change of the return over the change of the standard deviation. In equilibrium this slope has to be equivalent to the slope of the capital market line (CML), which is based on the work of Markowitz (1952). This relation is shown in equation 2.4, where the slope of the CML is on the left side and the slope of the opportunity set on the right side.

$$
\frac{E(\tilde{R}_m) - R_f}{\sigma_m} = \frac{E(\tilde{R}_i) - E(\tilde{R}_m)}{\frac{\sigma_{im} - \sigma_m^2}{\sigma_m}}
\tag{2.4}
$$

where R_f is the return on the risk-free asset. Equation 2.4 can be rearranged and expressed as equation 2.5.

$$E(\tilde{R}_i) = R_f + [E(\tilde{R}_m) - R_f]\frac{\sigma_{im}}{\sigma_m^2} \tag{2.5}$$

The last term of equation 2.5 is the so-called beta, which expresses the factor by which the asset's return is related to the return of the market portfolio.

Lintner (1965) shows that investors, who only hold the market portfolio, are exactly at the point of tangency between the capital market line and the opportunity set. By assumption there is a risk-free asset available, which the investor may lend or borrow and thereby adjust his position on the capital market line. Therefore, he might invest less or more than 100 percent of his wealth in the market portfolio.

In chapter 5.3.1 I will show, that Ingersoll (1975) uses the same idea to derive the three-moment CAPM, which I will also use in the analysis of chapter 7.

Although the CAPM expresses ex-ante asset returns, testing can only be performed on historical data. The common method is the linear regression of equation 2.6.

$$R_i - R_f = \alpha_i + \beta_i(R_m - R_f) + \epsilon_i \tag{2.6}$$

where α represents the under- or outperformance of the market, β is the beta defined in equation 2.5 and ϵ is the error term. By definition α should be zero. Further explanations of the testing procedure are contained in chapters 6.2 and 7.

2.2 Criticism

Most criticism of the classic CAPM is based on empirical tests, which contradict the main statements of the model. Fama and French (2004) provide an overview of previous studies, which yielded e.g. positive values for α in equation 2.6 or unexpected values of beta. Historically there have been two ways to test the CAPM, either using a cross-sectional regression or a time-series regression. As illustrated in chapter 6.2, I use a time-series regression, since the data of chapter 6.1 is already grouped in indices. While it is obvious that the assumptions of the model, as presented in chapter 2.1, are already simplifications of the real world, this chapter presents the three main points of criticism based on parts of the model and evidence from empirical studies.

The CAPM assumes the existence of a risk-free asset, which can be bought or sold at any quantity. Since in the real markets this asset does not exist, Black (1972) invented a version of the CAPM with a zero-beta portfolio. This portfolio replaces the risk-free asset, since its return is independent of the market return. Fama and French (2004) remark that this version includes the expectation, that the zero-beta portfolio can be bought and sold without constraints. Therefore, unrestricted short-selling must be possible, which is another unrealistic assumption.

Jensen (1967) published another study contradicting parts of the CAPM. In his paper he uses the alpha of the CAPM regression to determine the out- or underperformance of mutual funds compared to the market portfolio. According to the basic assumptions of the CAPM, the value of α in equation 2.6 has to be zero. In his analysis Jensen (1967) used a non-zero value of the coefficient as a sign of abnormal performance. Especially in the hedge fund industry, Jensen's alpha is a common indicator of superior performance by the fund manager, as illustrated by Ineichen (2000).

The most famous critic of the model was published by Roll (1977). He claims that due to the general definition of the market portfolio, it cannot actually be tested. The initial description of the market portfolio contains financial returns, as well as labour, real estate or other factors of economic value. Therefore, he concludes, that not only the standard testing of the CAPM - using stock market indices as proxies of the market portfolio - is wrong, but also that the CAPM can never be tested, since combining every available asset is unfeasible.

Chapter 3

Hedge funds

Chapters 3 and 4 describe the two asset classes used in this empirical study. First, chapter 3.1 explains the features of hedge funds, which distinguish them from other financial assets and investment funds. The three most important attributes are: non-transparency, increased illiquidity and constrained divisibility. Second, chapters 3.2.1 to 3.2.5 give information about the different hedge fund strategies as classified by the Hedge Fund Research Database (HFR) (2011). Third, chapter 4 provides an overview of mutual funds and explains the different categories used in this study.

3.1 Structure

The main reason for choosing hedge funds as part of the empirical analysis are the three attributes - illiquidity, low diversibility and non-transparency - which, according to Ranaldo and Favre (2004) represent market imperfection and cause higher skewness and kurtosis of the return distribution. Chapters 3.2.1 to 3.2.5 show that the majority of hedge fund managers chooses strategies aiming at holding illiquid assets or using derivatives, which protect against tail events.

All three characteristics above contradict some of the CAPM assumptions as described in chapter 2. Illiquidity is a common feature and is twofold for most affected hedge funds. On the one hand managers intentionally invest in illiquid assets to profit from the inherent illiquidity premium, as shown by Holmstroem and Tirole (2001), and on the other hand the hedge fund itself is illiquid, since investors cannot buy or sell shares instantly. According to Ineichen (2000) there are on average only 30 dates per year for investors to adjust their holdings in individual hedge funds.

Hedge funds generally violate the assumption of infinite divisibility. First, their low divisibility is linked to the limited number of trading days within a year, as described above. Second, Ineichen (2000) also calculates the average minimum investment amount for hedge funds at 695,000 USD in 1999.

The third feature is the non-transparency of hedge funds regarding information. This is also one of the key differences to mutual funds (more distinctive features are discussed in chapter 4). The main justification for the disclosure of investments and trading activities are the specific trading strategies, which are described in chapter 3.2. Full transparency would eliminate trading opportunities for hedge fund managers, although this information advantage is fading under new regulations and the constant striving for information transparency. Examples are the new regulations imposed by the Securities and Exchange Commission (SEC) in 2004 and the UCITS directive of the EU in 2001.

3.2 Strategies

The classification of hedge fund strategies in this thesis is taken from the Hedge Fund Research Database (2011). These strategies have been updated in 2011 and additional criteria have been used to adjust the former setup to the style of hedge fund investment strategies after the Global Financial Crisis in 2008. The new classification also allows a more detailed description of the various investment styles and a proper distinction between them. In general, there are five main categories: Equity Hedge, Event-Driven, Macro, Relative Value and Fund of Funds. In addition, there are several strategies focusing on different emerging markets. This chapter provides a brief description of the most common strategies, which are used in the regressions later in this thesis.

3.2.1 Equity Hedge

Equity Hedge fund managers can be divided into several additional sub-categories, but their general approaches are positions in equities and equity-based derivatives. Depending on their individual goal and assumptions, they position themselves on both sides of the market, adjust their leverage and general exposure, and vary holding periods and market capitalization concentrations. The various sub-groups are described below:

- Equity Market Neutral: Managers use technical and fundamental analysis to detect mispricings. Their net exposure does not exceed ten per cent most of the time and they often employ heavy leverage to increase their profit. Managers often rely on inefficient markets and patterns in security returns e.g. mean reversion. It is also common for them to use high frequency trading techniques. The term 'neutral' symbolizes their hedging against certain factors e.g. beta or gamma. Patton (2004) distinguishes between various forms of market neutrality and finds in his sample that 25 per cent of self-declared market neutral funds exhibit exposure to market risk. Wright (2002) analysed the observed failure of Equity Market Neutral hedge funds during the late 90s and concluded that abnormal reactions of investors to macroeconomic events diminished the effectiveness of the hedges employed.

- Fundamental Growth: This strategy focuses on the companies themselves, trying to identify those which are more likely to exceed the industry average in terms of earnings growth. Managers aim to hold equity of those firms, which are presumed to outperform their peers.

- Fundamental Value: In contrast to Fundamental Growth funds, Fundamental Value funds look for currently undervalued securities. They also study the underlying company in terms of potential earnings and growth, but specifically search for equities, which trade below their fundamental value.

- Quantitative Directional: Mainly technical, quantitative tools are used to determine the desired market and securities position of the hedge fund. These tools utilise factor-based analysis, which investigates characteristics of securities and their interaction between different equities, as well as statistical arbitrage and trading strategies, which exploit pricing anomalies. In contrast to market neutral funds, these managers usually choose a short or long position and have a higher net exposure.

- Sector - Energy/Basic Materials: Sector-based strategies rely on managers and analysts, whose knowledge and information in a certain industry exceeds the average investor or manager. The most important aspects are the development of industrial processes, as well as demand and supply for basic materials. In general more than 50 per cent of the fund's exposure is concentrated in this sector.

- Sector - Technology/Healthcare: Similar to the preceding strategy, this sector-based approach relies on investments in companies working in the field of biotechnology, developing pharmaceuticals and other medical products.

- Short-Biased: Managers of short-biased funds try to identify overvalued companies and generally have a short exposure to the market. Their profits increase in times of recessions and economic downturns. Therefore, they have to vary their amount of short exposure over time. In order to identify potentially overvalued companies they employ various analytical techniques. Brunnermeier and Nagel (2004) analysed the influence of hedge funds during the technology bubble of 2000. They find that most hedge funds, which took short positions at that time, managed to enter these positions almost at the peak, shortly before the bubble burst. But their findings also show that most hedge fund managers rode the bubble as long as possible.

- Multi-Strategy: This category includes all fund managers, who employ more than one of the strategies above. These managers may e.g. have long and short positions, focus on specific sectors or employ leverage. Generally they will not have an exposure of more than 50 per cent in any specific sub-strategy.

3.2.2 Event Driven

Strategies in this category are related to all kinds of corporate events. Fund managers search for companies undergoing structural changes, financial adjustments or other capital actions. They then take positions in equities and various derivatives to profit from these assumptions. Strategies are not only restricted to short-term trading profits, but may also include active involvement in corporate governance, e.g. replacing board personnel and initiating asset sales or share buybacks. In contrast to Equity Hedge managers, their toolset is composed mainly of fundamental approaches, rather than quantitative analysis.

- Activist: The Activist strategy comprises funds, which actively seek involvement in the board of companies especially during corporate events, such as restructuring, capital increase or buybacks. By influencing the decision-making process of a company they aim at optimizing their return on equity. These managers do not only restrict themselves to officially announced corporate events, but also use their private information to detect companies undergoing important changes. Clifford (2008) compared the active and passive investment blocks of event driven hedge funds. According to his findings, firms with Activist managers as investors show higher excess stock returns than their peers and the returns of the active blocks in Activist hedge funds were higher than the returns of the passive blocks. Kahan and Rock (2007) found that Activist managers seek significant changes in the management of their target companies, thereby ranking short-term gains above long-term profitability.

- Credit Arbitrage: The focus in this category lies on fixed income securities. Hedge funds buy claims in senior and subordinated bonds, as well as other forms of financial obligations. The analysis is based on evaluating the creditworthiness of the issuer and the likelihood of its improvement. Most assets are traded frequently and mostly in liquid markets. In contrast to the Activist strategy, managers do not aspire active management of the issuing companies.

- Distressed/Restructuring: As with Credit Arbitrage this strategy concentrates on fixed income securities. The main target are obligations by firms in distress which trade at a discount. Involvement in a firm's governance is typical for managers in this field. Most assets held by these managers are still actively traded at a reasonable public price, for which they expect an increase in value.

- Merger Arbitrage: Andrade et al. (2001), Jayaraman et al. (1991) and others have shown that companies realize abnormal returns around merger events. Typically the returns of the target company rise, while the returns of the bidding company fall. This usually occurs around the announcement day, on the day of the merger and in the period shortly afterwards. Merger Arbitrage hedge funds use these findings to profit by buying stocks of one company and selling stocks of the other company involved in the merger. These managers primarily focus on officially announced transactions, in order to minimize idiosyncratic credit risk.

- Private Issue/Regulation D: Managers employing this strategy hold a majority of their portfolio in private, illiquid assets. Initially they realize a profit from buying the security at a discount, since no reasonable public price is available. In the next step they hold the security until the value improves significantly, e.g. after bankruptcy proceedings.

- Special Situations: This strategy is comprised of a mixed portfolio of equity and corporate debt. Managers invest in companies currently involved in any kind of corporate event, which may be a new issue, bankruptcy proceedings or mergers. In general active involvement in a company's management is not included.

- Multi-Strategy: As with Equity Hedge - Multi-Strategy managers, these funds apply multiple of the above Event Driven strategies, but do not commit more than 50 per cent to any specific strategy.

3.2.3 Macro

The main investment decision criterion for Macro funds is the sensitivity of equity prices to macroeconomic variables. In order to select their assets, they employ a variety of techniques, including quantitative analysis and fundamental approaches. In addition, their holding periods vary across their portfolio, depending on their expectations about macroeconomic developments. In contrast to Equity Hedge managers, their decision does not solely depend on data and information about the company itself, but also about its expected development regarding macroeconomic trends. Furthermore, they can be distinguished from Relative Value funds - discussed in chapter 3.2.4 - since they do not seek to realize small profits based on valuation distortions, but rather make their investment decisions on their general assumption of future changes.

- Active Trading: The strategy involves mainly high-frequency trading of various asset classes. Fast reaction to changes in fundamental or technical data is essential to immediately adjust the portfolio composition. As in all Macro strategies, the main concern are the expectations for macroeconomic variables and their influence on asset prices. In contrast to Systematic Diversified funds, the holding period is shorter and the portfolio turnover is higher. Although this strategy also resembles Equity Hedge - Quantitative Directional, the use of more financial instruments than just equities is the distinguishing feature.

- Commodity - Agriculture: Managers hold a portfolio which mainly consists of positions in grains and livestock markets. Commodity strategies, in general, are almost 100 per cent dependent on market developments. Typically they invest in emerging and developed markets.

- Commodity - Energy: Another commodity strategy focusing on positions in crude oil, natural gas and other petroleum products.

- Commodity - Metals: Managers primarily trade gold, silver and platinum.

- Commodity - Multi: The Multi-strategy combines various kinds of commodities, as well as discretionary and systematic investment approaches. Discretionary techniques rely on the experience of the manager and his evaluation of current and future market movements. On the other hand systematic processes focus on computers and algorithms, which determine the portfolio composition. In most cases these algorithms detect trends in certain markets and try to profit by taking positions accordingly.

