Covariance Risk Models on the Swedish Stock Market
- Using a GARCH Framework

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Sammanfattning

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Syfte: Mitt syfte med denna uppsats var att undersöka vilka faktormodeller som i genomsnitt bäst kan uppskatta den samlade risken på den svenska aktiemarknaden i form utav GARCH-uppskattade kovariansmatriser. Vidare att specialgranska faktormodellernas uthållighet då de appliceras under en recession. Slutligen undersöka om och hur globaliseringen utav ekonomin påverkar dessa faktorer.

Metod: Tidsmässigt var undersökning avgränsad mellan 1996-2005. En GARCH-modell togs i anspråk för att uppskatta den tidsvarierande volatiliteten. Potentiella faktorer av olika slag analyserades. Ett urval inkluderas i modellen av ekonomin tillsammans med de representativa tillgångarna i form utav industriella portföljer. Dessa tillgångar representerade den svenska marknaden. Den representativa ekonomins kovariansmatris uppskattades genom GARCH-modellen. Till slut undersöktes faktorernas förmåga att fånga upp kovariansrisken på den svenska marknaden.

Teoretiska perspektiv: Riskhantering, faktormodeller, tidsvarierande volatilitet.

Empiri: Den svenska värdepappersmarknaden.

Slutsats: Marknadsfaktorn och en faktor som replikerar direktavkastning förklarar en mycket stor del av den totala risken på den svenska aktiemarknaden. Direktavkastningsfaktorn genererar dessutom överavkastning under recessioner. Under recessioner ökar även betydelsen av de inhemska faktorerna på bekostnad av världsmarknadsfaktorn samtidigt som risken på marknaden ökar. Den svenska värdepappersmarknaden är enbart delvis integrerad i världsekonomin.

Nyckelord:
- GARCH
- Kovariansmatris
- Riskhantering
- Faktormodell
- Syntetisk tillgång

Abstract

Title:	Covariance Risk Models on the Swedish Stock Market – Using a GARCH Framework
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Purpose: I set out to identify which factors / factor models could best capture the second moment of return in an environment of dynamic volatility (GARCH). Special consideration was given to how the factors managed during a recession in the economy. The equity market studied has been exposed to an increasingly level of globalization during the last decade. Finally my ambition was to assess if this affected the performance and or importance of the different factors.

Methodology: The time frame under consideration was 1996-2005. A GARCH-methodology was employed to deal with the time-varying variance. Candidate factors of different origin were analyzed and a selection of these was included in the model of the economy. Together with representative assets in the form of industrial portfolios, which proxy for the Swedish equity market, they were processed through a multivariate GARCH-model. The factors ability of capturing the second moment of return within the GARCH-context was investigated.

Theoretical perspectives: Risk management, factor models, volatility clustering.

Empirical foundation: The Swedish equity market.

Conclusions: The main conclusion is that the market factor and a factor mimicking dividend yield capture the overwhelming majority of the dispersion of the return from the representative assets. The dividend yield factor performs extraordinary well during periods of recession. The factor is also significantly priced during recessions, i.e. it produces excess return. During recessions, the total level of risk increases on the equity market and the importance of the world market factor decreases. The Swedish equity market is only partially integrated into the world economy.

Key Words:
- GARCH
- Covariance Matrix
- Factor Model
- Risk Management
- Mimicking Portfolio

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Chapter 1: Introduction

The first chapter introduces and outlines this master thesis. First, the background section puts the thesis in a relevant context. Next follows a problem discussion about the issues which this thesis will deal with. From the discussion, the purpose of the thesis and the concrete problem definition will evolve. The delimitations of the thesis, target audience and disposition follow accordingly.

1.1   Background

When thinking about how to characterize a financial asset most people probably think about its expected return, how much profit is feasible in a certain time horizon. This would seem perfectly normal. What comes to mind secondly is the concept of assessing and managing the risk of a financial asset or a portfolio of securities. The so called second moment of return (variance / covariance) may very well be almost as important, some would argue even more important given the fact that very few fund managers seem to be able to consistently produce return in excess of a relevant benchmark.[1] A testament to the dominance of asset pricing within research on financial economics is that a search for the phrase "asset pricing" in the electronic search tool ELIN[2] returns 4340 hits whereas "asset risk" returns a mere 192 hits and the phrase "risk management", which is a very broad concept being relevant within many different fields of science returns 2035 hits. Factor models in a financial context have both theoretical value as well as practical applications. Common examples of such models are equilibrium pricing models and models explaining the covariation of returns. Practical use for pricing models includes forecasting return and estimating the cost of equity. Models explaining covariation in return are used for portfolio risk optimization. Both types of factor models can also be used for performance evaluation and performance attribution.[3]

In other words, portfolio theory and risk minimization in portfolios are fields within finance which have great practical applicability. Hence, the field is very interesting to conduct research on. Reducing risk has always been one of the two most important objectives for investors, the other one being to strive for maximum return. In order to efficiently reduce risk in a reliable and relevant way, it is crucial to measure risk in a relevant way. Minimizing risk is usually done by diversifying among different securities. The maximum amount of diversification that is achievable is to eliminate the unsystematic or idiosyncratic[4] risk of the individual securities. One of the biggest challenges to overcome in the pursuit of minimizing risk is actually how to measure it in a relevant way. The reason why this is not straightforward is because of what is called volatility clustering. This simply means that return of high magnitude, positive or negative tend to be followed by return of a high magnitude, positive or negative, and not necessarily of the same sign as for the previous lag. This adds another dimension to the concept of risk management which adds to its complexity. Research aimed at trying out factor models has become common in the latest decades. Groundbreaking years were 1992 and 1993, when The Journal of Financial Economics published research papers[5] by Fama and French in which they concluded that certain firm characteristics in combination with a market factor could more accurately forecast expected return than the singe-factor

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[1] Chan et al. (1999), On Portfolio Optimization: Forecasting Covariances and Choosing the Risk Model, p. 937.
[2] Electronic Library Information Navigator, number of hits at 2008-05-24.
[3] Chan et al. (1998), pp. 159-160.
[4] Asset specific.
[5] Fama, French (1992), Fama, French (1993).

model of Capital Asset Pricing Model (CAPM). The methodology used in the 1993 paper had a huge impact on research within this field, using so called replicating portfolios to derive priced risk factors in addition to market beta.

1.2　　　Problem Domain

1.2.1　　　Problem Discussion

Even today, the CAPM is the de facto standard when it comes to relating financial assets risk and required rate of return. The CAPM assumes that an asset's average excess return can be fully attributed to the asset's covariance with the market portfolio. A lot of research during the last decades has shown that this is not necessarily true. The CAPM is supposed to be a global model since the "market portfolio" contains all financial securities in the world. In practice however, a single-factor model including weighted local securities usually works as a proxy for the "market portfolio". Another consequence of the CAPM is that only systematic risk is being priced, since the idiosyncratic[6] risk always can be diversified away by holding the optimal portfolio. However if CAPM does not completely hold and there exist other factors with associated risk premia, that would imply that portfolios allocated according to CAPM would to varying degrees be inefficient.

There may be additional factors that can help predict future return in an efficient way. Furthermore, these factors may also be associated with risk premia, which some, e.g. Fama and French have suggested in their research during the 90's. The practical use of increased risk forecasting performance should be vast. The higher percentage explained ex post by a forecasting model the closer the investor comes to finding out the "true" covariance between any particular assets. In other words, more reliable covariances estimates leads to more efficient portfolio management. Explaining the covariance matrix of return can be used as a risk management tool, helping portfolio managers reduce the risk level of the desired portfolio.

The first step which would seem trivial is how to actually measure and estimate covariance risk properly. Due to the previously mentioned volatility clustering this is not the case. This effect is demonstrated graphically in Figure (4) on page 32. To deal with dynamic variance so called GARCH-models can be employed.

Contrary to CAPM, a multi-factor model would not necessarily be global, different factors could be relevant on different markets. This makes multi-factor models much more complex and challenging to deal with. An example of this is that while the paper which is the main inspiration for this thesis, Moskowitz (2003), found that only the size[7] factor contributed alongside the market factor in predicting future covariances. Other researchers have come to different conclusions. It is of course possible as the economy and the financial markets become more globalized that discrepancies between different markets will fade away.

One characteristic of the Swedish economy is that it due to the deregulation of the credit markets during the 1980's and its high dependence on foreign trade can be categorized as a

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[6] Asset specific.
[7] The different factors are defined and explained in chapter 4.

small and open economy[8]. Recent globalization has made this feature even more prominent. From the beginning of the 90's until 2001 the exports share of the Swedish GDP rose from about 30% to 50%[9]. This implies a relatively high dependence on the outside world with comparison to the US, which is the market most of the relevant research has been conducted on. As a consequence one might expect other factors, e.g. the relative strength of the home market's currency, to play a more important role in pricing models than those emphasized in models derived from the US market. Research within this field has been conducted previously to some extent on the Swedish market by Asgharian & Hansson (2001). This thesis employs different methodology as well as it covers a recent recession, the turbulent years of 2000-2001, where the gross domestic product (GDP) of Sweden experienced a quarter of negative growth. It should be interesting to observe whether the factors previously found to be significant for the Swedish stock market have persisted through times of globalization and estimated on data in a GARCH framework.

The above discussion leads to the problem definition, which summaries what questions this paper is aiming at answering.

1.2.2   Problem Definition

- How can different alternative factor models capture covariance risk?
- How does the globalized economy affect the set of factors which are relevant?
- How well do the factor models perform during a period of recession.

Hypothesis H_1: The market factor will capture a majority of the return covariation.

1.3   Purpose

The purpose of this thesis is to evaluate factor models, especially multi-factor models on the premise of explaining covariance risk on the Swedish stock market. How these models perform during a recession is of primary importance.

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[8] Andersson et al. (2001), De Finansiella Marknaderna i ett Internationellt Perspektiv, p. 11.
[9] Ibid.

1.4 Delimitations

This thesis is primarily aimed at analyzing the second moments of return, the variance and covariance of returns for securities, collectively named the variance-covariance matrix (hereafter referred to as the covariance matrix or second moments of return). Because of the close nature between return and risk, the return of factors will also be subject to study in a limited way. The study is limited to the Swedish economy, to be more precise, the Swedish equity market since the bond market will not be addressed. The equity market will be defined as stocks publicly traded in stock exchanges in Sweden, which of by far the most dominant exchange being the Stockholm Stock Exchange. Financial instruments derived from stocks or exchange-traded mutual funds etc. are excluded from the dataset. The time frame under investigation is 1996 through 2005, a 10-year time frame. Longer time frames would present problem of acquiring data for some variables crucial for the statistical tests. Bank and financial firms are excluded due to their different capital structure which affects their firm characteristic metrics. The methodology employed with respect to GARCH and the model of the economy created for that purpose is mainly and heavily inspired by Moskowitz (2003), while the factor selection and the data selection criteria are derived mainly from Chan et al. (1998).

1.5 Target Audience

This thesis has been written for an audience which masters fundamental finance theory and statistics. E.g. higher level undergraduates and graduates at universities with an interest in finance, especially in risk management. Furthermore, this thesis should be of interest to professionals within the financial industry because of its empirical relevance to real stock markets.