- Currency Discretionary: As the name already states, hedge funds in this field apply discretionary techniques focused on the manager's evaluation of currency markets. They are active in global foreign exchange markets, which may be listed or unlisted.
- Currency Systematic: As described above, systematic strategies use algorithms to determine their portfolio, while managers only have very limited or no influence on the composition.
- Discretionary Thematic: This strategy applies generally to hedge funds relying on a discretionary investment style and may use various financial instruments.
- Systematic Diversified: The investment approach is similar to Discretionary Thematic funds, but instead of personal evaluation a computer algorithm is used.
- Multi-Strategy: The most important feature of hedge funds in this category is the simultaneous use of discretionary and systematic methods. In some cases the suggestions of automated trading systems are altered by managers, while with others there may be discretionary strategies including systematic sub-strategies.

3.2.4 Relative Value

The main goal of Relative Value strategies is to detect valuation discrepancies in the relationship between different financial instruments. These are not restricted to equity and may also include derivatives, such a futures and options. The investment approach is mostly quantitative, but can also include fundamental techniques. While funds sometimes take positions in companies which currently undergo a merger or acquisition, they are not to be confused with Event Driven funds. The latter are more focused on the outcome of the transaction, while Relative Value managers are interested in the valuation difference.

- Fixed Income - Asset Backed: As in most other Relative Value strategies, FI Asset Backed hedge funds are focused on the realization of a spread between different financial instruments. In the FI Asset Backed case at least one of the instruments involved has to be a fixed income instrument which is backed by a financial obligation other than those of a specific corporation. Managers often hedge the pure interest rate risk, in order to focus on the difference in the yield of the instruments.
- Fixed Income - Convertible Arbitrage: If convertible and non-convertible fixed income instruments of the same issuer exist, hedge fund managers try to realize

the valuation difference between these two assets. Various factors, such as realized and implied volatility, play an important role in the investment process.

- Fixed Income - Corporate: The instruments used for realizing the valuation difference are corporate fixed income securities, usually corporate bonds, sometimes also low-risk government bonds. Typically, managers are looking for spreads between different companies.

- Fixed Income - Sovereign: This strategy is similar to Fixed Income - Corporate, but the instruments involved are mainly government bonds and treasury bills. The quantitative and fundamental approaches are more driven by general macroeconomic figures than with the preceding strategies, which rely more on the idiosyncratic risk of individual companies.

- Volatility: Volatility hedge funds trade all types of instruments, mainly derivatives, containing implied volatility. They adjust their exposure to implied volatility across a range of financial assets and often try to realize a spread between implied and realized volatility. Christensen and Prabhala (1998) analyse the relationship between the two volatility measures and conclude that implied volatility often subsumes realized volatility. Carr and Madan (2001) explain the mechanism of trading volatility using the implied volatility index (VIX).

- Yield Alternatives - Energy Infrastructure: Managers focus on the yield differential between companies in the Energy Infrastructure sector, typically involving Master Limited Partnerships. In contrast to Equity Hedge strategies, managers are not looking at the price evolution, but rather on the yield of the various instruments.

- Yield Alternatives - Real Estate: This strategy is similar to the above-mentioned Yield Alternatives strategy, but managers are analyzing the real estate sector. They usually invest either directly in real estate or use real estate funds and REITs.

- Multi-Strategy: Multiple of the strategies described above are used by hedge funds which fall into this category. They are more appealing to investors who want to gain from opportunities across the whole market and diversify their risks.

3.2.5 Fund of Funds

Fund of Funds add another layer to the investment structure. Investors do not invest in a single manager anymore, but invest in a portfolio containing various hedge funds.The advantage is the diversification of risk, since the manager of a Fund of Funds seeks to include several funds practicing different strategies in his portfolio. Due to the fee structure of hedge funds, the investor has to pay more, since he is not only paying the premium of the Fund of Funds, but also indirectly the fees of the hedge funds in the portfolio. Lack (2008) calculated returns of the hedge fund and fund of hedge funds industry on a money-weighted basis. His findings reveal that hedge fund managers generated up to 98 percent of investors' profits in fees.

- Conservative: Conservative managers seek a constant return independent of current market trends and behavior. Usually their standard deviation is below the HFRI Fund of Funds Composite Index. The portfolio consists mostly of individual hedge funds engaged in Equity Market Neutral, Fixed Income Arbitrage and Convertible Arbitrage.

- Diversified: Managers are broadly diversified and use various individual hedge fund strategies. Their return and standard deviation is similar to the HFRI Fund of Funds Composite Index.

- Market Defensive: This strategy is applicable for fund of hedge funds which maintain a short position in the market. They invest in short-biased individual hedge funds and try to achieve positive returns in down markets.

- Strategic: Strategic managers are more risk-seeking and prefer individual strategies like Emerging Markets of sector-specific approaches. They lose more in down markets, but try to outperform the HFRI Fund of Funds Composite index in up markets.

Chapter 4

Mutual funds

The second asset class tested in this thesis are mutual funds. In chapter 3, I described the various strategies of hedge funds, since this asset class is very heterogeneous. Mutual funds, on the other hand, are rather homogeneous, the main reason being the strict legislation imposed on them. In general regulatory limitations are the main cause of differences between the two groups of funds. Strategies like Short Biased or Equity Market Neutral (see chapter 3.2.1) could not exist under the regulations applicable for mutual funds.

In contrast to index funds, mutual funds are actively managed like hedge funds. Their portfolio consists mainly of equity and fixed income positions. The portfolios used for the analysis in chapter 7 are segregated depending on their invested asset class, which is described in chapter 6.1.

In order to provide reasons for the choice of the two fund groups, the main differences between hedge funds and mutual funds are described in this chapter, as well as additional features of mutual funds. Ineichen (2000) listed the most important distinguishing characteristics, which I will summarize below. His findings are partly confirmed in the results of chapter 7.

As already mentioned above, due to regulatory differences, hedge funds are able to offer more downside protection than mutual funds. Hedge funds managers are allowed to have short positions, while mutual fund managers are usually restricted in that point. Therefore, hedge fund managers establish strategies which provide investors with positive returns even in periods of market downturn.

Another difference lies in the measurement and the source of the returns. Mutual funds are compared to a reference index and report relative performance. Hedge funds are also compared to specific indices, but they usually only report absolute returns. The reason behind this varied reporting style is the source of the returns. Mutual funds earn money through the classic risk premium, as represented by beta in the CAPM model. While this is also valid for some hedge funds, most of them focus on creating alpha, especially Relative Value funds (see chapter 3.2.4). The descriptive statistics in chapter 6.1 confirm these assumptions.

Other characteristics pointed out by Ineichen (2000), but less important for the analysis in this thesis, are the managerial incentives, dead weight and flexibility. Most hedge fund managers are invested in their own funds and, therefore, have increased personal interest in achieving a positive return. The remuneration of mutual fund managers is usually composed of their salary and a fee, which is based on the money under management of their funds. In contrast, hedge fund managers also receive part of the performance fee, which investors have to pay to the fund. Dead weight is connected to flexibility. Hedge fund managers generally have more freedom in choosing their investments and will select assets into which they have insight. Mutual fund managers on the other hand sometimes find themselves in a position where they need to add positions to their portfolio into which they have no insight, e.g. no knowledge about the relevant industry.

Chapter 5

Literature review

5.1 Multi-factor models

Soon after the initial publication of the CAPM, researchers started investigations to overcome shortcomings of the model and improve its explanatory power. Chapters 5.1.1 and 5.1.2 illustrate the two most established factor-extensions of the classic CAPM. Then chapter 5.2 investigates the arbitrage pricing theory (APT), which leads to the classic CAPM as a special case.

5.1.1 Fama-French three-factor model

The most prominent and established extension of the classic CAPM model is the Fama-French three-factor model. Fama and French (1992) investigated whether two additional risk components, firm size and book-to-market ratio, could be implemented to explain the variation in stock returns. In chapter 2, I presented the derivation of the CAPM, which contains one risk factor, i.e. the return on the market portfolio. To capture their additional risk components, Fama and French (1992) added two factors to the model.

The first one is the return on small cap stocks minus the return on big cap stocks. In their research they concluded that on average small cap stocks have larger returns than big cap stocks. Therefore, the factor usually has a positive sign.

The second factor is the return on value stocks minus the return on growth stocks. This is expressed as the return on stocks with high book-to-market ratio over the return on stocks with low book-to-market ratio.

Historical values for both factors are regularly calculated and published in the data library of Kenneth R. French[1]. The typical procedure to get the corresponding coefficients

[1] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

of the new risk factors is via a linear regression of the following form:

$$R_i - R_f = \beta_i(R_m - R_f) + s_i SMB + h_i HML + \epsilon_i \tag{5.1}$$

where R_i is the return of asset i, R_f is the return on the risk-free asset, R_m is the return on the market portfolio, β is the beta of the classic CAPM, *SMB* is the return on the size factor, *HML* is the return on the value factor and s_i and h_i are the respective coefficients of the two factors.

For the second model used in this thesis - the higher-moment CAPM - theory predicts the signs of the coefficients, which I will show in chapter 5.3. In contrast, there is no theoretical prediction for the sings of s and h. They represent whether the compensation for the respective risk is increased or decreased for asset i.

5.1.2 Carhart four-factor model

The last factor used in chapter 7 for the analysis of the FF-Carhart model, is the so-called momentum factor. Carhart (1997) added this risk component to the three-factor model of chapter 5.1.1. Equation 5.2 shows the extended regression formula.

$$R_i - R_f = \beta_i(R_m - R_f) + s_i SMB + h_i HML + m_i MOM + \epsilon_i \tag{5.2}$$

where *MOM* is the return on the momentum factor and m_i is its coefficient.

Carhart (1997) defined positive momentum in terms of a stock price which tends to rise after a preceding increase or a stock price which tends to fall after a preceding decline. In general, a stock is said to have positive momentum if its average price over the past twelve months is positive. The MOM factor is calculated by deducting the equally-weighted average return of the worst performing firms from the equally-weighted average return of the best performing firms lagged one month. Carhart argues that this return difference is priced in the markets via an additional risk premium. In his analysis of mutual fund returns the explanatory power of the model is higher after adding the new momentum factor.

As I will use this model in my analysis of chapter 7, I will refer to it as the FF-Carhart model. Thereby I affirm that all contributors to this model are mentioned.

5.2 Arbitrage Pricing Theory

Although the arbitrage pricing theory is not analysed in this thesis, this chapter gives a brief overview of the model, which was invented as an alternative to the CAPM and includes the classic CAPM as a special case. Ross (1976) used the rule of vector orthogonality to establish a new asset pricing model, which also uses economic factors to explain the variation of asset returns. He also criticizes the CAPM's assumptions of normality in returns and quadratic utility functions of investors. Therefore, he builds his model avoiding these restricting assumptions. The derivation in this chapter follows the construction of Ross (1976).

The starting point of the arbitrage pricing theory is the idea that a self-financing, riskless portfolio must earn zero return, due to the definition of arbitrage. Another assumption is that all terms in the equation, i.e. the factors used to explain the variation of returns, are uncorrelated, which is one of the strongest assumptions of the theory. Similar to the CAPM, the return on a security is given by a linear function of factors. In contrast to the classic CAPM, Ross (1976) initially allows a larger number of factors, as seen in equation 5.3.

$$\tilde{R}_i = E(\tilde{R}_i) + b_{i1}\tilde{F}_1 + ... + b_{ik}\tilde{F}_k + \tilde{\epsilon}_i \tag{5.3}$$

where $\tilde{R}_i$ is the random rate of return on asset i, b_{ik} is the sensitivity of asset i on factor k, $\tilde{F}_k$ is the value of factor k and $\tilde{\epsilon}_i$ is the noise term of asset i.

When many assets are aggregated to form the self-financing portfolio, each term in equation 5.3 is multiplied by the respective portfolio weight. Due to the law of large numbers the unsystematic risk captured in the noise term can be eliminated from the equation, since it approaches zero. By definition the riskless portfolio is also not affected by systematic risk. Therefore, all terms containing economic factors are also dropped from the equation. Equation 5.4 shows the remaining parts of the equation.

$$R_p = \sum_i w_i E(\tilde{R}_i) \tag{5.4}$$

where R_p is the return on the portfolio and w_i is the weight of asset i. As stated above, the portfolio return must be zero, therefore, the sum on the right side also needs to be zero, which inclines that the vectors $E(R)$ and w are orthogonal. Similarly this needs to be true for the vector of weights and a vector of ones as well as a vector of the sensitivities. From these assumptions, it follows that $E(R)$, e (the vector of ones) and b_k, for all k, must lie in the same plane. A vector can be expressed as a linear combination of other vectors in this plane. As a result, Ross (1976) expresses the return on asset i as:

$$E(\tilde{R}_i) = \lambda_0 + \lambda_1 b_{i1} + ... + \lambda_k b_{ik} \tag{5.5}$$

where λ_k is the coefficient of factor k. I stop the derivation at this point, as it is already sufficient to establish the connection to the CAPM. By taking the return on the market portfolio as the only factor in equation 5.5 we get the formula of the classic CAPM, but based on different assumptions.

5.3 Higher-moment CAPM

While normality of asset returns is a very common assumption in financial models, especially in asset pricing models, it can usually not be observed in realized returns. Chung, Johnson and Schill (2006) conduct tests for normality on their data set, which contains all assets in the CRSP database from 1930 to 1998. In addition, they test different return intervals, reaching from daily to yearly numbers. In each case normality is rejected, confirming, that a normal distribution of returns could not be observed in realized asset returns. Chapters 5.3.1, 5.3.2 and 5.3.3 explain the derivation of the higher-moment CAPM using various higher co-moments.

5.3.1 Three-moment CAPM

The groundwork for an extension including moments in addition to the first (mean) and second (variance) moment, represented by the mean-variance relationship of the classic CAPM, was performed by Rubinstein (1973). His initial assumption, which is shown in 5.6, is that every individual investor j maximizes his expected value of utility, dependent on future wealth $\tilde{W}$.

$$max\ E[U_j(\tilde{W}_j)] \tag{5.6}$$

The investor achieves this by adjusting the amount of his investments in the various assets i. The respective amount invested by individual j in asset i is denoted by s_{ij}. The only limiting restriction is that the total wealth equals the sum of all investments.

$$W_j = \sum_i s_{ij} \tag{5.7}$$

where W_j is the current wealth of individual j.

Given a continuously differentiable utility function and finite central moments of future wealth, Rubinstein forms a Taylor series expansion of the utility around the expected value of the investor's future wealth.

$$E[U_j(\tilde{W}_j)] = \sum_{n=0}^{\infty} \frac{U_j^{(n)}}{n!} \mu_{jn} \tag{5.8}$$

where μ_{jn} is the n^{th} central moment of $\tilde{W}_j$ and $U_j^{(n)}$ is the n^{th} derivative of U_j.
In order to maximize the future wealth a Lagrangian is used.

$$max\ s_{ij} \qquad \sum_{n=0}^{\infty} \frac{U_j^{(n)}}{n!} \mu_{jn} + \lambda_j [W_j - \sum_i s_{ij}] \tag{5.9}$$

where λ is the Lagrangian multiplier.
After solving the equation and implementing the existence of a risk-free asset, we get to the components of each security's expected rate of return.

$$E(R_i) = R_f + \sum_{n=2}^{\infty} \theta_{jn} \sigma_n (R_i, \tilde{W}_j) \tag{5.10}$$

where θ_{jn} is the individual degree of risk aversion for the n^{th} co-moment and σ_n is the n^{th} co-moment.

The adjustment of the individual's portfolio leads to the above equation. The rate of return of each asset is composed of a risk-free rate of return and the sum of the co-moments of the asset's return and the future wealth weighted by the respective risk aversion. This was the first model of this form, but it lacked a restriction of the respective signs in relation to the co-moments and did not include an economic interpretation.

The framework, also called the fundamental theorem, allows the modeling of security prices using various assumptions. In addition, extensions of the classic CAPM are possible and easily implementable.

Kraus and Litzenberger (1976) partially built on Rubinstein's work by including skewness into their asset pricing framework and extended it by predicting the sign of the coefficients. Rubinstein (1973) did not specify the utility function, but included two conditions:

1. The first derivative must be positive.

2. The second derivative must be negative.

Kraus and Litzenberger focused on a clear economic interpretation of their model. Initially they stated that only a cubic utility function would be suited to accurately order the preference for risky portfolios. But these third degree polynomials are not combinable with risk-averse investors. Therefore, they listed the mandatory requirements for a suitable utility function:

1. Positive marginal utility
2. Decreasing marginal utility
3. Non-increasing absolute risk aversion

Minding these assumptions only logarithmic, power and negative utility functions are available. Similarly to Rubinstein, Kraus and Litzenberger form a Taylor expansion around the expected utility of end-of-period wealth:

$$E[U(\tilde{W})] = U(\bar{W}) + \frac{U''(\bar{W})}{2!}\sigma_W^2 + \frac{U'''(\bar{W})}{3!}m_W^3 + \text{higher-order terms} \tag{5.11}$$

where $\bar{W}$ is $E[\tilde{W}]$, σ_W^2 is the second moment and m_W^3 is the third moment.

While Kraus and Litzenberger truncate the Taylor series after the third moment, since they could not find an economic interpretation for terms of higher order, they show that the series behaves according to their initial assumptions. Aversion to variance is implied by a negative second derivative of the utility function, i.e. decreasing marginal utility. To include their third point, non-increasing absolute risk aversion, they refer to Arditti (1967), who demonstrated that a positive third derivative, i.e. a preference for positive skewness, follows from the equation:

$$d\frac{-U''}{U'}dW \leq 0 \tag{5.12}$$

Building on these assumptions and including a nonsymmetrical distribution of the investor's portfolio returns, Kraus and Litzenberger express the first three relevant moments. q denominates the respective weights of the portfolio's assets:

$$\begin{aligned} \bar{W} &= \sum_i q_i \bar{R}_i + q_f R_f \\ \sigma_W &= \sum_i q_i \beta_{ip} \sigma p \\ m_W &= \sum_i q_i \gamma_{ip} m_p \end{aligned} \tag{5.13}$$

where σ_p is the standard deviation of the portfolio's rate of return and m_p is the skewness. Furthermore, β_{ip} is the beta of asset i with the investor's portfolio and γ_p is the gamma of asset i with the investor's portfolio, calculated as:

$$\gamma_{ip} = \frac{E[(R_i - \bar{R}_i)(R_p - \bar{R}_p)^2]}{m_p^3} \tag{5.14}$$

Similar to Rubinstein, Kraus and Litzenberger use the Lagrangian optimization method including the classic budget constraint. Their results yield the composition of the expected excess returns:

$$\bar{R}_i - R_f = -(\frac{d_{\sigma_W}}{d_W})\beta_{ip}\sigma_p - (\frac{d_{m_W}}{d_W})\gamma_{ip}m_p \tag{5.15}$$

where the expressions in brackets are the respective marginal rates of substitution between expected wealth and standard deviation, and expected wealth and skewness.

Building on these results, a strong assumption is introduced into the model in order to achieve market equilibrium and get from an investors portfolio to the market portfolio. Supposing identical probability beliefs, the optimal proportions of each risky asset and the risk-free asset held in the portfolio are those of the market portfolio. Therefore, the new formula for the excess return is:

$$\bar{R}_i - R_f = b_1\beta_i + b_2\gamma_i \tag{5.16}$$

In this case β is the common beta known from the classic CAPM and γ is the systematic skewness or co-skewness between the risky asset and the market portfolio. The investor's portfolio in equation 5.14 is replaced by the market portfolio while the coefficients b_1 and b_2 are expressed as:

$$\begin{aligned} b_1 &= (\frac{d\bar{W}}{d\sigma_W})\sigma_M \\ b_2 &= (\frac{d\bar{W}}{dm_W})m_M \end{aligned} \tag{5.17}$$

Equation 5.16 provides an economic interpretation of the coefficients b_1 and b_2. The first one is the market price of beta reduction, while the latter is the market price of gamma. This definition also enables us to predict the sign of b_2 under non-increasing absolute risk aversion. Since the expected value of utility will fall, as the skewness of wealth increases, the expression in brackets in the second part of equation 5.17 is negative. Therefore, coefficient b_2 will have the opposite sign of market skewness, implying a lower expected excess return for higher market skewness. This expectation is economically sound, as risk-averse investors prefer a higher probability of returns on the right side of the distribution.

Combining the findings of Rubinstein (1973) with Kraus and Litzenberger (1976) we can conduct the procedure of testing the three-moment CAPM. In chapter 7 the GMM regression of Hansen (1982) is used, which estimates the coefficients gamma and delta related to co-skewness and co-kurtosis.

Ingersoll (1975) published his approach towards a multidimensional CAPM two years after Rubinstein. He built on the work of Jean (1971, 1972, 1973), but corrected some of the errors and extended the CML to a capital market plane based on the first three central moments of the return distribution. Similar to Rubinstein, Ingersoll assumes decreasing absolute risk aversion, which includes a preference for higher skewness. For the construction in three-dimensional space he starts at the position of the risk-free asset, which has zero variance and zero skewness (R_f,0,0). Similar to the derivation in two-dimensional space, he draws tangents to the set of feasible portfolios and the result will be a cone. To determine the efficient frontier he employs three necessary conditions, which the relevant portfolios need to fulfill:

- Maximum skewness for given expected return and variance
- Minimum variance for given expected return and skewness
- Maximum expected return for given variance and skewness

The point of tangency between the new efficient frontier and the investor's utility surface is the individual investor's optimal portfolio composition (i.e. a convex combination of the risk-free asset and the market portfolio). To determine this utility plane, a utility function including a preference over the third moment is utilized. For this purpose Ingersoll (1975) proposes the Taylor series expansion of a cubic expected utility function, as shown in equation 5.18

$$E[U(W)] = U(W_t) + U''(W_t)\frac{\sigma}{2} + U'''(W_t)\frac{m^3}{6} \tag{5.18}$$

where W_t is the final wealth and m^3 is the unstandardised third central moment.

In order to derive the pricing equation, Ingersoll introduces the investor's choice of investing in the portfolio e, which represents the point of tangency between the capital market plane and the utility plane, and a new security i. This approach is similar to the derivation of the classic CAPM in chapter 2.1 The percentages invested into these two options are denominated by h and *1-h*, which add up to 1. The following three moments represent the resulting portfolio:

$$
\begin{aligned}
E &= hE_i + (1-h)E_e \\
\sigma &= \sqrt{h^2\sigma_i^2 + 2h(1-h)\sigma_{ie} + (1-h)^2\sigma_e^2} \\
m &= \sqrt[3]{h^3m_i^3 + 3h^2(1-h)m_{iie} + 3h(1-h)^2m_{iee} + (1-h)^3m_e^3}
\end{aligned}
\tag{5.19}
$$

where

$$
\begin{aligned}
\sigma_{ie} &= E[(R_i - Ei)(R_e - E_e)] \\
m_{iee} &= E[(R_i - Ei)(R_e - E_e)^2]
\end{aligned}
$$

In the case of e being the efficient portfolio, the amount invested in the new security i has to be 0. Therefore, Ingersoll states the necessary first-order condition:

$$
\left.\frac{dU}{dh}\right|_{h=0} = \left.(U_1\frac{dE}{dh} + U_2\frac{d\sigma}{dh} + U_3\frac{dm}{dh})\right|_{h=0} = 0 \tag{5.20}
$$

where U_1, U_2 and U_3 are the partial derivatives of the utility function. If equation 5.20 does not hold, the investor will adjust his holding of security i and will not hold portfolio e any longer. In the next step the three moments from equation 5.20 are used to compute the derivatives of equation 5.20.

$$
\begin{aligned}
\frac{dE}{dh} &= E_i - E_e \\
\frac{d\sigma}{dh} &= \frac{2h\sigma_i^2 + (2-4h)\sigma_{ie} - 2(1-h)\sigma_e^2}{2\sigma} \\
\frac{dm}{dh} &= \frac{3h^2m_i^3 + (6h-9h^2)m_{iie} + (3-12h+9h^2)m_{iee} - 3(1-h)^2m_e^3}{3m^2}
\end{aligned}
\tag{5.21}
$$

As shown in equation 5.3.1 these derivatives have to be evaluated at *h=0*. The first does not contain h and will not change, while the final form of the second and third ones are calculated in equation 5.22

$$
\begin{aligned}
\left.\frac{d\sigma}{dh}\right|_{h=0} &= \frac{\sigma_{ie} - \sigma_e^2}{\sigma_e} \\
\left.\frac{dm}{dh}\right|_{h=0} &= \frac{m_{iee} - m_e^3}{m_e^2}
\end{aligned}
\tag{5.22}
$$

Now these results are substituted back into the definition of the portfolio in equation 5.20 and yield:

$$
U_1(E_i - E_e) + U_2\frac{\sigma_{ie} - \sigma_e^2}{\sigma_e} + U_3\frac{m_{iee} + m_e^3}{m_e^2} = 0 \tag{5.23}
$$

In the case of the riskless security, the covariance and the co-skewness are both 0. In addition, the first derivative of the utility function has to be greater than 0. Combined, these two observations can be included, which is shown in equation 5.24

$$\begin{aligned}\frac{U_2}{U_1} &= (R_f - E_e - \frac{U_3}{U_1} m_e)\frac{1}{\sigma_e} \\ \frac{U_3}{U_1} &= (R_f - E_e - \frac{U_2}{U_1} \sigma_e)\frac{1}{m_e}\end{aligned} \tag{5.24}$$

These two equations can be inserted into formula 5.23

$$E_i - R_f = m_e \frac{U_3}{U_1}(\beta_i^e - \gamma_i^e) + (E_e - R_f)\beta_i^e \tag{5.25}$$

where β_i^e and γ_i^e stand for the standard CAPM beta and the three-moment CAPM gamma:

$$\begin{aligned}\beta_i^e &= \frac{\sigma_{ie}}{\sigma_e^2} \\ \gamma_i^e &= \frac{m_{iee}}{m_e^3}\end{aligned} \tag{5.26}$$

These equations are derived using the market portfolio e, while for a complete pricing framework the optimal combination of the market portfolio and the risk-free asset, portfolio o, is more desirable. Ingersoll (1975) shows that portfolio o is in fact just portfolio e levered with the risk-free asset. Therefore, equations 5.25 and 5.26 can also be rewritten using o instead of e.

5.3.2 Four-moment CAPM

As mentioned in chapter 5.3.1, researchers already had the idea of extending utility functions and the CAPM to moments higher than the third at the time of the development of the three-moment CAPM. Rubinstein (1973), although theoretically including moments above the third, did not offer an economic interpretation. Kraus and Litzenberger (1976) intentionally excluded kurtosis and the fourth moment from their observations, as they could not predict the relevant sign and meaning.

Scott and Horvath (1980) created an important basis for further analysis of moments higher than the third. They state that the preference for the third moment has been sufficiently dealt with by Arditti (1967), and Kraus and Litzenberger (1976) amongst others. Building on these findings, Scott and Horvath (1980) proceed by confirming the assumptions on the direction of preference for the third moment and extend this procedure for the fourth and higher moments.

They start by defining a utility function, which solely depends on an investor's wealth and income.

$$U = U(\tilde{x} + w) \tag{5.27}$$

where $\tilde{x}$ denotes the income and w the investor's wealth. In order to include the return, which is defined as income over wealth, they restate their definition of the utility function:

$$U = U(rw + w) \tag{5.28}$$

where r denotes the return. In order to approximate the investor's utility function, Scott and Horvath use a Taylor expansion and take the expected value of both sides:

$$E(U) = U(\mu) + \frac{U^2(\mu)}{2}\sigma^2 + \sum_{i=3}^{\infty} \frac{\mu_i}{i!} U^i(\mu) \tag{5.29}$$

where μ is the expected value of the utility function. In the next step they state the requirements for the proposed utility function, which include positive marginal utility and risk aversion. In addition, Scott and Horvath claim that the values of the utility function for each moment are either positive, zero or negative independent of wealth. Thereby, they assume that the preference for each moment is consistent. To prove their initial idea of finding a predetermined sign for each moment, they first construct a proof for the third moment:

In the first step they assume that $U^3(w) < 0$ or $U^3(w) = 0$ for all levels of wealth, in contrast to the fact that their assumptions imply $U^3(w) > 0$. Using the Mean Value Theorem, there has to be at least one value $\bar{w}$, which may be w_1 or w_2, for which, given $w_2 > w_1$:

$$U^1(w_2) - U^1(w_1) = U^2(\bar{w})(w_2 - w_1) \tag{5.30}$$

This formula can be reorganized as:

$$U^1(w_2) = U^1(w_1) + U^2(\bar{w})(w_2 - w_1) \tag{5.31}$$

Under the assumption of a third derivative, which is less than or equal to zero, we have:

$$\begin{aligned} &U^2(w_1) \geq U^2(\bar{w}) \\ &U^1(w_2) \leq U^1(w_1) + U^2(w_1)(w_2 - w1) \end{aligned} \tag{5.32}$$

Introducing w^*, under the assumption that $w_2 \geq w^*$, they show that if

$$w^* = w_1 + \frac{U^1(w_1)}{-U^2(w_1)} \tag{5.33}$$

we get $U^1(w_2) \leq 0$ and $U^1(w_2) < 0$ for all $w_2 > w^*$.