1.6 Disposition
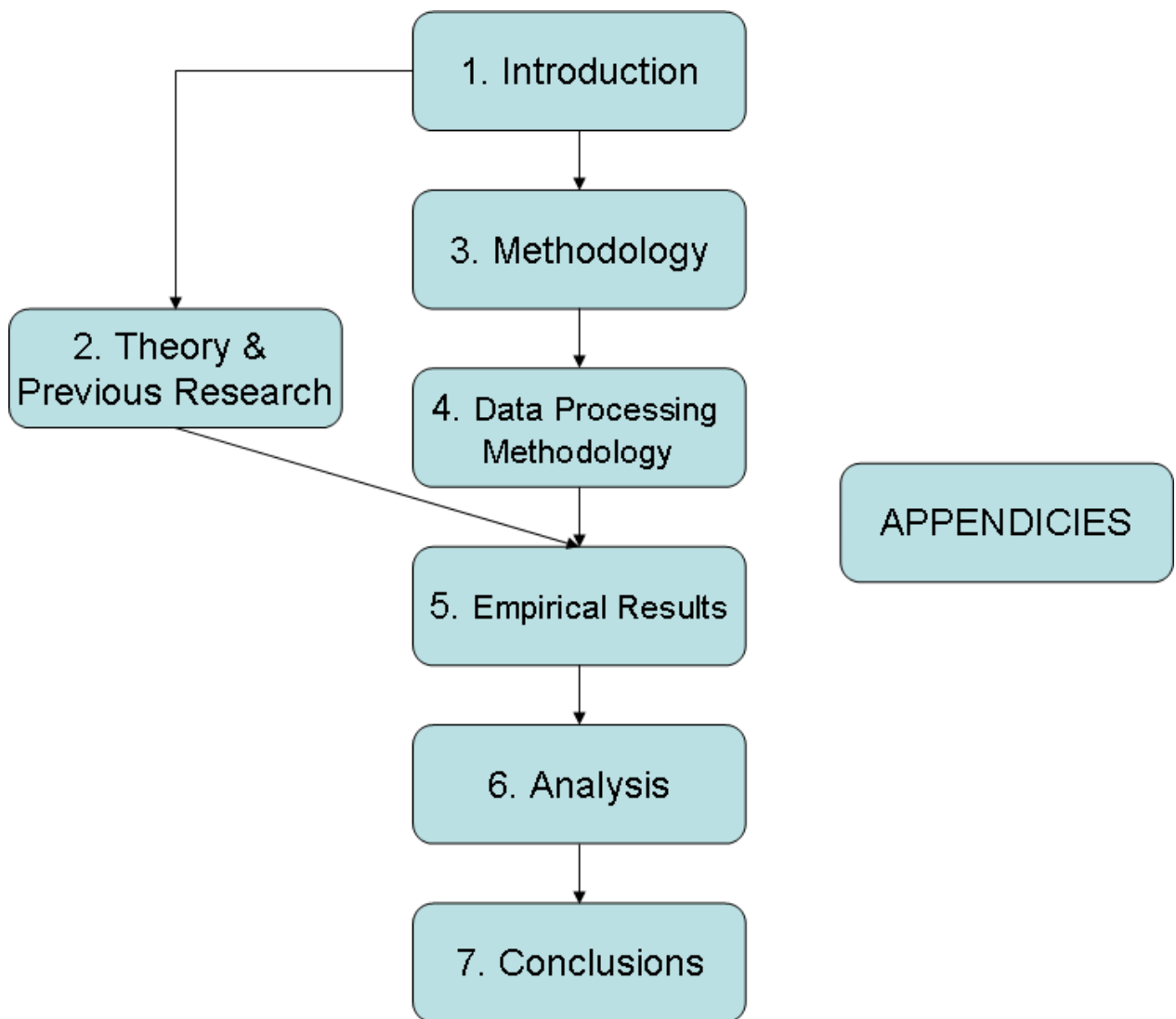
The conceptual model above envisions the disposition of this thesis. The choice of methodology follows primarily as a consequence of the problem domain as do the relevant theory discussion. The empirical results will be accounted for without elaborated comments. Instead, the results will be dealt with in the analysis-chapter. The ambition when writing this thesis has been to logically connect the problem formulation and purpose with the choice of methodology and the data set. Only when these three key areas form a logical thread, the analysis which follows is relevant, reliable and answers the correct research questions.

Chapter 2: Theory and Previous Research

This chapter accounts for the financial theory relevant for the subject of this thesis and previous research within these fields. In other words, this chapter connects the background and problem definition with theory and thus provides the theoretical foundation on which this thesis builds on.

2.1 Financial Theory

The main topics of theory which is of relevance for this thesis are: Portfolio Theory, Equilibrium Pricing, Covariance Risk Modeling and Risk Management Theory. Within this section the author covers the fundamental theory of these relevant fields as well as positioning this work in relation to recent research.

2.1.1 Portfolio Theory

Portfolio theory covers some concepts which are central to financial theory. Modern mean-variance portfolio theory was first created by Harry Markowitz[10] which he formulated in Markowitz (1952) and further elaborated in his book "Portfolio Selection: Efficient Diversification" in 1959. Markowitz divides the process of choosing a portfolio into two steps: The first stage involves assessing the expected future performance of available securities, while the second step involves the selection of these securities into a portfolio[11]. The first part is not addressed by Markowitz. Instead the assessment, ranking and allocation of assets are where equilibrium pricing and risk management models come into the picture, see 2.1.2 and 2.1.3.

At the foundation of all portfolio theory is the mean-variance portfolio, its name stems from the concepts of mean and variance. These are the two properties in which portfolios traditionally are being assessed. Before Markowitz (1952) there was no formalized theory within the field of financial asset pricing and portfolio theory. Markowitz based his portfolio theory upon the notion of stocks holding an intrinsic value, something first suggested by economist J.B. Williams[12].

Markowitz discusses several different approaches towards the selection criteria relevant for the portfolio selection. The hypothesis that diversification may produce a certain expected return from stocks by the law of large numbers is rejected on the basis of too high inter-correlation among the assets. Diversification could completely eliminate any risk if the return of the securities was uncorrelated. Since returns tend to be highly correlated, the implication is that diversification only will be able to reduce risk.[13] One implication of this being there is no guarantee that even the most diversified portfolio will yield a realized return in close proximity to that of the expected return of the portfolio. This is especially true for investors with a short investment horizon. The efficient set is efficient because the portfolios on it are portfolios with the right kind of diversification. E.g. diversification of many securities which all are highly correlated does not reduce risk in a significant way. Thus it is of paramount

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[10] Lindbeck (1989), Pionjärer i Finansiell Ekonomi, p. 733.
[11] Markowitz (1952), Portfolio Selection, p. 77.
[12] For further information see (1938) The Theory of Investment Value.
[13] Markowitz (1959), Portfolio Selektion, p. 5.

interest to find balance in the portfolio, by matching assets with low or even negative correlation. Also, the hypothesis that the investor should try to maximize the expected return without regard to risk is also rejected since such a theorem would never imply the superiority of diversification. In other words, it breaks the fundamental maxim in financial theory of risk-aversion. His conclusion is that an approach that both takes into account expected return and variance is the most plausible.[14] This is usually referred to as the mean-variance criterion (MV-criterion), and is what Sharpe and later others built on when they created the CAPM. In the context of portfolio risk management, the formula for the variance of a portfolio is:

$$(1) \qquad \sigma_p^2 = \sum_{i=1}^{N} \sum_{j=1}^{N} \sigma_{ij} w_i w_j$$

In Markowitz (1959) several aspects of the theory are developed. The use of variance as a metric for risk is by no means beyond question according to Markowitz, who compares it to the semi-variance (2). Thus the semi-variance only accounts for risk related to negative returns. However, evenly distributed returns around the mean will produce results which will be comparable relative different assets, in other words which metric one uses will be indifferent with respect to the order of the assets if the returns follow a symmetric distribution.[15] Markowitz also compares variance with the so called semi-variance. He concludes that the variance has several appealing characteristics, such as low computational cost (approximately four times as high for semi-variance). However, the Expected Return / Semi-Variance criteria in general produces better portfolios, because of the nature of semi-variance, i.e. it only considers down-side risk of a security.

Markowitz concludes that the reasonable thing is to begin theory building around the variance metric, and later on elaborate using other models which could include the semi-variance.[16]

$$(2) \qquad S_E = \frac{\sum_{i=1}^{n} \left((r_i - E(r))^- \right)^2}{n} \quad ; \quad x^- = \min(0, x^-)$$

Because of researchers' interest in multi-factor models and the suspicion among part of the academic society that expected return may be attributed to variables whose natural denominational unit is not relative return, the need to transform those variables into the form of return series was needed. One way of doing this is by creating synthetic factors using mimicking portfolios[17]. These were first used within a financial research setting for proving that synthetic factors could replace exact ones in an APT theory context.[18] The factors based on market capitalization and the book-to-market ratios (BM-ratio) are both examples of synthetic factors which are not directly observable in the same sense as e.g. a stocks return. The most extreme form of a mimicking factor is principal component analysis, in which the factor can be extracted from a data set. See 3.3.3.

Because of the revolutionary development of information technology and as an effect vastly increasing computational power, the objection concerning computational complexity of the

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[14] Markowitz (1952), Portfolio Selection, p. 90.
[15] Markowitz (1959), Portfolio Theory, pp. 193-194.
[16] Markowitz (1959), Portfolio Theory, p. 194.
[17] Also known as "Replicating Portfolios".
[18] Huberman (1987), Mimicking Portfolios and Exact Arbitrage Pricing, p. 8.

semi-variance metric would seem obsolete. Despite this, there seem to be limited usage of the semi-variance. The debate on the usefulness of the semivariance metric is still by no means settled. In (2007) Estrada, the author arguments in favour of replacing the MV-framework with a mean-semivariance framework.

2.1.2   Equilibrium Pricing

The most fundamental part when valuing a security is to know how to discount the cash-flows etc. To do so, the investor needs a method for estimating the cost of equity. Often this is provided by applying an equilibrium pricing theory. An equilibrium pricing theory within a financial market context provides a model for relating expected excess return[19] to risk in a generalized way. The expected excess return is the rate at which there will be market equilibrium between demand and supply of the security. Furthermore the expected return itself can be used for valuing a particular stock and hence deduct its "theoretical" price when the market is well-functioning, i.e. in equilibrium. Put another way, equilibrium pricing models tries to explain and or forecast the expected return for financial assets.

In Sharpe (1964) the first positivistic asset pricing theory was created. Sharpe formalized Markowitz's MV-criterion and Tobin's separation theorem into what today is known as CAPM. Modern capital asset theory and in the prolongation portfolio theory can be traced to Sharpe's groundbreaking paper on capital asset prices. This obviously came to be one of the most important papers ever written within financial economics. Sharpe defined the foundation of the capital asset pricing model (CAPM). Sharpe concludes that while there have been normative models by e.g. Markowitz, no positivistic theory existed. I.e., a theory for determining the required rate of return of an asset without the necessity of making any normative assessments.

The risk which can be diversified will not bear any excess return. Hence given that the CAPM holds, only risk which is due to the economy (the market factor) will be priced. Because CAPM-beta is a metric for a stock's risk in relation to the market portfolio, beta is only relevant as a proxy for risk in a diversified portfolio. If one were to hold only one stock, this stock beta would not be an appropriate proxy for the riskiness of the stock since the idiosyncratic risk would be huge.

Another central theme in the CAPM theory is the separation of the allocation of risky assets and the risk-free asset. This concept is usually referred to as Tobin's separation theorem and stems from Tobin (1958). The practical implication of this is that an investor first may allocate among and then within different asset categories.[20] In a CAPM world there are only two different classes of assets: the risk-free asset and the risk-bearing assets (stocks). Thus CAPM is an example of a single factor model.

The implication of this is that all rational investors should hold the same portfolio – the market portfolio, regardless of their individual preferences towards risk. Each investor can attain their desired level of risk by adjusting the ratio of the risk-free asset to the market portfolio. In Black (1972) it is shown that the CAPM holds under restricted borrowing even if there is no risk-free asset. Likewise in the case that there is a risk-free asset but going short[21]

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[19] In excess of the risk-free rate of return.
[20] Tobin (1958), Liquidity Preference as Behaviour Towards Risk, pp. 82-85.
[21] Borrowing.

in it is not allowed.[22] Obviously these relaxations strengthened CAPM because the assumption of unrestricted borrowing is not a good approximation of realistic settings.

One weakness with the CAPM theory has always been the low empirical support for it. Several researchers found that there existed a negative correlation between risk and return.[23] Naturally this has led some researchers to suggest different equilibrium pricing models.

Since the introduction of CAPM and modern portfolio theory there have been various attempts to challenge the single-index model of CAPM or at least to explain the anomalies of this model. The anomalies of the CAPM model stem e.g. from the fact that according to CAPM, the only priced risk is a stock's covariation with the market portfolio.

Natural alternatives to CAPM are multi-factor models. One of the oldest and most recognized is the arbitrage pricing theory (APT)[24]. One of the advantages of APT is that the market factor is not compulsory. In fact, APT does not specify what factors to include. It also puts less restriction on the investor's utility function. Thus it is a very flexible model. Recent multifactor models will be discussed in 2.2.1.

To summarize, the MV-criterion and CAPM has in combination constituted a dominant framework in financial theory even up to this day.