This result contradicts the pre-requisite of positive marginal utility and therefore, $U^3(w) > 0$. This proof confirms the findings of chapter 5.3.1, showing that an investor with negative preference for a positive third moment would prefer less wealth over more wealth. This contradicts the general theory of utility functions and the axioms of von Neumann and Morgenstern (1944). Comparing two portfolios with equal expected return and variance, it makes economic sense, that an investor would prefer the portfolio with a higher probability of outcomes on the right side of the return distribution.

Using the above proof, Scott and Horvath (1980) proceed by forming a similar approach for the fourth moment. They show that an investor, who exhibits positive marginal utility, risk aversion and positive preference for the third moment, must have negative preference for the fourth moment. They start again by proposing the opposite, $U^4(w) > 0$ or $U^4 = 0$. Then they apply the Mean Value Theorem, assuming $w_2 > w_1$, there has to be at least one value $\bar{w}$, which is either w_1 or w_2, for which

$$U^2(w_2) \geq U^2(w_1) + U^3(w_1)(w_2 - w_1) \tag{5.34}$$

Using w^*, with a different definition

$$w^* = w^1 + \frac{-U^2(w_1)}{U^3(w_1)} \tag{5.35}$$

and assuming it to be less than or equal to w_2, they show that $U^2(w_2) \geq 0$ and, if $w_2 > w^*$, $U^2(w_2) > 0$. Similar to their first proof, this result contradicts risk aversion and therefore, $U^4(w) < 0$. This finding is also compatible with a sound economic interpretation, since risk averse investors would demand additional expected return to compensate for a higher probability of results in the tails of the return distribution.

Scott and Horvath conclude that their method can be extended to any higher moment. As a result, they expect an investor, who exhibits positive marginal utility and consistent risk aversion, to have a positive (negative) preference for positive (negative) odd moments and negative (positive) preference for positive (negative) even moments.[2]

The remainder of this chapter will focus on the work of Dittmar (2002), who devel-

[2]For the fourth moment, we regard excess kurtosis, which is 0 for the normal distribution.

oped a four-moment CAPM and concentrated on the importance of a sound economic interpretation as well as an appropriate weighting of the advantages and disadvantages of extending the three-moment CAPM. Dittmar also approximates the relevant utility function using a Taylor series expansion and poses the question of the best point of truncation. An intuitive explanation would be to test first and let the data determine the relevant point. The main disadvantage of this approach is a possible overfit of the data. The inclusion of the first three moments was already explained by previous work using decreasing marginal utility, and decreasing risk aversion. By introducing decreasing absolute prudence, which was developed by Kimball (1993), he delivers a rationale for including kurtosis in the CAPM equation.

Dittmar's starting point is the problem of portfolio choice and intertemporal consumption for an investor. Under the law of one price, these problems include a stochastic discount factor, also called pricing kernel or marginal rate of substitution m. The last term defines the factor to be the rate at which an investor is prepared to waive one unit of consumption in the present for future consumption. This relation can be expressed as:

$$m = \frac{U'(C_{t+1})}{U'(C_t)} \tag{5.36}$$

where C_t is the consumption at time t. The pricing kernel is used to discount future expected returns. Instead of consumption, Dittmar (2002) uses wealth for the remainder of his derivation. As mentioned above, he is not using a pre-determined utility function, but approaches it using a Taylor series expansion:

$$m_{t+1} = h_0 + h_1 \frac{U''}{U'} R_{W,t+1} + \frac{U'''}{U'} R^2_{W,t+1} + ... \tag{5.37}$$

where R_W is the return on aggregated wealth.

Dittmar uses equation 5.37 to start his discussion on the preferred point of truncation. The standard CAPM already builds on the assumption of positive marginal utility and risk aversion, which leads to a-priori signs for the first two derivatives of the utility function, $U' > 0$ and $U'' < 0$. The assumption, that an investor becomes less risk-averse with increasing wealth, leads to an a-priori sign for the third moment, i.e. $U''' > 0$. The first one to show this relation was Arditti (1967). In chapter 5.3.1 these findings were already used to define the three-moment CAPM.

After this point, Bansal et al. (1993) let the data decide, which moments should be included. In their study they use the first, second, third and sixth moment. The main criticism is that there is no economic interpretation for the sixth moment. Therefore, Dittmar (2002) tries to find an explanation for the fourth moment, which he finds by using the concept of standard risk aversion developed by Kimball (1993). The basic statement of this concept is that a risk-averse investor will be unwilling to accept a bet with a negative expected payoff even if he already accepted a similar bet before. To achieve this concept, Kimball introduces decreasing absolute prudence:

$$-\frac{d\frac{U'''}{U''}}{dW} = \frac{(U''')^2 - U^{(4)}U''}{(U'')^2} < 0 \tag{5.38}$$

The previous assumptions on positive marginal utility and decreasing absolute risk aversion are inserted in the right side of equation 5.38, which yields $U^{(4)} < 0$. At this point Dittmar includes his strongest assumption. As preference theory is not providing any guidance for the a-priori signs of moments higher than the fourth, he assumes them to be irrelevant for the pricing kernel. His statement says, that the advantage of using the above signs and truncating the Taylor series of equation 5.37 after the fourth moment outweighs the possibly omitted explanatory power provided by higher moments. As a result the polynomial includes a linear, a quadratic and a cubic term, which have also been used by Ranaldo and Favre (2003). Eventually the pricing kernel has the form of equation 5.39 and the coefficients of each moment are denoted by d_0 to d_3:

$$m_{t+1} = d_0 + d_1 R_{W,t+1} + d_2 R_{W,t+1}^2 + d_3 R_{W,t+1}^3 \tag{5.39}$$

5.3.3 Higher-moment approaches

While the three- and four-moment CAPM have been investigated more thoroughly and have also been used in practice, moments above the fourth have not yet been widely integrated into the CAPM model. The most prominent reason is the lack of an economic interpretation of the fifth and higher moments of the return distribution. While chapters 5.3.1 and 5.3.2 provided an explanation for including skewness and kurtosis, a similar approach is not yet available for higher moments.

Albeit this general lack of an interpretation, Chung et al. (2006) provide reasons for an inclusion. Under the basic assumption of risk-averse investors and decreasing absolute risk aversion, investors should be particularly interested in the risk of extremely negative outcomes. On the other hand they link the popularity of lotteries and out-of-the-money options to an increasing interest in the right tail of the return distribution, thereby linking it to Prospect Theory, as developed by Kahnemann and Tversky (1979).

In order to illustrate their postulated inclusion of moments above the fourth, Chung et al. (2006) compare two distributions, where one is a standard normal distribution and the other a mixture of a bilateral exponential and a standard normal distribution. In their example the odd moments of both distributions are zero, while variance and kurtosis are very similar. Therefore, by simply looking at the first four moments, an exact description of the differences between the two distributions is not possible, although the tails look differently. With the fifth and higher moments a more detailed analysis would be possible.

Chung et al. (2006) do not provide an answer to the open question of whether there is an economic interpretation of these higher moments, but they try to eliminate the criticism of unreliability. By avoiding the use of only one moment above the fifth, they decide to include moments up to the tenth. Their explanation is that a set of higher co-moments should be able to adequately capture the risk of tail outcomes and extract the additional information, which these co-moments contain. They state that there might be vagueness in certain higher moments, but this vagueness can be reduced or even eliminated by looking at a set of higher moments.

Bansal et al. (1993) perform a comparison of different pricing kernels, looking at linear and non-linear models. One of their models is a one-factor, non-linear model, which is similar to the kernels presented in chapters 5.3.1 and 5.3.2. The only difference is that they use the return on different financial assets as their market portfolio, opposed to the general convention of using a stock market index. In addition, they omit the third and fourth co-moment, while including the fifth. Their motivations are that even and odd moments capture different characteristics of the distribution and they attempt to minimize collinearity between the various moments, therefore, choosing the fifth instead of the third moment.

The results in both cases indicate that the inclusion of higher-order co-moments leads to a higher explanatory power of the model. Chung et al. (2006) state that the Fama-French factors seem to proxy for higher-order co-moments, since their statistical significance is almost eliminated after including higher-order co-moments. In their analysis they use different frequencies of returns. When testing the monthly data, they find out that the SMB and HML factors become insignificant after adding co-moments above the fourth to the regression. They also account for the possibility of accidental elimination by simply including more variables. To test for this, Chung et al. (2006) add univariate moments to the equation. In this case the Fama-French factors remain significant.

Bansal et al. (1993) compare their model to others, including conditional and unconditional, as well as one-factor and multi-factor models. After running their tests with the returns of different financial instruments, the non-linear, one-factor model shows the highest statistical significance and, in general, does not require additional factors.

Chapter 6

Data and methodology

Chapters 6.1 and 6.2 give an overview of the dataset and the methodology of my regression analysis. The data contains return series for multiple mutual fund and hedge fund indices. Chapter 6.1 aggregates the most important descriptive statistics for the two sets and the market proxy. Afterwards, chapter 6.2 explains the GMM, which I used for the regressions in chapter 7.

6.1 Data and sample description

I took the data for my empirical analysis from various sources. The monthly hedge fund returns were taken from the HFR (Hedge Fund Research) database.[1] Their data is already aggregated in different indices, as described in chapter 3. In order to get similar data for mutual funds, I calculated three indices, which represent the categories of the S & P Capital IQ database. The mutual fund categories, Balanced, Equity and Fixed Income, were created from three sets of individual mutual funds' returns. In each category I took all available mutual funds from the S & P Capital IQ database. Therefore, I used 848 Fixed Income funds, 1,372 Equity funds and 181 Balanced funds. From these sets I created monthly equally-weighted returns. The descriptive statistics of my data sets are presented in tables 6.1 and 6.2. All three mutual fund categories have negative skewness and kurtosis above three for the relevant timeframe from January 1990 until December 2013. The Jarque-Bera test rejects normality for the three categories.

While the Jarque-Bera test also rejects normality of returns for the majority of the hedge fund indices, normality cannot be rejected for three out of the five Macro subindices. Active Trading, Discretionary Thematic and Systematic Diversified have almost

[1] www.hedgefundresearch.com

Table 6.1: Descriptive statistics of the three mutual fund categories

Univariate statistics for the three mutual fund categories are listed below. Kurtosis is not stated as excess kurtosis. A significant value for the Jarque-Bera test signifies the rejection of normality. January 1990 - December 2013. * = p-value below 0.05, ** = p-value below 0.01.

Index	Mean	Std. Dev.	Skewness	Kurtosis	JB	n
Balanced	0.009	0.046	-0.262	4.699	37.943**	288
Equity	0.007	0.044	-0.741	5.006	74.626**	288
Fixed Income	0.005	0.050	-0.033	6.013	108.982**	288

zero skew and and a kurtosis around 3. Most hedge fund indices are also negatively skewed. Whenever co-skewness is significant in chapter 7, it will be discussed there.

Table 6.2: Descriptive statistics of the HFRI indices

Univariate statistics for the HFRI indices are listed below. Kurtosis is not stated as excess kurtosis. A significant value for the Jarque-Bera test signifies the rejection of normality. January 1990 - December 2013.
* = p-value below 0.05, ** = p-value below 0.01.

Index	Mean	Std. Dev.	Skewness	Kurtosis	JB	n
Event Driven						
Activist	0.002	0.045	-0.769	5.446	25.043**	72
Distrssed	0.010	0.019	-1.032	7.861	334.662**	288
Merger	0.007	0.012	-2.068	11.874	1150.418**	288
Total	0.009	0.019	-1.304	7.054	278.828**	288
Equity Hedge						
Energy	0.013	0.052	0.093	4.721	28.473**	228
Market Neut.	0.006	0.009	-0.258	4.601	33.950**	288
Fund. Growth	0.001	0.040	-0.698	4.287	10.820**	72
Fund. Value	0.004	0.031	-0.758	3.882	9.228**	72
Quant. Dir.	0.010	0.037	-0.436	3.859	18.006**	288
Short	0.000	0.053	0.257	5.286	65.898**	288
Technology	0.012	0.046	0.446	6.217	128.138**	276
Total	0.010	0.026	-0.260	4.838	43.791**	288
Em. Markets						
Asia	0.008	0.039	-0.099	3.820	8.549*	288
Global	0.010	0.038	-1.706	15.066	1729.426**	264

Continued from previous page						
Index	Mean	Std. Dev.	Skewness	Kurtosis	JB	n
Latin	0.012	0.051	0.478	6.831	179.339**	276
Russia	0.014	0.076	-0.284	7.784	228.261**	236
Total	0.010	0.041	-0.835	6.658	194.032**	288
FoF						
Composite	0.006	0.017	-0.680	6.950	209.391**	288
Conservative	0.005	0.011	-1.707	10.615	835.633**	288
Diversified	0.006	0.017	-0.460	7.070	208.993**	288
Market Def.	0.006	0.017	0.234	3.943	13.287**	288
Strategic	0.008	0.025	-0.472	6.482	156.183**	288
Macro						
Active Trad.	0.002	0.011	0.096	2.836	0.160	60
Commodity	0.002	0.019	0.986	5.089	24.751**	72
Disc. Them.	0.001	0.016	-0.016	3.738	1.636	72
Sys. Divers.	0.008	0.021	0.149	2.683	2.271	288
Total	0.009	0.022	0.567	4.013	27.715**	288
RV						
FI-AB	0.008	0.012	-3.564	27.549	6861.379**	252
FI-Conv. Arb.	0.007	0.019	-3.059	31.789	10394.530**	288
FI-Corporate	0.007	0.019	-1.343	11.045	863.190**	288
Multi	0.007	0.013	-2.075	16.328	2338.511**	288
Yield Alt.	0.007	0.021	-0.940	6.109	132.020**	240
Total	0.008	0.013	-2.120	16.542	2416.277**	288

The remaining factors were taken from the data library of Kenneth R. French. The risk-free rate is the return of the one-month US Treasury bill and the proxy for the market portfolio return is the value-weighted monthly return on all CRSP firms incorporated in the US. It has to be noted that the market return proxy has shortcomings when it comes to explaining the returns of indices which include fixed income instruments and emerging markets. Table 6.3 displays the descriptive statistics of the market portfolio proxy. Normality is rejected, skewness is negative and the kurtosis is at 4.114.

For the FF-Carhart models the factors were also taken from the data library of Kenneth R. French. I selected monthly returns for the two FF-factors, SMB and HML, and the Carhart momentum factor. These are respectively calculated as return on small stocks minus big stocks, return on value stocks minus growth stocks and return on winner

Table 6.3: Descriptive statistics of the market proxy

Univariate statistics for the market proxy are listed below. Kurtosis is not stated as excess kurtosis. A significant value for the Jarque-Bera test signifies the rejection of normality. January 1990 - December 2013.
* = p-value below 0.05, ** = p-value below 0.01.

Index	Mean	Std. Dev.	Skewness	Kurtosis	JB	n
Market proxy	0.009	0.044	-0.679	4.114	37.040**	288

stocks minus loser stocks.

6.2 Methodology

The analysis of my data in the previous chapter has shown that normality is rejected for the majority of the return time series and the only exceptions are three hedge fund indices. Chapter 6.1 also shows that the returns of the market proxy are not normally distributed. The general forms of the Ordinary Least Squares (OLS) and Maximum Likelihood (ML) procedures are able to deal with issues, such as heteroskedasticity or autocorrelation, but one of their main assumptions is the normality of the time series. Following Hwang and Satchell (1999) and Ranaldo and Favre (2003) I used the Generalized Method of Moments (GMM), which was initially developed by Hansen (1982). In addition to the handling of heteroskedasticity and autocorrelation, which are both common features in fund return data, GMM does not require the data to be normally distributed. Equations 6.1 and 6.2 show the regression formulas for the higher-moment CAPM and the FF-Carhart model respectively. They are similar to the formulas used by Ranaldo and Favre (2003).

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \gamma_i(R_{mt} - E(R_m))^2 + \delta_i(R_{mt} - E(R_m))^3 + \epsilon_i \quad (6.1)$$

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + s_i SMB + h_i HML + m_i MOM + \epsilon_i \quad (6.2)$$

To conduct the regressions I used the statistical software EViews 6, which has an integrated GMM function. The returns of the indices are always adjusted by the risk-free rate at period t to account for the varying level of the risk-free rate over time. This excess return is then regressed on the excess market return and the relevant factors depending on the model. The regression results always contain an alpha and an error term, but only the alpha is reported in chapter 7.

Since the return series of the market proxy has negative skewness, as stated in chapter 6.1, a negative coefficient γ in equation 6.1 leads to a higher excess return. Therefore, a negative coefficient γ for co-skewness and a positive coefficient δ for co-kurtosis are in line with the theoretical background as outlined in chapters 5.3.1 and 5.3.2. These expected results fulfill the conditions of a rational and risk-averse investor. For the three FF-Carhart factors, there are no expected signs. Chapter 7 will determine whether they are relevant for the pricing of the various indices and whether they have a positive or a negative sign.

Chapter 7

Results

Before presenting the results for the two extensions of the CAPM, tables 7.1 and 7.2 contain the adjusted R-squared and the alpha for the classic CAPM, where only the market portfolio proxy is used to explain the returns. These figures are then compared to the regressions of the higher-moment CAPM and the FF-Carhart model, to see whether the additional variables add explanatory power. The results of the classic CAPM confirm one of the main differences between mutual funds and hedge funds, as mentioned in chapter 4. While all three strategies in table 7.1 do not have a significant alpha, there are 14 out of the 33 hedge fund indices in table 7.2 with a statistically significant alpha value. The full results of these regressions including the values of beta are listed in the appendix.

7.1 Mutual funds results

I aggregated the most important results in tables 7.3, 7.4, 7.5 and 7.6. The first two tables show the coefficients and their corresponding p-values as well as the adjusted R-squared for each mutual fund category. The last two tables present the same numbers for the hedge fund indices. In both cases the GMM regressions were run separately for the higher-moment CAPM and the FF-Carhart model. In table 7.3, as expected, mutual Equity funds have the highest adjusted R-squared, since the independent variables are only the market portfolio proxy and the higher co-moments. Fixed income funds show the lowest value, which is not surprising, as my market portfolio proxy is a stock market index. Compared to the values of adjusted R-squared in table 7.1, there are only minimal improvements. These small differences are not surprising, considering that the only coefficient with statistical significance is the gamma for the Balanced mutual fund

Table 7.1: GMM results for the three mutual fund categories using the standard CAPM

The three mutual fund categories are regressed against the excess market return using GMM. The alpha, its p-value and the adjusted R-squared are reported. January 1990 - December 2013.
* = p-value below 0.05, ** = p-value below 0.01.

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \epsilon_i$$

Index	α	*p-value*	**Adj.** R^2
Balanced	0.002	0.417	0.425
Equity	-0.001	0.578	0.676
Fixed Income	0.000	0.964	0.110

Table 7.2: GMM results for the HFRI hedge fund indices using the standard CAPM

The HFRI indices are regressed against the excess market return using GMM. The alpha, its p-value and the adjusted R-squared are reported. January 1990 - December 2013.
* = p-value below 0.05, ** = p-value below 0.01.

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \epsilon_i$$

Index	α	*p-value*	**Adj.** R^2	**Index**	α	*p-value*	**Adj.** R^2
Event Driven				**FoF**			
Activist	-0.003	0.370	0.685	Composite	0.002	0.054	0.339
Distressed	0.006**	0.000	0.319	Conservative	0.002*	0.039	0.313
Merger	0.003**	0.000	0.301	Diversified	0.002	0.102	0.314
Total	0.005**	0.000	0.564	Market Def.	0.003**	0.002	0.000
Equity Hedge				Strategic	0.003*	0.043	0.382
Energy	0.007	0.056	0.237	**Macro**			
Market Neut.	0.003**	0.000	0.079	Active Trad.	0.002	0.173	-0.011
Fund. Growth	-0.003	0.250	0.741	Commodity	0.001	0.591	0.034
Fund. Value	0.000	0.831	0.855	Disc. Them.	-0.001	0.407	0.522
Quant. Dir.	0.003*	0.018	0.730	Sys. Divers.	0.005**	0.000	0.181
Short Bias	0.003	0.088	0.637	Total	0.006**	0.000	0.126
Technology	0.005*	0.050	0.476	**Rel. Value**			
Total	0.005**	0.000	0.630	FI-AB	0.005**	0.000	0.032
Em. Markets				FI-Conv. Arb.	0.003	0.059	0.230
Asia	0.002	0.338	0.363	FI-Corporate	0.002	0.079	0.311
Global	0.004	0.132	0.364	Multi	0.003**	0.001	0.315
Latin	0.005	0.111	0.324	Yield Alt.	0.003*	0.026	0.298
Russia	0.006	0.297	0.257	Total	0.005**	0.000	0.280
Total	0.004	0.134	0.434				

Table 7.3: GMM results for the three mutual fund categories using the higher-moment CAPM

The three mutual fund categories are regressed against the excess market return, the co-skewness and the co-kurtosis using GMM. The alpha, the coefficients and their p-values, as well as the adjusted R-squared are reported. p-values are listed below the coefficients. January 1990 - December 2013.
* = p-value below 0.05, ** = p-value below 0.01.

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \gamma_i(R_{mt} - E(R_{mt}))^2 + \delta_i(R_{mt} - E(R_{mt}))^3 + \epsilon_i$$

Index	α	β	γ	δ	**Adj.** R^2
Balanced	0.006*	0.715**	-2.617*	-13.119	0.438
	0.015	0.000	0.032	0.183	
Equity	0.001	0.753**	-1.006	3.767	0.684
	0.505	0.000	0.226	0.484	
Fixed Income	0.003	0.246*	-0.304	15.994	0.121
	0.559	0.025	0.844	0.277	

category. The negative value of this coefficient is coherent with the initial assumptions in chapter 5.3.1, since the market skewness is negative. The other gammas and all deltas are not significant.

Table 7.4, containing the results of the FF-Carhart model delivers a similar picture, but two things are noteworthy. First, all three coefficients of the FF and Carhart factors are statistically significant for the Balanced and Equity category. Second, the alpha of the Balanced funds is not significant, while the alpha in the higher-moment CAPM is statistically significant. In this case the FF-Carhart model appears to work better than the higher-moment CAPM.

7.2 Hedge funds results

The analysis of tables 7.5 and 7.6 is more complex, due to the high number of different strategies in the hedge fund dataset. Therefore, I will structure the discussion by the main hedge fund strategies.

In three out of the four Event Driven sub-strategies co-skewness is highly significant. Activist funds are sufficiently described by beta, while Distressed, Merger and Total have a significant negative gamma. These results also confirm the assumption of a negative

Table 7.4: GMM results for the three mutual fund categories using the FF-Carhart model

The three mutual fund categories are regressed against the excess market return, the FF-factors the Carhart-factor using GMM. The alpha, the coefficients and their p-values, as well as the adjusted R-squared are reported. p-values are listed below the coefficients. January 1990 - December 2013.
* = p-value below 0.05, ** = p-value below 0.01.

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + s_iSMB + h_iHML + m_iMOM + \epsilon_i$$

Index	α	β	**s**	**h**	**m**	**Adj.** R^2
Balanced	0.002	0.660**	0.210**	0.227**	-0.105*	0.465
	0.453	0.000	0.000	0.002	0.010	
Equity	-0.001	0.773**	0.232**	0.140*	-0.075**	0.710
	0.476	0.000	0.000	0.013	0.004	
Fixed Income	-0.000	0.404**	0.010	0.114	0.011	0.105
	0.939	0.000	0.917	0.382	0.852	

coefficient for negative market skewness. On the other hand co-kurtosis does not play a role in the explanation of Event Driven funds' returns. Table 7.6 contains the numbers for the FF-Carhart model, where the adjusted R-squared is very similar to the higher-moment regressions. For Distressed funds the number is 0.440, but only 0.403 for the higher-moment results, which represents the largest difference. In both cases the alpha for Distressed, Merger and Total is positive and statistically significant, which implies a persistent out-performance of the market. The momentum factor is not significant for any of the four sub-categories, while SMB and HML both have positive and significant coefficients.

The higher-moment CAPM does not add any explanatory power to the eight Equity Hedge indices, since the improvement in adjusted R-squared is zero or minimal. Co-skewness is only significant at the five percent level for the Quantitative Directional class. The same strategy provides a significant coefficient for co-kurtosis. Both coefficients are negative, which only partly confirms the initial assumptions. Negative co-skewness increases the return, which is coherent with the expectations of a rational investor. But negative co-kurtosis also increases the return, which contradicts the assumption, that rational investors prefer negative co-kurtosis. As I will show in the discussion of the remaining categories, this result is the only exception from the initial assumption and Ranaldo and Favre (2003) also detected two deviations from this theory. The other noteworthy findings are the negative coefficient of co-skewness for the Total index, which is significant at the ten percent level, and the significant negative delta for the Technology index.

In table 7.6, on the other hand, the FF-Carhart factors seem to explain the Equity Hedge category much better. R-squared increased by more than 0.10 in five out of eight indices. The biggest improvements are for the Market Neutral and the Technology index. While all three factors are significant for the Technology index, HML and MOM are highly significant for the Market Neutral index. This implies that funds of this strategy are linked to the difference between market and book value of companies, as well as momentum effects. The HML factor is significant for all sub-indices except for the Total index, while the SMB factor is significant for Quantitative Directional, Short Bias, Technology and Total, and the momentum factor is significant for Market Neutral, Fundamental Value, Technology and Total.

The results for the group of Emerging Markets indices differ from most of the other hedge fund strategies. The results confirm the idea of Hwang and Satchell (1999), who claim that the higher-moment CAPM adds significant explanatory power to emerging market funds. Especially in the Russia category the adjusted R-squared improves from 0.257 to 0.302 when using co-skewness and co-kurtosis. With the exception of the Asia index the higher-moment approach outperforms the FF-Carhart model. The Russia index has insignificant co-skewness, but high and significant co-kurtosis. In addition, the Total index contains a coefficient for co-kurtosis that is significant at the 10 percent level and is also positive. Both cases confirm the intuition of rational investors disliking positive co-kurtosis and demanding higher risk premia. The superior performance of the higher-moment CAPM is in line with the assumption of higher skewness and kurtosis in emerging markets. The alpha of the Total index is positive and significant for the higher-moment CAPM, while it becomes insignificant when the FF-Carhart factors are used. The same effect is true for the Global and Russia indices, which hints at the FF-Carhart factors capturing a risk component, that is not concluded in the third and fourth co-moments.

With the FoF indices, the FF-Carhart factors, in general, add more explanatory power than the co-moments, with the exception of the Conservative class. This is also the only sub-index where co-kurtosis is significant at the five percent level, showing a positive coefficient. For the Strategic funds I get a negative and significant co-skewness coefficient. An interesting feature is the positive and significant alpha for all FoF indices under the higher-moment CAPM, while alpha becomes insignificant under the FF-Carhart factors, the only exception being the Market Defensive strategy. On the other hand, the MOM factor is significant for all FoF strategies, while it is only rarely significant for the other hedge fund indices, which implies that these managers are reliant on the past performance of the funds in their portfolios. Since in contrast to other hedge funds, fund of funds managers invest in other hedge fund managers, they are more dependent on the strategies and the performance of these other funds. Therefore, the outperformance of the FF-Carhart model and especially the MOM factor is not surprising. Another interesting feature of tables 7.5 and 7.6 are the results for the Market Defensive index. In both cases beta is insignificant, confirming the investment strategy of these managers, who strive to be independent from the market return. In both models alpha is positive and significant, confirming a constant outperformance of the market, although alpha is lower in case of the FF-Carhart model.