2.1.3 Dynamic Covariance Theory

Regular sample variance and covariance is trivial to estimate. Within the context of financial return series there is overwhelming support for the idea of clustering in the volatility. The clustering is a consequence of the fact that the magnitude of the return tends to be auto correlated. Further more, a sample covariance of historical data is not necessarily a good predictor of future variance and co-variance. One could argue that this is probably especially true for the co-variance since this is a bivariate metric. One way of improving forecast of covariances is to try to estimate them by using factor models analogously to the one used for predicting future expected returns. Previous research on such models is accounted for in 2.2.2. A solution to the first problem, the clustering of return is the Autoregressive Conditional Heteroscedasticity[25] (ARCH) model. It was created by Engle and first described in Engle (1982). The ARCH model eliminated an obstacle which had made previous heteroscedastic research models hard to implement, the need to explain the heteroscedasticity through an exogenous variable[26]. Conditional variance is defined by an ARCH-process to be dependent on lagged error-terms. As is obvious from the amount of contemporary research papers dealing with time-varying variance, these models brought a revolution within this field. An extension of the ARCH model – the GARCH model was developed in 1986, independently by two different persons, Bollerslev and Taylor. GARCH extends ARCH by letting the conditional variance be dependent not only on previous error terms but also on its own lagged conditional variance. In Hansson, Högdahl (1997) the authors show the existence of GARCH-effects in the returns on Swedish markets[27].

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[22] Black (1972), Capital Market Equilibrium with Restricted Borrowing, pp. 454-455.
[23] Black (1972), Capital Market Equilibrium with Restricted Borrowing, p. 445.
[24] Ross (1976), The Arbitrage Theory of Capital Asset Pricing.
[25] Disputed spelling, sometimes spelled "Heteroskedasticity".
[26] Engle (1982), ARCH with Estimates of the Variance of UK Inflation, p. 988.
[27] Hansson, Högdahl (1997), Changing Risk Premia: Evidence from a Small Open Economy, p. 349.

For formulas describing the ARCH/GARCH framework, see formal definitions in 3.3.

2.2 Previous Research

This section offers an introduction to the recent previous research within the boundaries of what is relevant for the subject of this thesis, thus positioning this report in relation to similar research.

2.2.1 Equilibrium Pricing

One unsatisfactory property of the APT model is that it provides no guidelines for which factor(s) to include. It is in this way very ad hoc. The implication of this being that it is impossible to know whether deviations from the defined model are due to inefficiencies in the market or misspecifications of the model itself.[28] According to scientific theorist Karl Popper, the apparent impossibility to falsify the theory would render it useless and hence of no scientific interest[29].

In Fama & French (1992) the authors aim at explaining the cross-sectional return during the time frame 1963-1989 using several accounting metrics as well as market beta as explanatory variables. The accounting metrics are derived from previous research. The first noteworthy result is absence of a significant correlation between market beta and average return. Secondly, the factors mimicking market equity (ME) and the book-to-market ratio (BM-ratio) seems to be adequate in order to explain average realized returns.
Another interesting finding is that when comparing average monthly returns by pre-sorting market beta into ten groups ranging from low to high beta and compare against size (ME), there is a significant negative relation between average return and size. At the same time there is no significant difference in average return across the different beta-groupings, which is in accordance with was stated above.[30] The conclusions are that two variables are robust in a multivariate context, ME and the BM-ratio, and that the CAPM does not describe the last 50 years (1939-1989) of average return on stocks[31]. As is suggested in the paper, if their findings are correct it should have some practical implications. Not only in the way risk is managed in portfolios but also how fund management performance is evaluated. Evaluating a fund based on beta makes no sense in a world where the actual risk-bearing attributes are completely different.

The authors extended their research in Fama & French (1993) by including pricing of bonds in their analysis. A time-series rather than cross-sectional approach yields the result that the market factor is highly relevant. The authors find that while the actual market-beta does not account for much when explaining the return of a single equity it does provide a linkage for the spread in returns between the bond market and the equity market It is important to distinguish the common market factor from asset beta The stock loading (beta) on the market factor is similar to CAPM-beta but regressed in a multivariate setting together with HML[32] and SMB[33]. Here HML and SMB are replicated factors constructed in a fashion to minimize

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[28] Haugen (2000), Modern Investment Theory, p. 266.
[29] Thurén (1991), Vetenskapsteori för Nybörjare, p. 62.
[30] Fama, French (1992), The Cross-Section of Expected Stock Returns, p. 434.
[31] Fama, French (1992), The Cross-Section of Expected Stock Returns, p. 464.
[32] **H**igh **M**inus **L**ow.
[33] **S**mall **M**inus **B**ig.

the collinearity between the book-to-market and size present in the data. The market factor, HML and SMB are collectively referred to as the Fama and French three-factor model (FF3). Most research within the multi-factor models boundaries after 1993 have been influenced directly or indirectly by their findings and model of mimicking portfolios.

The inclusion of a market factor unfortunately means that the problem of estimating the market factor in a reliable way which has plagued the CAPM still persists.

In contrast to the sharp criticism of CAPM by Fama and French, Kothani et al (1995) finds that beta indeed have helped explain a substantial part of average return historically provided that beta is sampled at an annual interval. They also conclude that the BM-ratio's ability to explain cross-sectional return is exaggerated due to survivor bias. I.e. firms with high BM-ratios are more inclined to experience financial distress and going bankrupt. These firms will not be included in the sampling of financial data, since they do not exist. On the other hand, firms experiencing financial distress but which survive are often characterized by a turn-around, yielding high return in the subsequent year.[34]

Replying to this Fama & French (1996) points out that the size effect is unexplained for. They find the survivor effect not to be able to fully explain BM-factors apparent power to explain average return.

From a theoretical viewpoint, the FF3-model may be flawed in at least one way. While the case can be made that the existence of a return premium for Size is coherent with the fundamental axiom of risk-aversion, this may not be the case with BM. Fama and French makes the argument that HML is the so-called relative distress factor[35]. The logic being that a high BM-ratio (a company valued relatively low) corresponds to high risk. The counter-argument is that stocks with low BM-ratios in general are overvalued and thus incur a lower expected return, in other words, the BM-ratio factor could be an effect of market inefficiency.

In Asgharian & Hansson (2000) research was made on the Swedish market using Fama and French style variables. Using a GARCH methodology for estimating time-varying asset betas the main findings were that the BM-factor and leverage explains cross-sectional returns with statistical significance. However, excluding the recession between 1990-1992 yields somewhat different results. BM-factor is consistent and remains a very significant factor while leverage is not significant at all. Interestingly, while not statistically significant, the size factor seems to be a good candidate for explaining cross-sectional return when excluding the recession period. These dramatic changes is probably mainly due to the collapse of the property market and the associated market value of listed real estate and constructing firms[36]. The authors' explanation for the importance of the recession period is the relative short time frame under investigation, 15 years.

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[34] Kothani et al (1995), Another Look at the Cross-Section of Expected Stock Returns, p. 220.
[35] Fama, French (1992), The Cross-Section of Expected Stock Returns, p. 444.
[36] Asgharian, Hansson (2000), Cross-sectional Analysis of Stock Returns, p. 230.

Research Paper	Rm	Beta	Size	BM	Lev.	P/E
(1992) FF	-	No	Yes	Yes		
(1993) FF	Yes	-	Yes	Yes	-	-
(2000) AH	-	No*	No*	Yes	Yes*	No

Table 1, Summary of previous studies. Yes indicates factor significance in explaining average return.
* Omission of recession period yields reversed results.

In Table 1 the findings of research conducted on both the Swedish and American markets regarding explanation of the cross-sectional return are presented. It appears that the role of classic beta is insignificant on all markets. To summarize, there seem to be strong support for a market factor as well as for a size factor and a book-to-market factor contributing to explaining cross-sectional return on the US stock market. The results from the Swedish market are somewhat different, however this may be due to testing of the data under extreme market conditions.

The support for macroeconomic factors contribution in explaining the average return on the equity market is scarce.

Finally it is worth noting that despite contemporary research in the field of equilibrium pricing, among practitioners the dominant determinant for estimating discount rates for projects and cost of capital for evaluation of stocks, CAPM is still dominant according to Graham & Harvey (2001).

2.2.2 Risk Management

Risk Management within this context refers to the practice of adequately measuring, explaining and forecasting risk associated with the returns from financial assets. In practice, how investors manage the risk of equity portfolios. The large amount of research on the relation between firm characteristics and expected return raises the question of how these characteristics are related to the variance of return. So far, there have been little studies on this subject.[37] Understanding which factors drive the covariance of return among assets is a related but not as explored area of financial research. Of particular interest due to the purpose of this thesis is previous research based on finding an explanatory model by exploring variables of different type sources.

In Chan et al. (1998) the authors use five different classes of explanatory variables for explaining the covariance matrix[38]. A noteworthy observation is that the return spread for the BM-factor is close to zero in expansion while being significant during times of recession. The size-factor exhibits the same tendency although to a lesser degree. To conclude: size, BM-ratio and dividend yield are relevant factors from a risk management perspective. Dividend yield exhibit a strong tendency of being more relevant during periods of recession. A strong negative correlation between the size factor and the BM-factor is observed. The authors attribute the relation to the tendency for value stocks (high BM) to be of smaller size than so called glamour stocks (low BM).[39] While some macro variables display a relative high level of return covariation they are of minor to no interest for explaining risk in a multifactor setting.

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[37] Moskowitz (2003), An Analysis of Covariance Risk and Pricing Anomalies, pp. 417-418.
[38] Accounting, momentum, market, macro and statistical factors.
[39] Chan L, Karceski J, Lakonishok J (1998), The Risk and Return from Factors, p. 186.

In Asgharian & Hansson (2001) the Swedish stock market is investigated from a risk management perspective. The time frame under investigation being 1977 to 1997. The market factor is divided into a world market factor and a residual national market factor. They group the explanatory variables in four categories: market, fundamental, technical and macroeconomic. Mimicking factor technique is employed to create return series from the variables which are not return-denominated. The results from this research stress the importance of the market factor and to a lesser degree BM- and size-factors. The technical and macro factors seemed redundant.[40] The national market factor is found to be surprisingly important given the properties of the Swedish economy which the authors categorize as a small open economy.

In Moskowitz (2003) the author sets out to investigate the links between CAPM anomalies and covariance risk, where the anomalies supposedly are factors like HML, SMB and momentum effects. He estimates conditional covariance in a GARCH-framework utilizing representative assets. The representative assets compromises industry portfolios, six intersected BM-ratio and ME factor portfolios, a market portfolio and five momentum portfolios. The main results are two-fold: The market factor is the most important factor for capturing covariance risk. Secondly the author also infers highly significant results for SMB and is able to connect the factor to what could be priced risk. These results stems from the fact that both the average premium and increased power of capturing covariance associated with SMB is amplified during recessions. The FF3-model outperforms principal components out-of-sample which could make the model useful in forecasting applications. While HML add some explanatory power its relation to covariance risk is weak. The momentum factors do not seem to posses any power. The author also identifies that the conditional covariance is much higher during recessions than expansions in general.

In Asgharian & Hansson (2003) industrial portfolios constitute the assets which return and risk are to be explained. The main result is that the market portfolio is by far the dominating factor in explaining both return and risk. As in Asgharian & Hansson (2001) the authors find the low explanatory power of the world market factor hard to explain.

Research Paper	Rm	DY	Size	BM	Lev.	P/E
Chan et al. (1998)	Yes	Yes	Yes	Yes	-	-
AH (2001)	Yes	-	Yes	Yes	No	No
Moskowitz (2003)	Yes	-	Yes	Yes	-	-
AH (2003)	Yes	-	-	-	-	-

Table 2, Summary of previous studies. Yes indicates factor significance in explaining covariation of returns.

Table 2 summaries the findings of the research papers presented in this section. The factors which are found relevant in all cases are highlighted.

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[40] Asgharian, Hansson (2001).

Chapter 3: Methodology

First of all, the methodology chapter motivates the author's choice of method. Secondly, it describes the methodology used for the thesis and account for the working process. Furthermore this chapter describes and categories the data used. Finally, statistical methods are described in Chapter 3.3.

3.1 Choice of Methodology

As can be derived from the purpose of this paper, this is a positivistic thesis. This means that the aim of this thesis is to find the "truth" about the various problem definitions defined in the first chapter. This thesis is in its nature statistical and quantitative and hence so is the methodology chosen for it. In other words, this thesis relies almost solely on quantitative and statistical methods in order to verify or reject the research's problem definition. As with all empirical research which builds on previous findings, this thesis could be considered being both inductive, since the goal of the paper is to draw generalized conclusions inferred from the empirical data, and hypothetico-deductive since certain results are anticipated beforehand.