The Macro funds show a very differentiated picture depending on the various sub-indices. With Commodity and Systematic Diversified funds, the higher-moment CAPM adds more explanatory power, while Active Trading, Discretionary Thematic and Total have a higher adjusted R-squared under the FF-Carhart model. The only significant co-moment of the Macro funds in table 7.5 is the co-kurtosis of the Systematic Diversified funds. Active Trading has a generally low adjusted R-squared and the only significant coefficient is the MOM factor, which also seems to cause the relatively high adjusted R-squared of the FF-Carhart model. Similar to the FoF Market Defensive managers, these funds aim to be uncorrelated to the market, which is confirmed by the insignificant beta coefficients in all three tested models. As with most other hedge fund categories, the Total index has a positive and significant alpha for both CAPM extensions.

In table 7.5, as with the mutual fund Fixed Income category, the first three sub-indices in the Relative Value group of hedge funds show a relatively low adjusted R-squared. All three Fixed Income indices - Asset Backed, Convertible Arbitrage and Corporate have a significant alpha in case of the higher-moment CAPM. Alpha only remains significant for the Asset Backed case when using the FF-Carhart factors. These factors seem to capture more of the Fixed Income returns than the co-moments of the market return. The only significant co-moment in table 7.5 is co-kurtosis for the Convertible Arbitrage funds. For the Multi and Total sub-indices the higher-moment CAPM yields a higher adjusted R-squared and co-kurtosis is positive and significant for the Total funds.

Table 7.5: GMM results for the HFRI hedge fund indices using the higher-moment CAPM

The HFRI indices are regressed against the excess market return, the co-skewness and the co-kurtosis using GMM. The alpha, the coefficients and their p-values, as well as the adjusted R-squared are reported. p-values are listed below the coefficients. January 1990 - December 2013. * = p-value below 0.05, ** = p-value below 0.01.

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \gamma_i(R_{mt} - E(R_{mt}))^2 + \delta_i(R_{mt} - E(R_{mt}))^3 + \epsilon_i$$

Index	α	β	γ	δ	**Adj.** R^2
Event Driven					
Activist	0.002	0.614**	-1.301	4.470	0.702
	0.659	0.000	0.108	0.301	
Distressed	0.009**	0.183**	-1.683**	0.832	0.403
	0.000	0.000	0.000	0.726	
Merger	0.005**	0.118**	-0.758**	0.017	0.342
	0.000	0.000	0.003	0.996	
Total	0.008**	0.297**	-1.544**	-1.511	0.616
	0.000	0.000	0.000	0.482	
Equity Hedge					
Energy	0.006	0.471**	0.096	13.215	0.235
	0.103	0.000	0.398	0.176	
Market Neut.	0.003**	0.052*	0.031	0.712	0.073
	0.000	0.015	0.892	0.680	
Fund. Growth	-0.003	0.619**	0.138	3.262	0.734
	0.222	0.000	0.858	0.566	
Fund. Value	-0.000	0.552**	-0.200	1.405	0.851
	0.990	0.000	0.628	0.639	
Quant. Dir.	0.005**	0.762**	-1.453**	-11.779**	0.738
	0.000	0.000	0.003	0.008	
Short Bias	0.005**	-1.067**	0.113	14.192	0.644
	0.023	0.000	0.888	0.087	
Technology	0.006*	0.826**	-1.659	-17.871*	0.483
	0.012	0.000	0.053	0.012	
Total	0.006**	0.460**	-0.594	1.225	0.631

Index	α	β	γ	δ	Adj. R^2
Continued from previous page					
	0.000	0.000	0.061	0.637	
Em. Markets					
Asia	0.005	0.538**	-1.343	-5.757	0.365
	0.124	0.000	0.073	0.266	
Global	0.009**	0.354**	-1.431	14.811	0.422
	0.001	0.000	0.087	0.229	
Latin	0.005	0.531**	0.810	19.713	0.333
	0.105	0.000	0.671	0.155	
Russia	0.013*	0.516**	-0.980	36.858**	0.302
	0.032	0.000	0.586	0.020	
Total	0.007**	0.465**	-0.854	14.552	0.465
	0.006	0.000	0.319	0.072	
FoF					
Composite	0.004**	0.174	-0.722	2.618	0.370
	0.000	0.000	0.057	0.374	
Conservative	0.003**	0.094**	-0.482	3.973*	0.371
	0.000	0.000	0.060	0.027	
Diversified	0.003**	0.178	-0.657	2.178	0.335
	0.000	0.000	0.094	0.499	
Market Def.	0.004**	0.007	-0.088	1.541	-0.005
	0.002	0.890	0.854	0.780	
Strategic	0.006**	0.293**	-1.353**	1.099	0.414
	0.002	0.000	0.007	0.816	
Macro					
Active Trad.	-0.001	0.049	0.674	-10.385	0.008
	0.701	0.404	0.053	0.147	
Commodity	-0.002	0.150**	0.605	-4.281	0.059
	0.557	0.008	0.380	0.371	
Disc. Them.	-0.002	0.220**	0.308	1.670	0.511
	0.214	0.000	0.503	0.612	
Sys. Divers.	0.003	0.367**	-0.223	-21.055**	0.296
	0.053	0.000	0.763	0.000	
Total	0.006**	0.221**	-0.344	-7.259	0.129
	0.001	0.000	0.607	0.183	

Continued from previous page					
Index	α	β	γ	δ	**Adj.** R^2
Rel. Value					
FI-AB	0.007**	0.033	-0.855	-1.423	0.064
	0.000	0.195	0.085	0.568	
FI-Conv. Arb.	0.004**	0.069	0.366	18.591*	0.331
	0.000	0.133	0.571	0.014	
FI-Corporate	0.005**	0.153**	-0.938*	7.302	0.383
	0.000	0.000	0.038	0.016	
Multi	0.005**	0.097**	-0.522	5.914	0.391
	0.000	0.000	0.106	0.058	
Yield Alt.	0.005**	0.212**	-0.402	3.881	0.308
	0.001	0.000	0.434	0.308	
Total	0.007**	0.075**	-0.734	6.534*	0.400
	0.000	0.000	0.091	0.017	

Table 7.6: GMM results for the HFRI hedge fund indices using the FF-Carhart model

The HFRI indices are regressed against the excess market return, the FF-factors the Carhart-factor using GMM. The alpha, the coefficients and their p-values, as well as the adjusted R-squared are reported. p-values are listed below the coefficients. January 1990 - December 2013.
* = p-value below 0.05, ** = p-value below 0.01.

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + s_i SMB + h_i HML + m_i MOM + \epsilon_i$$

Index	α	β	s	h	m	**Adj.** R^2
Event Driven						
Activist	-0.003	0.753**	-0.037	-0.241**	-0.050	0.689
	0.328	0.000	0.801	0.007	0.156	
Distressed	0.005**	0.232**	0.195**	0.153**	0.005	0.440
	0.000	0.000	0.000	0.001	0.779	
Merger	0.003**	0.141**	0.065**	0.055*	0.010	0.336
	0.000	0.000	0.000	0.037	0.433	
Total	0.004**	0.315**	0.190**	0.101**	0.006	0.656
	0.000	0.000	0.000	0.004	0.682	

Continued from previous page						
Index	α	β	s	h	m	**Adj.** R^2
Equity Hedge						
Energy	0.005	0.580**	0.167	0.348**	0.011	0.271
	0.131	0.000	0.258	0.003	0.849	
Market Neut.	0.002**	0.090**	0.024	0.070**	0.090**	0.337
	0.003	0.000	0.114	0.000	0.000	
Fund. Growth	-0.004	0.701**	-0.048	-0.351**	-0.077	0.778
	0.127	0.000	0.698	0.001	0.093	
Fund. Value	-0.001	0.554**	0.041	-0.184*	-0.054*	0.872
	0.614	0.000	0.590	0.021	0.018	
Quant. Dir.	0.003**	0.635**	0.325**	-0.140**	0.033	0.849
	0.001	0.000	0.000	0.000	0.145	
Short Bias	0.003*	-0.812**	-0.478**	0.362**	-0.030	0.803
	0.049	0.000	0.000	0.000	0.447	
Technology	0.006**	0.594**	0.389**	-0.511**	0.084*	0.751
	0.000	0.000	0.000	0.000	0.013	
Total	0.004**	0.445**	0.222**	-0.013	0.074**	0.734
	0.000	0.000	0.000	0.677	0.005	
Em. Markets						
Asia	0.002	0.493**	0.213**	0.016	-0.010	0.386
	0.361	0.000	0.000	0.813	0.801	
Global	0.004	0.493**	0.237**	0.048	0.024	0.399
	0.191	0.000	0.000	0.419	0.481	
Latin	0.004	0.660**	0.127	-0.022	0.073	0.331
	0.162	0.000	0.082	0.816	0.210	
Russia	0.005	0.852**	0.264	0.165	0.049	0.263
	0.376	0.000	0.100	0.204	0.525	
Total	0.003	0.588**	0.206**	0.054	0.037	0.456
	0.193	0.000	0.001	0.411	0.365	
FoF						
Composite	0.001	0.221**	0.103**	0.013	0.077**	0.433
	0.199	0.000	0.001	0.631	0.000	
Conservative	0.001	0.148**	0.032	0.022	0.039**	0.344
	0.118	0.000	0.074	0.301	0.002	
Diversified	0.001	0.218**	0.113**	0.008	0.084**	0.422

Continued from previous page						
Index	α	β	s	h	m	**Adj.** R^2
	0.340	0.000	0.000	0.797	0.000	
Market Def.	0.003*	0.043	0.039	0.035	0.078**	0.049
	0.016	0.164	0.277	0.205	0.001	
Strategic	0.002	0.333**	0.168**	-0.037	0.103**	0.492
	0.111	0.000	0.000	0.317	0.000	
Macro						
Active Trad.	0.001	0.018	-0.155	-0.093	-0.067**	0.133
	0.288	0.593	0.058	0.050	0.000	
Commodity	0.001	0.140**	-0.128	-0.090	0.035	0.043
	0.530	0.007	0.206	0.182	0.452	
Disc. Them.	-0.001	0.253**	-0.091	-0.143**	-0.050*	0.573
	0.342	0.000	0.181	0.008	0.029	
Sys. Divers.	0.005**	0.200**	0.009	-0.138**	0.071**	0.255
	0.000	0.000	0.777	0.000	0.000	
Total	0.005**	0.190**	0.073*	0.003	0.105**	0.192
	0.000	0.000	0.034	0.933	0.000	
Rel. Value						
FI-AB	0.005**	0.046*	0.059	0.055	-0.009	0.055
	0.000	0.046	0.112	0.057	0.485	
FI-Conv. Arb.	0.003	0.195**	0.072**	0.079	-0.042	0.259
	0.078	0.002	0.005	0.108	0.180	
FI-Corporate	0.002	0.229**	0.148**	0.133**	-0.023	0.389
	0.122	0.000	0.000	0.000	0.193	
Multi	0.003**	0.149**	0.088**	0.058*	-0.016	0.366
	0.002	0.000	0.000	0.044	0.193	
Yield Alt.	0.002	0.270**	0.110**	0.161*	0.015	0.351
	0.081	0.000	0.009	0.012	0.461	
Total	0.004**	0.144**	0.081**	0.078**	-0.013	0.335
	0.000	0.000	0.002	0.008	0.339	

Test of the three-moment CAPM, which excludes co-kurtosis from the analysis, have also been done and are reported in Appendix 2.

7.3 Tests excluding the GFC-period

The last tests are the regressions of the higher-moment CAPM and the FF-Carhart factors excluding the period of the Global Financial Crisis (GFC), also termed subprime mortgage crisis. To test which effect this period of economic downturn has on the results of this thesis, I did the same calculations as reported in tables 7.3, 7.4, 7.5 and 7.6 but the timeframe does not include the 36 months during the years 2007 to 2009, reducing the maximum number of observations from 288 to 252. Tables 7.7, 7.8, 7.9 and 7.10 report the results of these updated versions.

Table 7.7: GMM results for the three mutual fund categories using the higher-moment CAPM and excluding the period of the GFC

The three mutual fund categories are regressed against the excess market return, the co-skewness and the co-kurtosis using GMM. The alpha, the coefficients and their p-values, as well as the adjusted R-squared are reported. p-values are listed below the coefficients. January 1990 - December 2013 (excluding January 2007 - December 2009).
* = p-value below 0.05, ** = p-value below 0.01.

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \gamma_i(R_{mt} - E(R_{mt}))^2 + \delta_i(R_{mt} - E(R_{mt}))^3 + \epsilon_i$$

Index	α	β	γ	δ	**Adj.** R^2
Balanced	0.006*	0.751**	-3.201*	-27.506**	0.365
	0.023	0.000	0.010	0.003	
Equity	0.003	0.728**	-1.608*	3.211	0.635
	0.278	0.000	0.026	0.543	
Fixed Income	0.000	0.301**	-1.184	-6.107	0.091
	0.934	0.000	0.175	0.326	

All three mutual fund categories show a lower adjusted R-squared when the GFC-period is not included in the analysis. The only exception is the Fixed Income class, which has a slightly higher value under the FF-Carhart model. The statistical significance of two higher-moment factors is changed. Co-kurtosis for the Balanced group and co-skewness for the Equity funds are now statistically significant. Table 7.8 shows the results for the mutli-factor model with the SMB and HML factors having significant coefficients when the months during 2007 to 2009 are excluded.

Table 7.8: GMM results for the three mutual fund categories using the FF-Carhart model and excluding the period of the GFC

The three mutual fund categories are regressed against the excess market return, the FF-factors the Carhart-factor using GMM. The alpha, the coefficients and their p-values, as well as the adjusted R-squared are reported. p-values are listed below the coefficients. January 1990 - December 2013 (excluding January 2007 - December 2009).
* = p-value below 0.05, ** = p-value below 0.01.