3.1.1 Working Process

The working process can be categorized into the following points:

- Theoretical studies: Studying relevant research papers and finance literature.
- Decide upon the problem formulation and purpose of the paper.
- Choice of methodology: This choice was being made primarily from the starting point of the above points and from an analysis of the availability of data.
- Collecting the data. Processing the data to suit the need of this thesis.
- Perform relevant (statistical) tests on the data in order to acquire results of the problem formulations.
- Analyze and interpret the empirical results, draw conclusions from the analysis.

The working process has not been this straightforward though. The first three points in the scheme above have been iterated several times until they all have been found to be coherent.

3.1.2 Sources of Data

Both primary and secondary data have been used. Primary data is defined as data which have created directly or secondary data which has been significantly altered. Secondary data is all sorts of data which have been acquired from another source than oneself.

3.1.2.1 Primary Data

No primary data in the form of newly created data[41] has been used in the thesis. All data were retrieved from the financial data provider Datastream. Instead, the primary data consists of altered secondary data in form of: stock market raw data, company specific ratios which has been calculated from secondary data etc.

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[41] E.g. interviews, tape recordings etc.

3.1.2.2   Secondary Data

The selection of secondary data consists of several different sources. Raw data, in the form of stock market prices, index, ratios etc. Included in secondary data are by definition all research papers, news articles etc.

3.2   Methodological Data Properties

3.2.1   Reliability

Given the thesis quantitative nature a relatively high degree of reliability is implied. Since the raw data has been retrieved from well-known sources with a good reputation the data should be considered highly reliable. Due to the nature of the raw data, stock prices and different kind of financial ratios at specific points in time, there should be no measurement errors.

3.2.2   Validity

According to theory the validity of quantitative research is as a rule of thumb relatively weak. As have been noted in 3.2.1 the opposite is true for reliability. This relation is called "the methodological dilemma"[42] because there is a natural opposition between reliability and validity. Nevertheless, given the rather strict rules governing accounting etc the validity is sufficient in order to produce credible output from it. Differences in accounting policy do hurt the validity of the thesis somewhat. This damage is being minimized since the assets in given data models consists mainly of industry index or portfolios rather than individual stocks, hence odd accounting policies should tend to be diversified away.

3.2.3   Sources of Error

The risk for "measurement" errors in the data is negligible. Most likely any errors in the data can be attributed to mistyping on my account or erroneous data processing, i.e. the so called "human factor".

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[42] Holme & Solvang (1997), Forskningsmetodik, p. 83.

3.3 Statistical Methodology

The statistical models which some readers may not be familiar with are defined and explained in this section.

3.3.1 Definition of ARCH / GARCH

An ARCH (q) process is defined as follows:

$$(3) \qquad y_t = \beta_1 + \sum_{i=2}^{n} \beta_i x_i + u_t$$

$$(4) \qquad \sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i u_{t-i}$$

The conditional variance in an ARCH-process is correlated with its previous error terms.

A GARCH (p, q) process is defined as follows:

$$(5) \qquad y_t = \beta_1 + \sum_{i=2}^{n} \beta_i x_i + u_t$$

$$(6) \qquad \sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i u_{t-i} + \sum_{i=1}^{p} \beta_i \sigma_{t-i}^2$$

Because GARCH is an extension of ARCH, GARCH (0, x) = ARCH(x).In addition to the heteroscedastic part of the conditional variance, α_0 is the long-term mean of the variance.

There is no easy general test to determine whether heteroscedasticity is present in a data set.[43] As will be accounted for in later chapters, the factors under study will be subject to an ARCH test, which is highly relevant because of the relationship between these processes. "Engle's hypothesis test for presence of ARCH/GARCH effects"[44] is designed to detect heteroscedasticity in the dataset.

The input needed for such a test is residuals from some kind of data fitting process. Simple univariate regression of the return series on a constant (mean of variable) was used for this purpose.

$\mathbf{Y}$; asset realizations.

$\mathbf{X} = \bar{y}$

$\widehat{\mathbf{Y}} = \beta_x \cdot \mathbf{X}$

$\varepsilon_i = y_i - \hat{y}_i$; $\forall_i$

Subsequently the residual vector is passed as input to the ARCH-test function.

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[43] Bollerslev (1986) Generalized Autoregressive Conditional Heteroskedasticity, p. 308.
[44] See APPENDIX D.

3.3.2　　　Definition of Orthogonality

Two variables, *x* and *y* is orthogonal with respect to each other if the property below is satisfied:

$$(7) \qquad \sum_{i=1}^{n} x_i y_i = 0$$

In a two-dimensional vector space orthogonality is equivalent to the two vectors being perpendicular.

3.3.3　　　Definition of Principal Components

Closely related to orthogonality is *Principal Components Analysis*. Principal components (PC) are by definition the linear combination of variables (i.e. factors derived from the data) which capture the highest rate of the covariance matrix in-sample. By definition the principal components are orthogonal with respect to each other. The economic logic is that each PC captures covariance which the other PC's do not. See Campbell et al. (1997) for a more formal definition.

Chapter 4: Data Modeling, Selection and Processing

This chapter describes the model of the economy. The modeling, selection and processing of factor portfolios follows. The recession period is being delimited and finally the GARCH-estimation is being accounted for. The working process and selection of data is explained in a hands-on manner, hence this chapter is of interest for replicatory purposes.

4.1   Model of the Economy

The model of the economy, in this case effectively the equity market of Sweden, is based on the same conceptual model as in Moskowitz (2003), using so-called representative assets. The idea behind the model is to simulate the economy using aggregated assets instead of using each individual asset. The gain one incurs is a reduction of noise which would otherwise be generated by individual return returns.[45] Another advantage of this approach is the facilitation of data collection and data processing. Nine industry portfolios represent the equity market. A summary of these assets is presented below, see Table 5.

4.1.1   Data Properties

All portfolio returns are continuously compounded returns, i.e. log returns. One appealing property of log-returns is that they will be normally distributed around the mean. This is not the case with simple return, since limited liability in general makes -100% the maximum loss an investor can occur[46]. Another desirable property when using time series data is that an average positive or negative return over time will correspond to the return investors would incur over time in real returns since positive and negative log-returns are symmetrical, i.e. a negative and positive log-return of the same magnitude will cancel each other out. As a consequence normality is assumed for all data series. All return series are on a weekly basis. This avoids confounding microstructure influences[47] and facilitates as well as speeds up data processing. The latter is important given the large pool of assets from which the replicating factors are created from, especially the macro variables since the loadings are estimated through regression analysis. For all variables, historical data is sampled over one period of time and then their predictive power is tested on period subsequent of the sample period.

All returns are returns in excess of the risk-free rate. The risk-free asset in financial theory is defined as an asset with a perfectly predictable rate of return during the length of an investor's time horizon.[48] Since this thesis is written from a Swedish perspective the unit of return of the risk-free asset must be denominated in SEK. It will be assumed that the time horizon is 30 days. Thus, an appropriate proxy is the yield on one-month Swedish treasury bills. Although there is a zero correlation between the risk-free asset and the market premium, it is still important use excess return when doing research over time since the rate of return on the risk-free asset in itself is not static. Using nominal return will in general yield misleading results when analyzing over time due to influences from inflation.[49]

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[45] Moskowitz (2003), An Analysis of Covariance Risk and Pricing Anomalies, p. 422.
[46] Campbell, Lo, MacKinley (1997), The Econometrics of Financial Markets, pp. 15-16.
[47] E.g. nonsynchrounous trading, see Moskowitz (2003), p. 420.
[48] Bodie & Merton (2000), Finance, p. 323.
[49] Merton (1980), On Estimating The Expected Return on the Market, pp. 327-328.

Since all factors except the market portfolios are created from the individual stock source dataset, the risk-free rate relevant at each date were simply deducted from the all returns. The market portfolios were corrected in an analogous fashion.

4.2   Factor Selection

4.2.1   Selection Criteria

The candidate variables were assessed based on their power of providing excess return, exhibit higher variance than a relevant benchmark and their level of heteroscedasticity. A high level of variance implies that the factor captures risk in excess of its idiosyncratic risk which is desirable given the stated purpose of the thesis. As has been stated in the theory section, financial time series do in general display the property of heteroscedasticity. This is not always the case. The candidate factors are tested for ARCH/GARCH according to the methodology accounted for in 3.3.1. If the data is not stationary, statistical tests using a t-distribution will not be reliable.[50] Since all data series are returns they can safely be assumed to be stationary. The factors excess returns were tested through an ordinary one-sampled t-test for difference from 0.

4.2.2   Factor Mimicking Portfolios

A *factor mimicking portfolio*, also referred to as a *replicating portfolio* is a kind of *synthetic asset*. Basically it is a portfolio whose return series is supposed to mimic the "return" from a factor which is not directly observable. The factor portfolio is a zero investment portfolio, meaning that it is long in the same relation that it is short. If the portfolio is properly defined and empirically sampled, i.e. it is in equilibrium, the expected return to a factor mimicking portfolio corresponds to the return premium of the factor. The accounting, macro and momentum factors are all constructed by going long in stocks ranked in the quintile with the highest loading on the variable factor and going short in the quintile of stocks with lowest loading on the variable. This is done in the same fashion as in Chen et al. (1998).

The total number of stocks traded in Stockholm on the Swedish part of the Nordic Stock Exchange, First North and Aktietorget exceeds 400. All factor portfolios except for the market portfolios were created from these stocks with the exclusion of stocks representing banks and financial firms. The average number of stocks included in the underlying dataset is 171. Unlike most research where the composition of the accounting factors are determined at the 1st of April or 1st of May each year, the replicating portfolio representing the accounting factors are recreated at each point in time, i.e. on a weekly basis. This is possible since the accounting data was acquired in time series shape. Recreating the factors at a weekly level should assure maximum efficiency in the factors composition.

In the first evaluation of potential factors, each factor's explanatory power was tested separately. The composition of the factors is updated each week in order to achieve a maximum level of efficiency in the estimations. Obviously this requires a huge number of

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[50] Brooks (2002), Introductory Econometrics for Finance, p. 368.

calculations. Since all data, even the firm specific accounting ratios are available in tabulated form this was problem which could be surmounted.

The stocks which were used as source data when forming the size and book-to-market portfolios and the momentum portfolios were virtually all the stocks publicly traded in Sweden as of 2008. Excluded are the stocks of banks and other financial firms, since their account key ratios such as e.g. book-to-market differ substantially from other firms stock.

There is no consensus whether to use value-weighted or even-weighted portfolios when forming the replicating portfolios. The argument for using value-weighted can be understood by assuming only one corporation exists in the economy, which was created by acquiring all existing companies. This hypothetical corporation would possess key ratios analogously to those of the value-weighted mimicking factors, assuming no difference in valuation between the sum of all companies and the aggregated company.

On the other hand, in reality any investor may freely allocate over the available assets and thus decide if he wants to expose himself to a certain factor. The possible exception being highly capitalized investors looking to exploit excess return from the size-factor. Given this, the value-weighted approach incorporates a higher fraction of idiosyncratic risk which could yield misleading results. Especially if stocks associated with high market capitalization companies have high loadings on a factor. In that case their performance could end up dominating the portfolio. Because of this the even-weighted approach was chosen. Hence for a portfolio consisting of n assets, each asset will have a weight of 1/n.

4.2.3   Candidate Variables

Candidate variables/factors can be attributed to one of four groups: accounting, macro, technical and market factors. As accounted for in 2.2.2 and 2.2.3 previous research, both on Swedish and international markets have shown that factors derived from accounting variables exhibit the highest level of explanatory power. Because of this, they are included as candidate factors without motivation.

The following variables served as candidate factors:

Accounting factors (5):

- Book-to-Market ratio (*BM*), accounting value of the firm divided by its market value.
- *Size*, the market value of the equity.
- Dividend Yield (*DY*), the ratio between the latest dividend and the current market value of the equity.
- Leverage (*Lev*), defined as the ratio of total liabilities to total assets.
- P/E-ratio (*PE*), ratio between the price of the equity and its annual earnings.

Macro factors (4):

- Foreign exchange-rate (*FEX*), the relative weekly change in the SEK/USD exchange rate.
- Industrial Production (*IP*), the relative weekly change in *IP*.
- The slope of the yield curve (*SLOPE*), defined as the difference in yield between a ten-year government bond and a three-month treasury bill.

- The maturity premium (*TERM*) is the absolute difference in return between a ten-year government bond and a one-month treasury bill.

The motivation for including *IP* and *SLOPE* as candidate factors is that their variances were close of being significantly higher than that of a relevant benchmark in previous research performed on the Swedish market[51]. *FEX* is included due to the increasingly globalized economy discussed in the first chapter. The SEK/USD exchange-rate is the favoured one in spite of "Euroland" being Sweden's most important trading partner. The SEK/USD-rate is much more volatile[52] as well as being the most important currency internationally, hence if there is truly an exchange-rate factor the SEK/USD would probably be the best proxy. Finally, *TERM* has shown explanatory power internationally and is included solely because of that.[53]

Technical Factors (1):

- One-year previous return (*MOM*). The factor is created by going long in the highest quintile of stocks sorted by past return and short in the lowest quintile.

4.2.4   Evaluation of Variables

Below are the results from the evaluation of candidate factors. A Chi-square test for equality of variance[54] is employed to test if the factor's variance differs from that of its benchmark. Statistically significant results mean that the null hypothesis of equality in variance can be rejected. It is worth reiterating that *Size* is long in high cap stocks and vice versa, the negative average return is in line with previous research.

4.2.4.1   Summarized Results

In the following tables the mean is equivalent to the excess return produced by the factor.

Factor	Std Dev.	Mean	ARCH
Lev	0.03057 (0.93)	-0.0017 (0.217)	7/8
DY	0.05995 (0.00**)	-0.0041 (0.123)	0/8
BM	0.04145 (0.00**)	0.0078 (0.00**)	6/8
Size	0.07548 (0.00**)	-0.0140 (0.00**)	0/8
PE	0.03858 (0.00**)	-0.0015 (0.39)	0/8
MOM	0.06726 (0.00**)	-0.0083 (0.01**)	0/8

Table 3, * Indicates significance at p=5% level. ** Indicates significance at p=1% level.

Given the importance of *BM* and *Size* from previous research and their high level of variance they are selected to be included in the GARCH-estimation. Factors based on the relative valuation of the firm in comparison to its profitability, e.g. the P/E-ratio, have not proved to add any explanatory power and thus will not be included as a factor. Another problem with the P/E-ratio is that firms with a negative P/E usually are left out of the analysis. In the source data used (DataStream) it is not even possible to tell whether a firm has a negative P/E or if

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[51] See Asgharian, Hansson (2001).
[52] During 1996-2005, SEK/USD$_{high}$ % SEK/USD$_{low}$ = 1.68, SEK/EUR$_{high}$ % SEK/EUR$_{low}$ = 1.23.
[53] Chan et al. (1998), The Risk and Return from Factors, pp. 175.
[54] MATLAB command *vartest*.

the information simply is missing for a particular firm at a specific date. Hence a model partially based around the P/E-ratio trying to explain or forecast anything will fail to do so when applied to a firm with a negative P/E-ratio. This is obviously another drawback. Unlike *PE*, *Lev* and *DY* both have merit in previous research. Judging by the heteroscedastic properties *Lev* would seem like a good candidate. However, judging by the mean and variance of the factor it can not be significantly separated from general noise. The fact that it exhibits ARCH-like residuals does not by itself justify its inclusion. The benchmark factor discussed below also produces a certain fraction of the return series with these properties. The leverage factors empirical foundation is also relatively weak. *DY* has not previously been tested from a risk management perspective on the Swedish equity market. From research conducted internationally it seems that *DY* does a good job at capturing risk in recessions. Given the results from the data as well as drawing from previous research, *Size*, *BM* and *DY* were selected as factors to be included in the economy matrix.

It is worth noting that the excess return (mean) of the momentum factor is highly significant negative. Thus it produces excess return in the opposite direction compared to the momentum factor identified in Jegadeesh, Titman (1993). Because one of the multi-factor models under investigation includes a momentum factor it is selected as a factor despite failing to show signs of heteroscedasticity.

Factor	Std Dev.	Benchmark SD.	p	ARCH
FEX	0,041158	0,036783	0.00**	0/8
IP	0,036797	0,036524	0.79	0/8
SLOPE	0,036959	0,036442	0.63	0/8
TERM	0,119415	0,036837	0.41	0/8

Table 4, * Indicates significance at p=5% level. ** Indicates significance at p=1% level.

The results are clearly unambiguous as for the second moment of return. *FEX* is obviously a solid candidate for inclusion in the model of the economy. Unfortunately the ARCH-test null-hypothesis is not even close of being rejected at any lag. Because of the relatively volatile SEK/USD exchange-rate and the characteristics of the Swedish economy discussed in the first chapter *FEX* is selected as a factor. None of the macro factors produced statistical significant excess return.

4.2.4.2   Benchmark factors
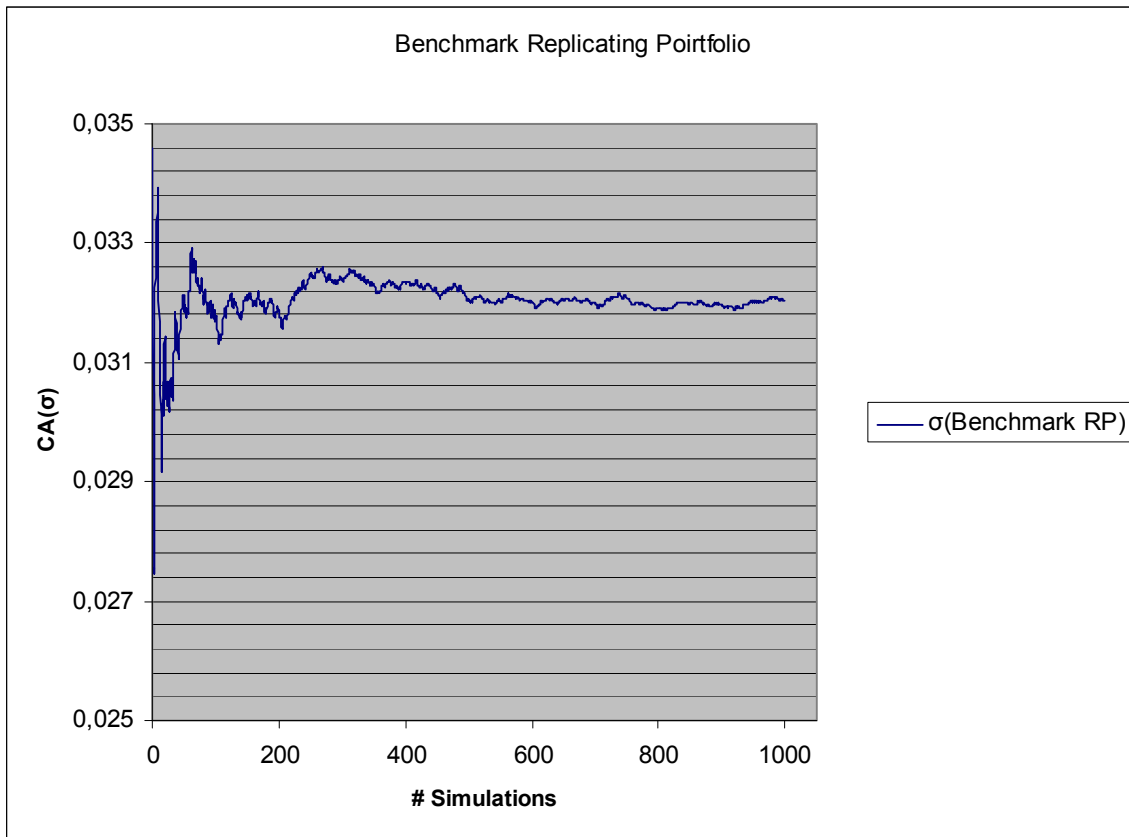
Figure (1), The cumulative average for the standard deviation of the Benchmark Replicating Portfolios.

In order to be able to relate the factors variances, a benchmark factor were created. The benchmark is employed for the sake of providing a way to evaluate the variance of the replicated factors created from the momentum and accounting group. The factor is a zero-investment portfolio just like the other replicated factors. This factor is randomized among the over 400 stocks in the database Stocks were randomly assessed for each formation period (each week) to the High and Low subsets and the resulting return calculated. The previous process was repeated 1000 times causing the moving average to converge at a satisfactory level. This factor exhibits an average excess return of 0% and a standard deviation close to 0.03205 (N = 522).

This benchmark however, is not suitable for testing on macroeconomic factors. The reason is that the loadings on stocks with a similar return history will tend to be similar when regressed on a third variable regardless of the significance of the third variable. To correct for this each macro factor needs it own benchmark. The benchmark is created by scrambling the time series of the candidate variable by selection without replacement.[55]

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[55] Chan et al. (1998), The Risk and Return from Factors, pp. 173-175.
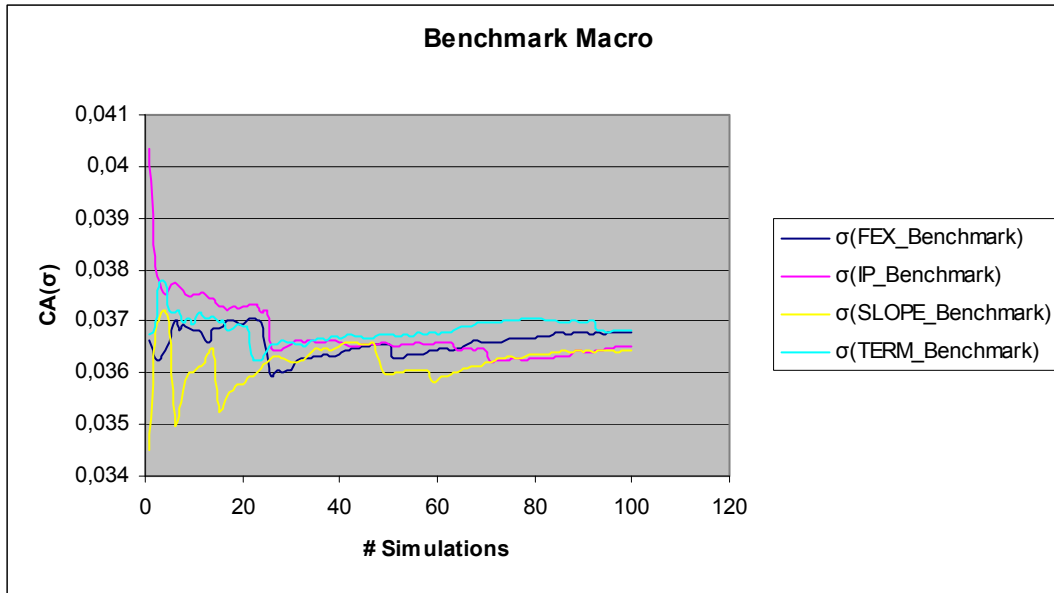
Figure (2), The cumulative average for the standard deviation of the Benchmark Macro.

To test the macro variables' variances each candidate factor was measured against a tailor made benchmark. As expected, all macro benchmark factors trend towards a significantly higher variance compared to the dummy benchmark. Because of the huge number of regressions[56] necessary to perform when creating the benchmark factors an algorithm for univariate regression analysis with increased performance had to be created in VBA.

4.2.5 Market Factors

Following Asgharian & Hansson (2001), two separate market factors are constructed. R_w is the world market factor, which simply is the weekly return of the USD-denominated Morgan Stanley World Index (MSWI) converted into returns corrected for the relative change in the weekly SEK/USD exchange rate. The reasons behind the transformation are twofold: The return should be relevant from a Swedish-based perspective; secondly there is another factor in the model of the economy which is supposed to capture foreign-exchange fluctuations.
The AFGX[57], which is the proxy used for the overall Swedish stock market is regressed on R_w (8). The part of R_s which can not be explained by R_w, the constant term and the residual constitute R_{so}. This is the return on the Swedish market orthogonalized against the MSWI.

$$(8) \qquad R_{st} = \alpha + \beta R_{wt} + u_t \; ; \; \forall_t$$

$$(9) \qquad R_{sot} = \alpha + u_t \; ; \; \forall_t$$

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[56] Approximately 171*400*522 = 35 704 800.
[57] Affärsvärldens Generalindex, an index enclosing stocks listed on the Stockholm Stock Exchange.