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + s_i SMB + h_i HML + m_i MOM + \epsilon_i$$

Index	α	β	**s**	**h**	**m**	**Adj.** R^2
Balanced	0.002	0.659**	0.271**	0.314**	-0.139**	0.401
	0.547	0.000	0.000	0.002	0.007	
Equity	-0.001	0.780**	0.283**	0.223**	-0.080**	0.674
	0.407	0.000	0.000	0.000	0.006	
Fixed Income	-0.004	0.367**	0.154*	0.344**	0.033	0.144
	0.086	0.000	0.015	0.000	0.407	

Table 7.9: GMM results for the HFRI hedge fund indices using the higher-moment CAPM and excluding the period of the GFC

The HFRI indices are regressed against the excess market return, the co-skewness and the co-kurtosis using GMM. The alpha, the coefficients and their p-values, as well as the adjusted R-squared are reported. p-values are listed below the coefficients. January 1990 - December 2013 (excluding January 2007 - December 2009).
* = p-value below 0.05, ** = p-value below 0.01.

$$R_{it} - R_{ft} =$$
$$\alpha_i + \beta_i(R_{mt} - R_{ft}) + \gamma_i(R_{mt} - E(R_{mt}))^2 + \delta_i(R_{mt} - E(R_{mt}))^3 + \epsilon_i$$

Index	α	β	γ	δ	**Adj.** R^2
Event Driven					
Activist	0.002	0.646**	-2.202	2.560	0.547
	0.730	0.000	0.137	0.899	
Distressed	0.010**	0.160**	-1.834**	1.690	0.353
	0.000	0.000	0.000	0.647	
Merger	0.005**	0.088**	-0.816**	4.665	0.323
	0.000	0.002	0.004	0.085	
Total	0.009**	0.287**	-1.725**	-0.644	0.593

Continued from previous page					
Index	α	β	γ	δ	**Adj.** R^2
	0.000	0.000	0.000	0.827	
Equity Hedge					
Energy	0.006	0.524**	0.890	-0.344	0.170
	0.157	0.000	0.535	0.974	
Market Neut.	0.003**	0.044	0.186	2.448	0.072
	0.000	0.065	0.472	0.287	
Fund. Growth	-0.002	0.595**	-1.031	8.389	0.789
	0.424	0.000	0.275	0.551	
Fund. Value	0.001	0.555**	-0.932	2.113	0.907
	0.654	0.000	0.060	0.770	
Quant. Dir.	0.005**	0.788**	-1.563**	-8.447	0.744
	0.000	0.000	0.004	0.113	
Short Bias	0.005*	-1.117**	0.621	12.257	0.645
	0.030	0.000	0.518	0.300	
Technology	0.007*	0.865**	-2.039*	-11.562	0.498
	0.017	0.000	0.048	0.160	
Total	0.006**	0.470**	-0.694	-3.772	0.605
	0.000	0.000	0.054	0.288	
Em. Markets					
Asia	0.004	0.547**	-1.701*	-9.929	0.329
	0.180	0.000	0.035	0.126	
Global	0.010**	0.282**	-2.011*	29.996*	0.421
	0.001	0.001	0.035	0.012	
Latin	0.005	0.526**	0.578	27.677	0.308
	0.152	0.000	0.804	0.184	
Russia	0.016*	0.423**	-1.336	53.071**	0.248
	0.019	0.008	0.556	0.005	
Total	0.008**	0.418**	-1.226	24.315**	0.440
	0.004	0.000	0.209	0.003	
FoF					
Composite	0.004**	0.160**	-0.615	4.895	0.331
	0.000	0.000	0.174	0.302	
Conservative	0.003**	0.090**	-0.357	3.344	0.323
	0.000	0.000	0.215	0.187	

Continued from previous page					
Index	α	β	γ	δ	**Adj.** R^2
Diversified	0.004**	0.163**	-0.536	4.880	0.302
	0.000	0.000	0.250	0.349	
Market Def.	0.004**	-0.029	-0.052	8.750	0.014
	0.002	0.604	0.929	0.187	
Strategic	0.006**	0.268**	-1.343*	7.281	0.396
	0.000	0.000	0.022	0.193	
Macro					
Active Trad.	-0.001	0.096	0.661	-18.352*	-0.005
	0.624	0.155	0.179	0.046	
Commodity	-0.004	0.244*	0.559	-4.644	0.260
	0.157	0.030	0.492	0.757	
Disc. Them.	-0.003	0.268**	0.027	-4.992	0.560
	0.119	0.000	0.963	0.591	
Sys. Divers.	0.003	0.394**	-0.086	-17.998*	0.381
	0.086	0.000	0.909	0.011	
Total	0.006**	0.222**	-0.358	-2.271	0.156
	0.001	0.000	0.639	0.739	
Rel. Value					
FI-AB	0.008**	0.006	-1.141*	-1.709	0.053
	0.000	0.718	0.045	0.578	
FI-Conv. Arb.	0.004**	0.088**	0.038	3.982	0.185
	0.000	0.004	0.888	0.110	
FI-Corporate	0.006**	0.140**	-1.225**	4.640	0.291
	0.000	0.001	0.008	0.101	
Multi	0.005**	0.103**	-0.705**	0.641	0.307
	0.000	0.000	0.007	0.686	
Yield Alt.	0.006**	0.175**	-0.280	7.799	0.271
	0.000	0.000	0.584	0.079	
Total	0.007**	0.068**	-0.879*	3.506	0.287
	0.000	0.004	0.023	0.401	

Table 7.10: GMM results for the HFRI hedge fund indices using the FF-Carhart model and excluding the period of the GFC

The HFRI indices are regressed against the excess market return, the FF-factors the Carhart-factor using GMM. The alpha, the coefficients and their p-values, as well as the adjusted R-squared are reported. p-values are listed below the coefficients. January 1990 - December 2013 (excluding January 2007 - December 2009).
* = p-value below 0.05, ** = p-value below 0.01.

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + s_i SMB + h_i HML + m_i MOM + \epsilon_i$$

Index	α	β	s	h	m	**Adj.** R^2
Event Driven						
Activist	-0.001	0.654**	0.023	0.000	-0.223*	0.540
	0.848	0.000	0.863	0.997	0.014	
Distressed	0.006**	0.219**	0.236**	0.197**	-0.013	0.471
	0.000	0.000	0.000	0.000	0.439	
Merger	0.003**	0.145**	0.085**	0.092**	0.001	0.320
	0.001	0.000	0.000	0.000	0.934	
Total	0.004**	0.318**	0.230**	0.157**	-0.014	0.691
	0.000	0.000	0.000	0.000	0.356	
Equity Hedge						
Energy	0.004	0.621**	0.314*	0.589**	-0.051	0.274
	0.198	0.000	0.031	0.000	0.467	
Market Neut.	0.002**	0.091**	0.035*	0.084**	0.095**	0.374
	0.002	0.000	0.017	0.000	0.000	
Fund. Growth	-0.004	0.600**	0.174	-0.057	-0.167**	0.807
	0.097	0.000	0.063	0.617	0.007	
Fund. Value	0.000	0.527**	0.119*	0.068	-0.154**	0.922
	0.958	0.000	0.019	0.264	0.000	
Quant. Dir.	0.003**	0.668**	0.376**	-0.069	-0.006	0.864
	0.001	0.000	0.000	0.101	0.778	
Short Bias	0.004*	-0.856**	-0.463**	0.361**	-0.056	0.805
	0.011	0.000	0.000	0.000	0.213	
Technology	0.006**	0.602**	0.393**	-0.517**	0.101*	0.750
	0.001	0.000	0.000	0.000	0.027	
Total	0.004**	0.429**	0.250**	0.014	0.089**	0.753

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Index	α	β	s	h	m	**Adj.** R^2
	0.000	0.000	0.000	0.665	0.000	
Em. Markets						
Asia	0.001	0.494	0.293**	0.125**	-0.020	0.374
	0.632	0.000	0.000	0.051	0.619	
Global	0.003	0.507**	0.299**	0.134	0.018	0.376
	0.365	0.000	0.000	0.065	0.656	
Latin	0.002	0.700**	0.180*	0.084	0.090	0.309
	0.433	0.000	0.028	0.424	0.186	
Russia	0.007	0.852**	0.391*	0.289	0.012	0.218
	0.335	0.000	0.023	0.098	0.897	
Total	0.003	0.596**	0.275**	0.150*	0.035	0.439
	0.302	0.000	0.000	0.037	0.461	
FoF						
Composite	0.002	0.202**	0.127**	0.033	0.081**	0.441
	0.101	0.000	0.000	0.267	0.000	
Conservative	0.002**	0.124**	0.047**	0.029	0.037*	0.353
	0.004	0.000	0.009	0.187	0.012	
Diversified	0.001	0.203**	0.136**	0.031	0.089**	0.429
	0.241	0.000	0.000	0.327	0.000	
Market Def.	0.002	0.049	0.062	0.060	0.090**	0.070
	0.093	0.232	0.112	0.091	0.001	
Strategic	0.003	0.317**	0.199**	-0.008	0.108**	0.488
	0.077	0.000	0.000	0.858	0.000	
Macro						
Active Trad.	0.001	0.051	-0.189	-0.016	-0.044	0.028
	0.330	0.228	0.087	0.855	0.515	
Commodity	-0.004	0.245**	-0.034	-0.145	0.012	0.261
	0.127	0.000	0.775	0.263	0.856	
Disc. Them.	-0.002	0.236**	0.025	-0.006	-0.124*	0.610
	0.096	0.000	0.621	0.933	0.015	
Sys. Divers.	0.004**	0.253**	0.039	-0.090*	0.049*	0.369
	0.000	0.000	0.195	0.020	0.021	
Total	0.004**	0.229**	0.104**	0.056	0.110**	0.230
	0.002	0.000	0.004	0.174	0.001	

Index	α	β	s	h	m	Adj. R^2
Continued from previous page						
Rel. Value						
FI-AB	0.005**	0.025	0.054	0.044	0.002	0.012
	0.000	0.299	0.163	0.157	0.901	
FI-Conv. Arb.	0.003**	0.122**	0.080**	0.081**	0.002	0.241
	0.001	0.000	0.000	0.001	0.891	
FI-Corporate	0.003*	0.205**	0.174**	0.160**	-0.031	0.356
	0.040	0.000	0.000	0.000	0.145	
Multi	0.004**	0.121**	0.104**	0.075**	-0.014	0.380
	0.000	0.000	0.000	0.000	0.305	
Yield Alt.	0.003*	0.287**	0.154**	0.255**	0.009	0.390
	0.030	0.000	0.000	0.000	0.694	
Total	0.005**	0.117**	0.098**	0.098**	-0.012	0.312
	0.000	0.000	0.001	0.000	0.407	

Similar to the differences between the two models for the hedge fund indices, their reaction to an exclusion of the GFC-period also varies. In tabel 7.9 Event Driven funds show a lower adjusted R-squared, while the significance of the co-skewness and co-kurtosis coefficients is unchanged. Equity Hedge managers have mixed results, since the Energy and the Total index have less explanatory power without the crisis months, all other indices have higher power. For Quantitative Directional and Technology funds co-kurtosis is rendered insignificant and co-skewness becomes statistically significant for the Technology index. Emerging Markets funds all have a lower adjusted R-squared and co-kurtosis is now significant for the Global and Total indices in addition to the Russia index. Fund of Funds show lower explanatory power, only the Market Defensive funds rise, but the value of adjusted R-squared is almost zero as under the complete analysis. Macro funds generally have a higher adjusted R-squared and Relative Value funds have a lower adjusted R-squared. The only noteworthy changes of coefficients in these two categories are the significant values of co-skewness for Fixed Income Asset-Backed, Multi and Total funds in the Relative Value group.

The last table 7.10 shows a similar effect for the FF-Carhart model, therefore, only the differences are described below. In the Event Driven class, Distressed and Total funds have a higher adjusted R-squared compared to the values of the the timeframe from 1990 to 2013. In contrast to the results of the higher-moment CAPM excluding the crisis period, Fund of Funds managers have a higher adjusted R-squared than under the full observation period. Factors rarely change their significance, Emerging Markets indices report the most differences, since SMB is significant for the Latin and Russia index, while HML is significant for the Asia and Total funds.

Overall the exclusion of the GFC-period does not have a large effect on the results. The comparison between the two models does not change and the better performance of the FF-Carhart factors for the Fund of Funds indices is strengthend and confirmed.

Chapter 8

Summary

Both, the higher-moment CAPM and the FF-Carhart model only slightly add explanatory power to the returns of the three mutual funds categories. The increase of the adjusted R-squared is always below 0.04. The only significant co-moment is co-skewness for the Balanced category. All FF-Carhart factors have significant coefficients for the Balanced and Equity funds, while none of them is significant for the Fixed Income funds. Alpha remains insignificant, as under the standard CAPM in table 7.1.

To sum up the hedge fund analysis: Event Driven funds mostly show significant co-skewness, SMB and HML, as well as a significant and positive alpha. For this group there is no big difference between the two models in terms of adjusted R-squared.

The various categories of the Equity Hedge funds are not affected by the higher-moment CAPM. In contrast, the FF-Carhart factors add explanatory power to the majority of the Equity Hedge indices. The HML factor is significant for all sub-indices except the Total index.

The Emerging Markets indices show a completely different picture. While under the FF-Carhart model only the SMB factor is significant for three out of the six indices, co-kurtosis is significant for the Russia funds and has a large, positive value. In addition, the higher-moment CAPM adds more explanatory power than the FF-Carhart model.

The most interesting feature of the results for the FoF group is the MOM factor, since it is significant for all five sub-indices. In general, the FF-Carhart factors have a higher adjusted R-squared than the higher co-moments, with the exception of the Conservative hedge funds, where co-kurtosis is positive and significant. Co-skewness has a significant and negative coefficient for the Strategic group. Market Defensive funds have a positive alpha under both models and only the MOM factor is significant.

In the Macro segment, Commodity and Systematic Diversified have a higher adjusted R-squared under the higher-moment CAPM, while Active Trading, Discretionary Thematic and Total have a higher adjusted R-squared under the FF-Carhart model. Co-kurtosis is significant and negative for the Systematic Diversified group. SMB is only significant for the Total index, HML for Discretionary Thematic and Systematic Diversified funds, while MOM is significant for all but the Commodity funds.

Relative Value funds are, in general, better explained by the higher-moment CAPM, with the exception of Yield Alternative funds. Co-skewness is significant for the Fixed Income Corporate index and co-kurtosis is significant for Fixed Income Convertible Arbitrage and Total funds. For the FF-carhart model, MOM does not play a role in explaining the returns of hedge fund indices, while SMB is significant in all cases but Fixed Income - Asset Backed.

In terms of general performance, the Total funds in each hedge funds category outperform the market and have a significant and positive alpha under both models, the only exception being the Total Emerging Markets index under the FF-Carhart model.

In general, both models improve the adjusted R-squared for the majority of indices. The FF-Carhart factors work better for the mutual fund categories Equity and Balanced, while the higher-moment CAPM outperforms the factors for the Fixed Income index. However, as mentioned in chapter 6.1, the analysis of Fixed Income indices is impaired due to the choice of the market proxy.