4.3 Resulting Model

#	Asset / Factor	Asset / Factor Type	ARCH
1	COMMODITIES	Industry Index	6/8
2	INDUSTRIALS	Industry Index	8/8
3	CONSUMER GOODS	Industry Index	8/8
4	H/C	Industry Index	6/8
5	FINANCE	Industry Index	8/8
6	IT	Industry Index	8/8
7	TELECOM	Industry Index	7/8
8	MEDIA	Industry Index	8/8
9	SERVICES	Industry Index	8/8
10	MOM	Momentum	0/8
11	R_w	Market	8/8
12	R_{so}	Market	8/8
13	FEX	Macro	0/8
14	SmB	Accounting	7/8
15	HmL	Accounting	1/8
16	HYmLY	Accounting	8/8

Table 5, The assets included in the GARCH-estimation. Assets 1-9 constitutes the data, 10-16 are the independent factors from which factor models are created.

In Table 5 the representative assets included in the model of the economy and the independent factors are summarized. Three factors were created in a Fama and French-fashion.

4.3.1 Replicated Accounting Factors

The methodology is quite straightforward. At each date, the stocks get sorted by their size, BM-ratio and dividend yield. 16 different portfolios are created from these ranked sets by intersecting the variables. See e.g. Fama & French (1993). The outcome is the three replicating factor SmB, HmL and HYmLY[58]. The logic behind the creation is to decrease the correlation between the factors as much as possible.

$$SmB = Avg(S/L + S/M + S/H + S/HY + S/LY) - Avg(B/L + B/M + B/H + B/HY + B/LY)$$

$$HmL = Avg(B/H + S/H + H/HY + H/LY) - Avg(B/L + S/L + L/HY + L/LY)$$

$$HYmLY = Avg(L/HY + M/HY + H/HY + S/HY + B/HY) - Avg(L/LY + M/LY + H/LY + S/LY + B/LY)$$

4.4 Recession

It is not evident how to delimit the time frame constituting the recession. A special account of how the factor models perform during recessions will be made (see 5.2.3). According to the US National Bureau of Economic Research (NBER), a recession is defined as two consecutive quarters of declining Gross Domestic Product.[59] Nevertheless this is just a rule of thumb and on the list of expansions and recessions compiled by the same organization the

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[58] **H**igh **Y**ield **m**inus **L**ow **Y**ield.
[59] (2005), Oxford Dictionary of Finance and Banking, p. 341.

latest and only recession given the time frame of the dataset - is a recession ranging between March and November 2001[60].

The correlation coefficient between the US and Swedish GDP, measured as the quarterly relative growth is 0.25. Given the relative change in quarterly Swedish GDP as well as taken the stock market return into account, the time frame of the recession is estimated from September 2000 – September 2001. See APPENDIX C.

Also note that there is a period of strongly negative return in 2002. This time frame will not be subject to study since this period is considerably shorter and the GDP growth is much higher than in the defined recession period.
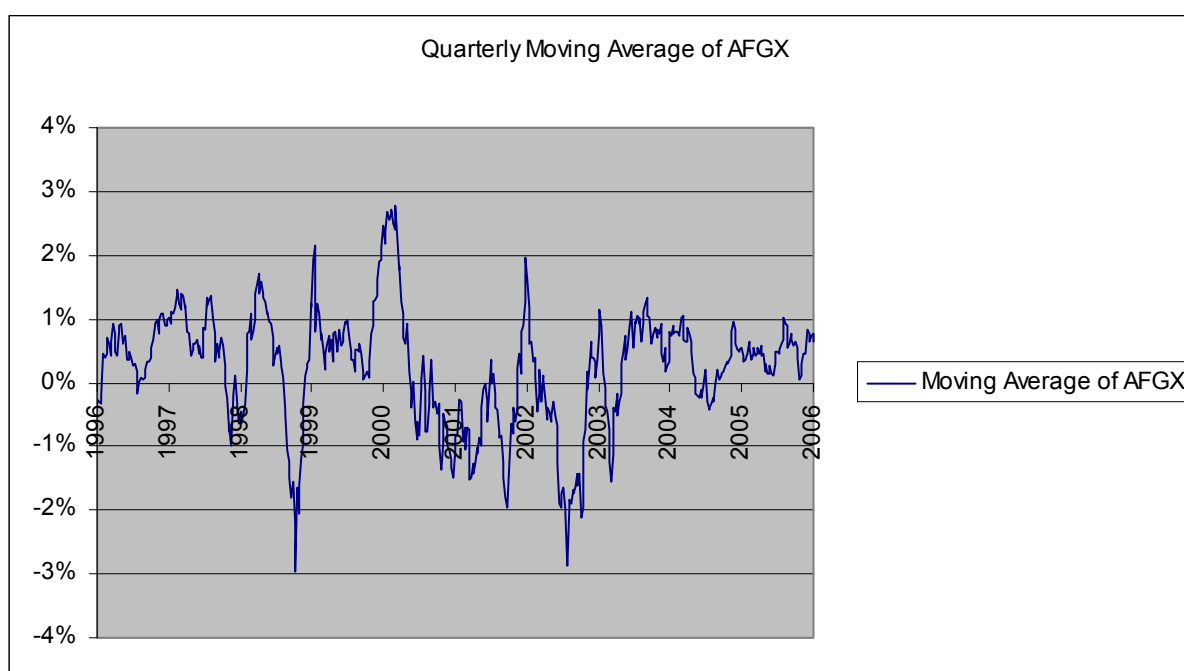
Figure (3), Moving average of the last 13 weeks weekly returns.

4.5   GARCH Estimation Process

In this investigation a GARCH (1,1)-model is employed. This type of model is the one most frequently used for financial modeling since such a model in general is sufficient to capture volatility clustering from return series[61].

As shown in 2.1.3 the first step when working with models explaining or forecasting variance/covariance matrices is how to assess the true variance/covariance at each time spot. While there are many different GARCH-models which can be used to estimate the covariance matrix, it is beyond the scope of this thesis to engage in such a comparison. The estimation of the true covariance matrix replicates the method employed in Moskowitz (2003). The model is a multivariate GARCH (1,1)-model created and described by the authors in Ledoit et al. (2003). It is multivariate since it is used to estimate not only the variance components of the covariance matrix, but also the off-diagonal elements (covariance part).

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[60] http://www.nber.org/cycles/ [2008-05-23]
[61] Brooks (2002), Introductory Econometrics for Finance, pp. 452-455.

The model of Ledoit et al. (2003) is:

$$(10) \qquad \text{Cov}[x_{i,t}, x_{j,t} \mid \Omega_{t-1}] = h_{ij,t} = c_{ij} + a_{ij} x_{i,t-1} x_{j,t-1} + b_{ij} h_{ij,t-1}$$

In order to derive the most efficient GARCH-parameters we need to maximize the following Maximum-Likelihood Estimators.

$$(11) \qquad \max \quad -\frac{T}{2} \cdot \ln(2\pi) - \frac{1}{2} \sum_{t=1}^{T} \left[\ln(h_{ii,t}) + \frac{x_{it}^2}{h_{ii,t}} \right]$$

$$(12) \qquad \max \quad -T \cdot \ln(2\pi) - \frac{1}{2} \cdot \sum_{t=1}^{T} \left[\ln\left((\det H_{ij,t}) \right) - \frac{1}{2} (X_{ij,t} \cdot H_{ij,t}^{-1} \cdot X_{ij,t}) \right]$$

The first attempt was to create an algorithm to solve the optimization problem using so called genetic algorithms. This approach was abandoned. While the algorithm worked, the run time was approximately 8 hours and the output could not be guaranteed to be semi-definite. In contrast the algorithm supplied by the authors of Ledoit et al. (2003) creates the necessary output within minutes and satisfies the requirement of semi-definiteness.

The method employed ensures that the conditional covariance matrix is positive semidefinite. This is absolutely crucial for the validity of the covariance matrix since positive semidefinitness is equivalent to the matrix having a positive determinant. The determinant of the covariance matrix is usually interpreted as the generalized variance of the matrix. Since negative variance is not defined in a financial context any such covariance matrix is meaningless.[62] To summarize, if the GARCH-estimation algorithm is completed successfully this ensures that the covariance matrix makes sense from an economical perspective.

Some assets do not exhibit ARCH/GARCH-like effects as can be seen in Table 5. Despite this, GARCH is used to estimate the variance-covariance for all variables in order to maintain model consistency and keeping to the stated aim at parsimonious-ness.

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[62] See e.g. (2006) Wilcox for a discussion of generalized variance.

Chapter 5: Empirical Findings

This chapter begins by describing the GARCH environment. Furthermore the metrics used to assess the factor models are accounted for. Subsequently the factor models are presented. In the second section of the chapter the empirical findings are presented.

5.1 The GARCH Environment

5.1.1 Test Environment

Initially the same set of assets was included in the GARCH-model as in Moskowitz (2003)[63], although three accounting factors are employed in this thesis resulting in 16 instead of 6 intersected accounting-based portfolios. Moskowitz creates his factors from the dataset. Because of too high correlation among the assets the results were highly unreliable. Mainly due to the fact that random factors recorded very high scores on the metrics used (see 5.1.2). The details of these tests are left out for brevity. The original setup was abandoned and instead the model of the economy accounted for in the previous chapter was employed. The average correlation coefficient between the industry factors is 0.497. The main difference though is that the covariance matrix is divided in a dataset and a set of factors.

5.1.2 Test Metrics

The covariance matrix was created for the whole time frame under consideration from the output of the GARCH-estimation, essentially three vectors containing the a, b and c-parameters[64]. Details regarding the GARCH-estimation are available on request.

The estimated covariance matrix (V_t) is assumed to be correct, and will serve as a benchmark against the covariance matrices estimated from regressions on the representative assets.

$$(13) \qquad V_t = \beta_t \sum{}_t \beta_t^{'} + \Omega_t$$

In (13) $\beta_t \sum_t \beta_t^{'}$ is the covariance matrix at time t estimated from the factor model.

The different models were put to test in and out-of-sample through metrics appropriate for matrices.[65] The same metrics as in Moskowitz (2003) were used in this thesis.

$$(14) \qquad Eig_t = \frac{\sqrt{\text{trace}\{(\widehat{\beta}_t \widehat{\Sigma} \widehat{\beta}_t^{'})'(\widehat{\beta}_t \widehat{\Sigma} \widehat{\beta}_t^{'})\}}}{\sqrt{\text{trace}\{V_t^{'} V_t\}}} \; ; Eig_t = [0,1]$$

$$(15) \qquad Magnitude_t = \frac{\iota'(|V_t - \widehat{\beta}_t \widehat{\Sigma} \widehat{\beta}_t^{'}|)\iota}{\iota'(V_t)\iota} \; ; Magnitude_t = [0,1]$$

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[63] (2003) Moskowitz, An Analysis of Covariance Risk and Pricing Anomalies, pp. 420-422.
[64] Ledoit et al., Flexible Multivariate GARCH Modeling with an Application to International Stock Markets, p. 735.
[65] (2003) Moskowitz, An Analysis of Covariance Risk and Pricing Anomalies, pp. 432-434.

$$(16) \qquad Direction_t = \frac{\mathbf{\iota}'\text{sign}(V_t(\hat{\beta}_t\hat{\Sigma}\widehat{\beta_t'}))\mathbf{\iota}}{[\text{rank}(V_t)]^2} \; ; Direction_t = [-1,1]$$

Eig_t measures the overall similarity of the matrices expressed by comparing the trace of the matrices, where trace is equal to the sum of the matrix's eigenvalues. $Direction_t$ compares corresponding covariances pairwise and returns -1 if the covariances are of different signs and +1 if they are the same. It simply benchmarks the models ability to correctly assign the right direction of the covariance. Finally $Magnitude_t$ measures to what degree the size of the covariances are captured. The logic behind squaring the matrices in the formula is to prevent negative and positive covariances from cancel each other out and instead capture the absolute level of covariation.

5.1.3 Pricing Models

All seven independent variables were tested in a univariate way. The two market factors were tested both by themselves and grouped together, summing to a total of eight different univariate estimates Three different multi-factor models plus the unconditional principal components (UPC), essentially a statistical multi-factor model were also tested.

Additionally a random single model factor was created in order to be able to compare how good the pricing models actually are. This was done by sampling five different return-series from the benchmark portfolio used for evaluating the accounting factors. Since 1000 different series were created, a fraction of them were bound to exhibit heteroscedasticity. Although this does not enable the possibility of putting the actual factor models through statistical testing it at least creates a way to assess the performance of the models.

All models with a mod-subscript include the two market factors. Hence technically $FF3_{mod}$ consists of four factors.

(1) $FF3_{mod}$; Fama and French three-factor model: (R_w+R_{so}) + HmL + SmB.
(2) $FF4_{mod}$; Fama and French three-factor model + HYmLY.
(3) CAR_{mod} ; Carhart four-factor model, equivalent to $FF3_{mod}$ + MOM.
(4)   Unconditional Principal Component (UPC).

The UPC was created from the unconditional covariance matrix.

5.2 Empirical Results

The time frame under investigation is 1996 through 2005. During this time frame a worldwide recession occurred. Although a relatively mild one, it is interesting to investigate possible deviations. The recession period is accounted for in 5.2.3.

5.2.1 Empirical Results Accounting Factors

A comparison between the full period and the recession period of the unconditional (not GARCH-estimated) standard deviation and excess return for the accounting-based factors is presented below.

10Y	Mean	Std Dev	REC	Mean	Std Dev
SmB	0.0045 (0.00**)	0.02426		0.0032 (0.26)	0.02015
HmL	0.0063 (0.00**)	0.03263		0.0181 (0.00**)	0.02914
HYmLY	-0.0023 (0.168)	0.03879		0.0145(0.04*)	0.05047

Table 6, mean excess return and std dev, 10 year time frame vs. recession period.
* Indicates significance at p=5% level. ** Indicates significance at p=1% level.

5.2.2 Empirical Results 1996-2005

In the tables below follow the results of the test on the factor models during the whole time frame under consideration.

Single factors – 1996 - 2005

	Eig	Magnitude	Direction
R_{so}	0.408	0.574	0.980
R_w	0.372	0.581	0.993
$(R_{so} + R_w)$	0.788	0.133	0.992
MOM	0.004†	0.998	0.607
SmB	0.092	0.894	0.943
HmL	0.048	0.976	0.336†
HYmLY	0.204	0.847	0.838
FEX	0.006	0.999†	0.136†
Benchmark	0.005	0.998	0.370

Table 7, Results of the single factor models. Values marked with † performs worse than the benchmark which is heteroscedastic general noise.

Multiple factor – 1996 - 2005

	Eig	Magnitude	Direction
$FF3_{mod}$	0.778	0.142	0.990
$FF4_{mod}$	0.804	0.129	0.990
$CAR4_{mod}$	0.780	0.141	0.990
UPC	0.958	0.077	0.980

Table 8, Results of the multifactor models.

5.2.3 Empirical Results During a Recession (Sep 2000-Sep 2001)

First the results of the factor models are presented below in a fashion analogous to that of 5.2.2. Secondly, results from tests which compare the total level of variance over time are covered.

Single factors – Recession (2000 Sep – 2001 Sep)

	Eig	Magnitude	Direction
R_{so}	0.442	0.572	0.923
R_w	0.278	0.645	0.974
$(R_{so} + R_w)$	0.699	0.219	0.968
MOM	0.002	0.999	0.505
SmB	0.047	0.935	0.955
HmL	0.102	0.939	0.391
HYmLY	0.435	0.675	0.845

Table 9, Results of the single factor models during the recession period.

Multiple factor – Recession (2000 Sep – 2001 Sep)

	Eig	Magnitude	Direction
$FF3_{mod}$	0.740	0.196	0.966
$FF4_{mod}$	0.825	0.154	0.964
$CAR4_{mod}$	0.740	0.196	0.966
UPC	0.958	0.098	0.913

Table 10, Results of the multifactor models during the recession period.

The above results will be analyzed thoroughly in the analysis chapter.

The second issue is whether the conditional covariance of the assets in general differs in amplitude during a recession. As reported in the theory section, the covariances tended to be higher in general during recessions[66]. Figure (4) below seems to support the notion that the variance of return increases during recessions[67]. To test this the sum of the industry portfolios variances were plotted against time. See APPENDIX E for the resulting graph. As is obvious, the cumulative variance during the recession time frame is considerably higher than the average for the whole 10 year period.
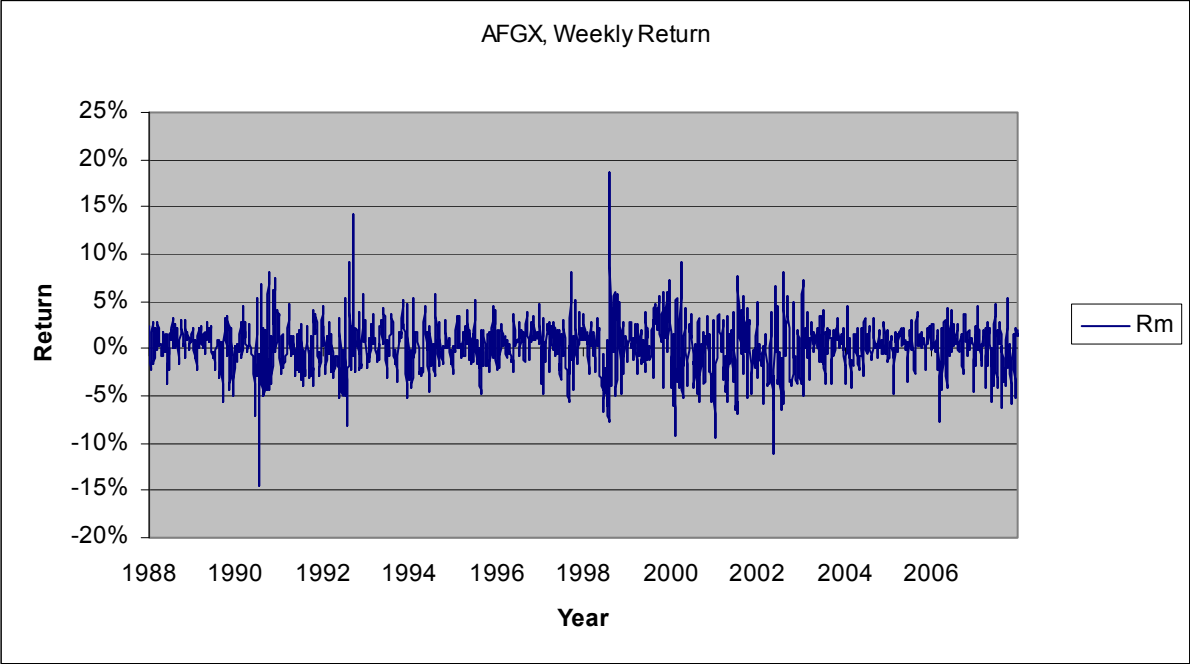
Figure (4), Weekly return of the Swedish general market index.

Previous research on both Swedish and international markets has shown significant difference for some factors ability to explain covariance risk depending on whether the market is in an expansion period or under a recession. To investigate this further the variance were sampled at each point in time for the accounting-based factors and plotted against time. See APPENDIX E.

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[66] See e.g. Moskowitz (2003).
[67] 1991 and 2001.

Chapter 6: Analysis

In this chapter a thorough analysis will be will conducted of the results obtained in the previous chapters. A summary of possible sources of errors and their implications is included in the latter part of the chapter.

6.1 Analysis of the GARCH Framework

The results of the ARCH tests give strong support for the use of a dynamic model of volatility, such as the GARCH (1,1)-model employed. The analysis of the industry factors reveals significant heteroscedasticity. Using a multivariate GARCH-model to create conditional covariance matrices is not a well tried-out method. That being said the results were disappointing for several reasons. Applying a model analogous to Moskowitz (2003) with respect to the representative assets and creating the "independent" factors from the data set yielded random factors able to capture such large part of the covariance matrix that made performance evaluation of the actual factor models impossible. This could to some degree be mitigated by using the approach employed in this thesis, i.e. dividing the covariance matrix into one data part and one factor part. Since all factors were created from replicating portfolios derived from individual stock return while the assets in question were indices a somewhat more balanced model was made possible. The industry portfolios used covers the Swedish equity market cross-sectional, and as such they provide a certain level of legitimate to the results. The implication of the amazing results from the scaled unconditional principal components is that the covariance matrix was relatively trivial to assess. The estimated covariance matrix does provide for a more realistic and advanced model of the general risk level on the equity market. This can be observed by studying the correlation matrix between all factors included in the GARCH economy and their average magnitude (positive or negative) on the correlation coefficients with the representative assets. While it is possible to infer approximately how well each factor will do in explaining the covariation of the assets it is far from being a straight linear relationship. Because a GARCH-estimation transforms the data in a nonlinear way this is a sign of health.

6.2 Analysis of Covariance Risk Models

Despite the shortcomings of the original model of the economy, this investigation is not without any merit. As was hypothesized the market factor does capture the majority of covariance risk regardless of what kind of metric is used. Research hypothesis H_1 is accepted.

The poor performance of the *SmB*-factor was surprising and goes contrary to previous research. Especially when comparing with the results from Moskowitz (2003) which uses a similar model of the economy. However even when looking at a broader set of investigations, *SmB*-factors in general possess strong explanatory power both with respect to average return and variance. The most likely explanation is that the results are a consequence of a statistical artefact. The fact that *SmB* is strongly negatively correlated with *HYmLY* and that their explanatory power deviates during the recession time frame supports this explanation. It is noteworthy that the *SmB*-factor is able to explain the Direction-metric to such a high degree. The implication of this is that the factor has a high latent potential in explaining the dispersion

of return, but that the factors variance in this investigation is too low to be able to accurately capture the magnitude and the overall structure of the covariance matrix.

The very poor performance by *FEX* is obviously due to low variance as well. *FEX* is the only factor which performs worse than the benchmark dummy factor. The *FEX* factor may very well have explanatory power if measured in another way. In the long run however an internationalized economy will probably yield a higher degree of international financial integration. A perfect integration of different currency zones would mean that any relative change between two currencies would reflect a corresponding difference in inflation. Hence, at least theoretically an export-intensive company which would suffer from a weaker foreign currency would be offset by local increases in the general price

The foreign influence on the Swedish equity market mediated through the world market factor seems to have increased though. During the recession period it appears to collapse however. This is perfectly logical since the recession in 2000-2002 did not occur simultaneously in all countries, at least not with the same magnitude. The effect of this being that the correlation between all type of Swedish assets increase relative those of foreign origin. R_{so} does actually outperform R_w during the whole decade under study. The difference in captured return between the two factors is very small though, and if excluding the recession period R_w would certainly capture a higher fraction of return variation than the orthogonalized Swedish factor. Previous research on the Swedish market has shown that the world market factor is unable to beat the orthogonalized factor. This may indicate that the increased globalization of the Swedish economy has made the equity markets more dependent on international factors.

HYmLY shows remarkable power and even more so during recessions. This is line with previous research conducted internationally[68]. The very large increase in the fraction explained by the *HYmLYs* factor makes perfect sense from an investor point of view. The most likely interpretation is that during recessions and periods characterized by bear markets risk-averse investors will seek to hedge against this by placing a proportionally higher share of their portfolios into stable mature firms, firms usually associated with a high payout-ratio. Something which further corroborates this hypothesis is that *HYmLY* appears to generate excess positive return during recession. While not statistically significant during the whole 10-year period *HYmLY* has a negative average return if measured under the whole period of analysis. An inspection of the factor's conditional variance reveals an increase in variance in excess to that of the other accounting replicating factors. Another interesting result is that the variance appears to be significantly higher in general for the assets during periods of negative return (e.g. both in 2001 and 2002).

What is unique about the dividend yield factor in the Swedish setting is its ability to capture second moments of return for the whole length of the study. Different factors having diverse ability to explain both the first and second moment of return does not automatically imply model misspecification or that some equity markets are less efficient than other, although this is of course a plausible possibility. An alternative theory is that national segmentation of the equity markets to some degree prevails. As noted above, the economy is probably moving towards international integration. The fact that the home market orthogonalized against a world index corrected for currency exchange effects still is more important in terms of capturing covariance risk strongly corroborates such an alternative hypothesis in the opinion

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[68] See Chan et al. (1998).

of the author. The multifactor models are in general very similar to the market factor, the exception being FF4$_{mod}$ during the recession which of course is due to the *HYmLY* factor.