With the hedge fund indices, the results are mixed. The FF-Carhart model yields a higher adjusted R-squared for all Equity Hedge indices and most Fund of Funds indices. But the explanatory power of the higher-moment CAPM is higher for the Emerging Markets funds and the Relative Value indices. Macro and Event Driven have some subindices where the factors add more power and some where the higher-moment CAPM is superior.

The testing of the effects of the crisis period on the results showed that the effect is rather negligible and does not change the findings described above. In general, the values of adjusted R-squared slightly change, but the overall comparison results remain.

Chapter 9

Conclusion

This study investigated the explanatory power of two extended capital asset pricing models, the FF-Carhart model and the higher-moment CAPM. Instead of using traditional portfolios, I took return data of two types of funds, mutual funds and hedge funds. Previously, Hung (2007) performed a comparison of the two models, but used specifically sorted portfolios for his analysis. He concludes that the four-moment CAPM has higher explanatory power for momentum and size portfolios, while the FF-Carhart model better explains the value portfolios. These results already indicate, that one model does not generally outperform the other one, and there are differences depending on the asset class. In case of hedge funds, Ranaldo and Favre (2003) tested the classic, three-moment and four-moment CAPM against various hedge fund indices. Their findings are similar, as they also conclude that it depends not only on the analysed asset class, but also on the investment strategy, which is represented by the index.

My findings are in line with these previous studies, since neither model outperforms the other consistently. With mutual funds, the FF-Carhart model has higher values of adjusted R-squared for Equity and Balanced funds, while adjusted R-squared is slightly below the higher-moment CAPM for Fixed Income funds. These results are not surprising given that Carhart (1997) invented his factor by using mutual fund data. The hedge fund results are much more diverse. Although there is no preferential model for Event Driven, Macro, Fund of Funds and Relative Value funds, there are clear tendencies for Equity Hedge and Emerging Markets funds. In all sub-categories of Equity Hedge funds, the FF-Carhart factors add more explanatory power than the higher-moment CAPM. As these managers mostly hold portfolios composed of US equities, it is not surprising, that the FF-Carhart factors are superior, since they are mainly calculated from US equities. As proposed by Hwang and Satchell (1999), co-skewness and co-kurtosis are better suited to explain the variation of returns for Emerging Markets funds. Chapter 6.1 alrady provided evidence of higher skewness and kurtosis for the Emerging Markets managers.

Studies investigating whether the FF-Carhart factors actually proxy for higher-order co-moments have already been undertaken by e.g. Hung (2007). The results indicate, that co-moments above the fourth eliminate the explanatory power of the multi-factor model, but there is no economic interpretation available.

By highlighting the differences amongst strategies and indices, this thesis adds to the field of CAPM extensions. It appears that the choice of the appropriate model depends on the analysed asset class.

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Appendix

Appendix 1

In chapter 7 tables 7.1 and 7.2 only displayed the values of alpha and its p-value for the GMM regressions of the standard CAPM. This appendix provides the original tables including the values of beta and its corresponding p-value. Tables A.1 and A.2 show the full results of the standard CAPM regressions.

Table A.1: GMM results for the three mutual fund categories using the standard CAPM (full results)

The three mutual fund categories are regressed against the excess market return using GMM. The alpha, beta, their p-values and the adjusted R-squared are reported. January 1990 - December 2013.
* = p-value below 0.05, ** = p-value below 0.01.

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \epsilon_i$$

Index	α	*p-value*	β	*p-value*	**Adj.** R^2
Balanced	0.002	0.417	0.688**	0.000	0.425
Equity	-0.001	0.578	0.813**	0.000	0.676
Fixed Income	0.000	0.964	0.383	0.000	0.110

Table A.2: GMM results for the HFRI hedge fund indices using the standard CAPM (full results)

The HFRI indices are regressed against the excess market return using GMM. The alpha, beta, their p-values and the adjusted R-squared are reported. January 1990 - December 2013.
* = p-value below 0.05, ** = p-value below 0.01.

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \epsilon_i$$

Index	α	*p-value*	β	*p-value*	**Adj.** R^2
Event Driven					
Activist	-0.003	0.370	0.715**	0.000	0.685
Distressed	0.006**	0.000	0.240**	0.000	0.319
Merger	0.003**	0.000	0.140**	0.000	0.301
Total	0.005**	0.000	0.331**	0.000	0.564
Equity Hedge					
Energy	0.007	0.056	0.550**	0.000	0.237
Market Neut.	0.003**	0.000	0.057**	0.001	0.079
Fund. Growth	-0.003	0.250	0.648**	0.000	0.741
Fund. Value	0.000	0.831	0.545**	0.000	0.855
Quant. Dir.	0.003*	0.018	0.711**	0.000	0.730
Short Bias	0.003	0.088	-0.958**	0.000	0.637
Technology	0.005*	0.050	0.732**	0.000	0.476
Total	0.005**	0.000	0.468**	0.000	0.630
Em. Markets					
Asia	0.002	0.338	0.532**	0.000	0.363
Global	0.004	0.132	0.522**	0.000	0.364
Latin	0.005	0.111	0.666**	0.000	0.324
Russia	0.006	0.297	0.858**	0.000	0.257
Total	0.004	0.134	0.607**	0.000	0.434
FoF					
Composite	0.002	0.054	0.217**	0.000	0.339
Conservative	0.002	0.039*	0.140**	0.000	0.313
Diversified	0.002	0.102	0.215**	0.000	0.314
Market Def.	0.003**	0.002	0.022	0.524	0.000
Strategic	0.003*	0.043	0.342**	0.000	0.382
Macro					

Continued from previous page					
Index	α	*p-value*	β	*p-value*	**Adj.** R^2
Active Trad.	0.002	0.173	-0.018	0.489	-0.011
Commodity	0.001	0.591	0.080	0.070	0.034
Disc. Them.	-0.001	0.407	0.225**	0.000	0.522
Sys. Divers.	0.005**	0.000	0.206**	0.000	0.181
Total	0.006**	0.000	0.174**	0.000	0.126
Rel. Value					
FI-AB	0.005**	0.000	0.050*	0.030	0.032
FI-Conv. Arb.	0.003	0.059	0.206**	0.001	0.230
FI-Corporate	0.002	0.079	0.239**	0.000	0.311
Multi	0.003**	0.001	0.160**	0.000	0.315
Yield Alt.	0.003*	0.026	0.149**	0.000	0.298
Total	0.005**	0.000	0.258**	0.000	0.280

In general, the results of the standard CAPM regressions are in line with the theoretical expectations. Balanced and Equity mutual funds have a statistically significant value for beta, while Fixed Income funds do not show significant beta. Three hedge fund indices show an insignificant beta value: FoF - Market Defensive, Macro - Active Trading and Macro - Commodity. While the numbers for the first two are not surprising, since these managers claim to be independent of general market movements. Commodity funds still have a significant value at the ten percent level. Another interesting number is the significant value of beta for the Equity Hedge - Market Neutral index, since these hedge funds aim to be unaffected by the direction of the market.

Appendix 2

The analysis of chapter 7 was restricted to two models, the four-moment CAPM and the FF-Carhart model. For a complete view on the development from the standard CAPM to the four-moment CAPM, the results of the three-moment CAPM are shown in tables A.3 and A.4. The mutual fund categories are almost unchanged in terms of adjusted R-squared. In table 7.3 co-kurtosis was never statistically significant, therefore, the results of the three-moment CAPM are not surprising. The hedge fund results generally do not show much difference with only a few exceptions. The indices which had a statistically significant factor for co-kurtosis in table 7.5 have a lower adjusted R-squared under the three-moment CAPM. For the Event Driven funds the only difference is a significant co-skewness factor of the Activist strategy, while three of the Emerging Markets indices (Global, Russia and Total) show significant co-skewness in table A.4. Bansal et. al (1993) already suggested that some co-moments might reflect identical effects of the return variation. These results confirm this idea, since the absence of co-kurtosis leads to a significant coefficient of co-skewness. Further interesting results are the co-skewness coefficients of the Fund of Funds group, since all except for the Conservative index, show significant co-skewness. The same is true for the Relative Value funds, where Fixed Income Convertible Arbitrage is the only exception.

Table A.3: GMM results for the three mutual fund categories using the three-moment CAPM

The three mutual fund categories are regressed against the excess market return and the co-skewness using GMM. The alpha, the coefficients and their p-values, as well as the adjusted R-squared are reported. p-values are listed below the coefficients. January 1990 - December 2013.
* = p-value below 0.05, ** = p-value below 0.01.

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \gamma_i(R_{mt} - E(R_{mt}))^2 + \epsilon_i$$

Index	α	β	γ	**Adj.** R^2
Balanced	0.005*	0.641**	-1.572*	0.434
	0.035	0.000	0.031	
Equity	0.002	0.774**	-1.306	0.684
	0.415	0.000	0.016	
Fixed Income	0.004	0.336**	-1.578	0.116
	0.412	0.000	0.198	

Table A.4: GMM results for the HFRI hedge fund indices using the three-moment CAPM

The HFRI indices are regressed against the excess market return and the co-skewness using GMM. The alpha, the coefficients and their p-values, as well as the adjusted R-squared are reported. p-values are listed below the coefficients. January 1990 - December 2013.
* = p-value below 0.05, ** = p-value below 0.01.

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \gamma_i(R_{mt} - E(R_{mt}))^2 + \epsilon_i$$

Index	α	β	γ	**Adj.** R^2
Event Driven				
Activist	0.002	0.645**	-1.698**	0.705
	0.577	0.000	0.005	
Distressed	0.009**	0.188**	-1.749**	0.405
	0.000	0.000	0.000	
Merger	0.005**	0.118**	-0.760**	0.345
	0.000	0.000	0.004	
Total	0.008**	0.288**	-1.424**	0.617
	0.000	0.000	0.000	
Equity Hedge				
Energy	0.007	0.542**	-0.215	0.233
	0.057	0.000	0.835	
Market Neut.	0.003**	0.056**	-0.025	0.075
	0.000	0.001	0.879	
Fund. Growth	-0.003	0.641**	-0.152	0.737
	0.273	0.000	0.736	
Fund. Value	0.000	0.542**	-0.075	0.853
	0.935	0.000	0.712	
Quant. Dir.	0.004**	0.696**	-0.516**	0.731
	0.000	0.000	0.003	
Short Bias	0.006*	-0.988**	-1.017	0.640
	0.023	0.000	0.888	
Technology	0.005*	0.726**	-0.194	0.474
	0.045	0.000	0.835	
Total	0.006**	0.453**	-0.496*	0.632
	0.000	0.000	0.015	
Em. Markets				

Continued from previous page				
Index	α	β	γ	**Adj.** R^2
Asia	0.004	0.506**	-0.885	0.366
	0.153	0.000	0.089	
Global	0.010**	0.431**	-2.741*	0.414
	0.001	0.000	0.045	
Latin	0.006*	0.642**	-0.806	0.324
	0.030	0.000	0.433	
Russia	0.016**	0.712**	-4.264*	0.288
	0.007	0.000	0.026	
Total	0.008**	0.547**	-2.012*	0.457
	0.002	0.000	0.019	
FoF				
Composite	0.004**	0.189**	-0.931**	0.370
	0.000	0.000	0.006	
Conservative	0.003**	0.116**	-0.799**	0.364
	0.000	0.000	0.002	
Diversified	0.004**	0.190**	-0.831*	0.336
	0.000	0.000	0.025	
Market Def.	0.004**	0.015	-0.211	-0.002
	0.004	0.674	0.694	
Strategic	0.006**	0.299**	-1.441**	0.416
	0.000	0.000	0.005	
Macro				
Active Trad.	0.000	-0.015	0.663	0.001
	0.830	0.582	0.108	
Commodity	-0.002	0.121**	0.986*	0.066
	0.464	0.007	0.027	
Disc. Them.	-0.002	0.232**	0.159	0.517
	0.240	0.000	0.561	
Sys. Divers.	0.002	0.249**	1.453*	0.226
	0.313	0.000	0.039	
Total	0.005**	0.180**	0.234	0.124
	0.003	0.000	0.658	
Rel. Value				
FI-AB	0.007**	0.026	-0.728*	0.066

Continued from previous page				
Index	α	β	γ	**Adj.** R^2
	0.000	0.362	0.014	
FI-Conv. Arb.	0.006**	0.173**	-1.114	0.262
	0.000	0.000	0.289	
FI-Corporate	0.006**	0.194**	-1.519**	0.374
	0.000	0.000	0.000	
Multi	0.005**	0.130**	-0.993*	0.378
	0.000	0.000	0.013	
Yield Alt.	0.005**	0.233**	-0.748*	0.309
	0.001	0.000	0.043	
Total	0.007**	0.112**	-1.254**	0.382
	0.000	0.000	0.002	

ACADEMIC EXPERIENCE

MSc. Business Science **10/2011-12/2014***

University of Vienna

Master of Science

Specialisation in Financial Markets and Operations Research

Current weighted average grade: 1.4

Non-EU Student Exchange **07/2013-12/2013**

University of Sydney

Exchange semester

Master courses with specialisation in Financial Modelling and International Banking

Final weighted average grade: 1.2

BSc. Business Science **10/2007-01/2011**

Vienna University of Economics and Business

Bachelor of Science

Specialisation in Finance and International Business

Final weighted average grade: 1.9

Matura (Higher School Certificate) **09/1998-06/2006**

GRG3 Kundmanngasse, Vienna

Final average grade: 1.0

WORK EXPERIENCE

P & L Analyst **01/2014-present**

Erste Group Bank AG, Part-time / Full-time

Responsible analyst for the calculation and monitoring of the P & L for equity and equity derivatives in the midoffice of Erste Group. Central point of contact for the trading units and reconciliation with backoffice and accounting.

Fund of Hedge Funds Administrator **02/2011-07/2013**

Erste Group Bank AG, Part-time / Full-time

Administration of various Fund of Hedge Funds in the portfolio of Erste Group. Performance estimation, risk-reporting and portfolio management support.

Customer support agent **10/2007-01/2011**

CSSC GmbH, Part-time

Inbound agent for customers of Erste Bank der sterreichischen Sparkassen AG. Customer support, technical helpdesk, credit card fraud management, teaching and supervision of new employees.

SCHOLARSHIPS

2012 - e-fellows.net: Austrian/German network for talented students
01/2010 Performance Scholarship of the Vienna University of Economics and Business
2008-2010 WU Top League: University program for talented students

* expected graduation