It is interesting to compare the validity of multifactor pricing models across different markets and countries. What would the implications be if different factors are shown to be relevant for explaining return and risk in different countries? A world standardization of accounting principles is in action, i.e. the continuous implementation of the IFRS in many countries as well as the diminishing difference between the IFRS and US GAAP. In 2008 several aspects of IFRS and US GAAP are supposed to converge[69]. The logical outcome of this process should be less discrepancy between different firms within a legal jurisdiction as well as between different legal jurisdictions.

The fantastic performance by the unconditional principal components has no practical implications since it is an effect of using relatively few assets which are positively correlated. It also highlights the problems of creating factors from the data as benchmark.

Finally it is of interest to assess the importance of the different metrics. The Eig-metric is clearly the most important since it is constructed in such a way that it captures the overall structure of the covariance matrix. The least important is the Direction-metric which due to high overall correlation among the assets is general are easy to capture.

6.3   Sources of Error

One potential source of error is the lack of statistical evaluation of the GARCH-estimation process. Only stocks presently (as of 2008) listed were available from Datastream which could case survivor bias in the data.

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[69] "Memorandum of Understanding between the FASB and the IASB 27 February 2006"
http://www.iasb.org/About+Us/About+IASB/Memorandum+of+Understanding+with+the+FASB.htm [2008-05-23]

Chapter 7: Conclusions

This concluding chapter briefly summaries the thesis and reports its relevant conclusions. Finally, further research based on the findings of this thesis is being suggested.

7.1 Conclusions

The following conclusions can be made

- Research hypothesis H_1 is accepted. The market factor is the most important factor for capturing equity risk.
- The equity market in general exhibits heteroscedastic properties which supports the choice of estimation method.
- International integration of the Swedish equity market is only partial but the importance of the world market factor is slowly increasing.
- The *HYmLY* factor is the most important factor from a risk management perspective next to the market factor. This is especially true during recessions.
- The conditional variance increases during times of recession.

7.2 Future Research

Little research has been conducted on the Swedish market regarding the explanatory power regarding both the first and the second moment of return for a dividend yield factor. Further research is obviously required in order to corroborate the importance of this factor.

The usage of lagged dependencies, e.g. when creating macro factors such as those based on foreign exchange rates could yield valuable insights about the nature of these factors. Since they constantly underperform in studies but seem to make sense from an economical standpoint one can not rule out that they are simply measured in an incorrect fashion.

Finally, following the advice of Markowitz and building models around the semi-variance concept rather than variance would constitute a very interesting development within the field of risk management.

APPENDIX A – References

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Datastream, Thomson Financial

APPENDIX B – Derivation of MLE

Proof of Maximum Likelihood Estimators

$$f = \prod_{t=1}^{T} \frac{1}{\sqrt{2\pi h_{ii,t}}} \exp(-x_{it}^2/(2h_{ii,t}))$$

Since $\frac{d \ln(x)}{dx} = \frac{1}{x}$ and ln(x) only are defined for positive numbers, ln(x) is always increasing with x. Hence, the variable values which maximizes f will also maximize $\ln(f)$.

$$\ln(f) = \sum_{t=1}^{T} \ln\left(\frac{1}{\sqrt{2\pi h_{ii,t}}} \exp(-x_{it}^2/(2h_{ii,t}))\right) = \sum_{t=1}^{T}\left[\ln\left((2\pi h_{ii,t})^{-0.5}\right) - \frac{x_{it}^2}{2h_{ii,t}}\right] = \sum_{t=1}^{T}\left[\frac{\ln(2\pi)}{2} - \frac{\ln(h_{ii,t})}{2} - \frac{x_{it}^2}{2h_{ii,t}}\right] =$$

$$= -\frac{T}{2}\cdot\ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T}\left[\ln(h_{ii,t}) + \frac{x_{it}^2}{h_{ii,t}}\right]$$

$$g = \prod_{t=1}^{T}\frac{1}{2\pi\sqrt{\det(h_{ij,t})}}\exp(-X_{ij,t}'\cdot H_{ij,t}^{-1}\cdot X_{ij,t}/2)$$

$$\ln(g) = \sum_{t=1}^{T}\ln\left(\frac{1}{2\pi\sqrt{\det(H_{ij,t})}}\exp(-X_{ij,t}'\cdot H_{ij,t}^{-1}\cdot X_{ij,t}/2)\right) = \sum_{t=1}^{T}\left[\ln\left(\frac{1}{2\pi}\cdot(\det H_{ij,t})^{-0.5}\right) - (X_{ij,t}'\cdot H_{ij,t}^{-1}\cdot X_{ij,t}/2)\right] =$$

$$= -T\cdot\ln(2\pi) - \frac{1}{2}\cdot\sum_{t=1}^{T}\left[\ln\left((\det H_{ij,t})\right) - \frac{1}{2}(X_{ij,t}'\cdot H_{ij,t}^{-1}\cdot X_{ij,t})\right]$$

Derivation of Portfolio Variance

$$Var(\sum_{i=1}^{n}X_i) = \sum_{i=1}^{n}\sum_{j=1}^{n}Cov(X_i, X_j)$$

$$Var(aX) = a^2 Var(X)$$

$$Var(r_p) = Var(\sum_{i=1}^{n}(\gamma_i X_i)) = \sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_i\gamma_j Cov(X_i, X_j)$$

APPENDIX C – Recession Data
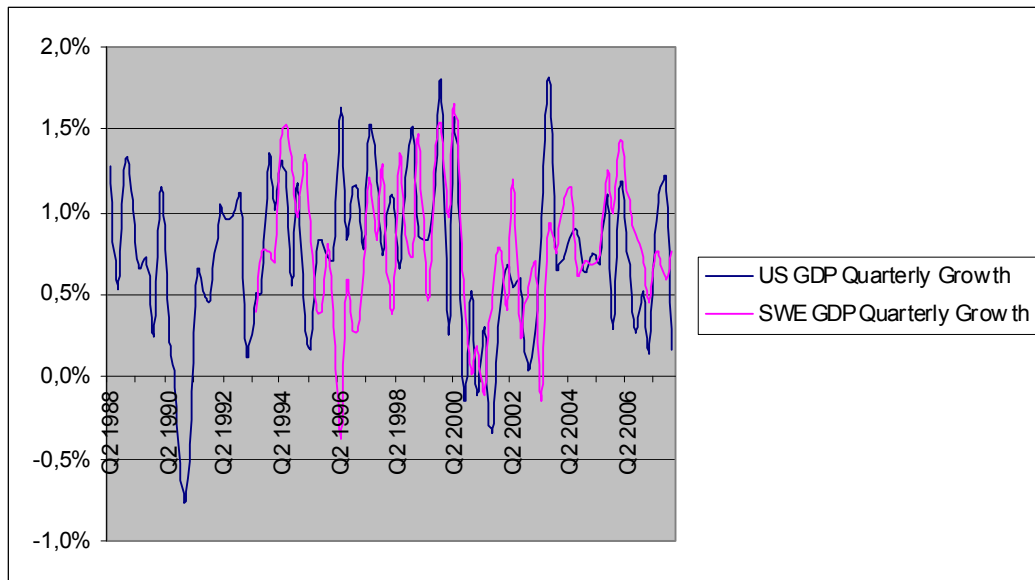
Figure (5), GDP quarterly growth rates.

Q1 1996	-0,38%	Q3 1998	0,74%
Q1 2003	-0,15%	Q3 2003	0,76%
Q1 2001	-0,12%	Q3 2001	0,79%
Q3 2000	0,03%	Q2 1997	0,83%
Q4 2000	0,19%	Q2 1998	0,86%
Q2 2002	0,25%	Q2 2003	0,93%
Q3 1996	0,27%	Q4 1999	0,98%
Q4 1997	0,38%	Q3 2005	1,00%
Q4 2001	0,42%	Q4 2003	1,08%
Q1 1999	0,46%	Q1 2004	1,14%
Q2 2001	0,49%	Q1 2002	1,21%
Q3 2002	0,52%	Q1 1997	1,21%
Q2 2000	0,53%	Q2 2005	1,26%
Q2 1996	0,58%	Q3 1997	1,27%
Q2 2004	0,62%	Q1 1998	1,35%
Q4 1996	0,64%	Q2 1999	1,41%
Q4 2004	0,68%	Q4 2005	1,44%
Q4 2002	0,68%	Q4 1998	1,48%
Q3 2004	0,70%	Q3 1999	1,54%
Q1 2005	0,74%	Q1 2000	1,66%

Table 11, List of the GDP growth 1996-2005, sorted by negative growth.

APPENDIX D – Software

The following software has been used to process and test the data:

- Microsoft Excel 2003 / VBA[70]
- MATLAB 7.2
  - FlexM – Software routine which implements the multivariate GARCH (1, 1)-method from Ledoit et al. (2003). Available for download, see Appendix A
- SPSS 11.5

Engle's test for presence of ARCH/GARCH: MATLAB routine *archtest*

More than 1000 lines of code were produced specifically for the thesis. Since these software routines are of little or no use for external usage and because of the enormous space they would occupy they are omitted from the text.

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[70] Visual Basic for Applications

APPENDIX E – Cumulative Variance
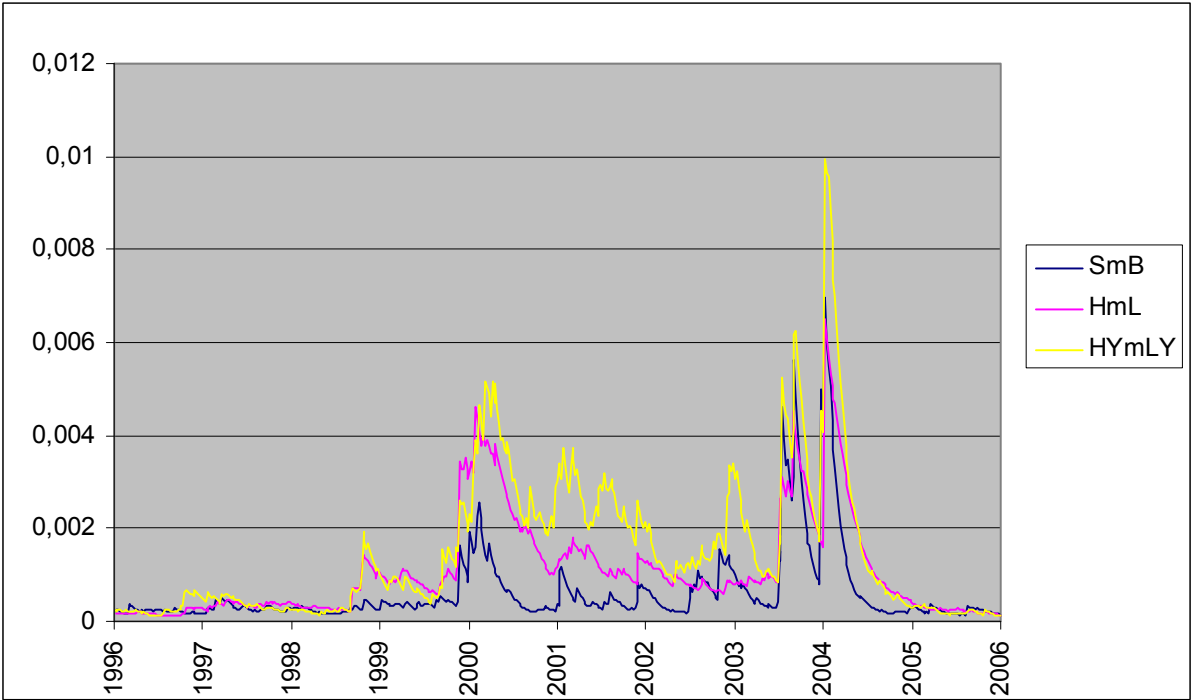
Figure (6) Variance for the accounting based replicated factors.

Figure (7) The cumulative variance from the nine representative assets.

APPENDIX F – Correlation Matrices

	Lev	DY	BM	Size	PE
Lev	1,00	0,19	0,21	-0,03	-0,22
DY	0,19	1,00	0,20	0,66	-0,23
BM	0,21	0,20	1,00	-0,09	-0,11
Size	-0,03	0,66	-0,09	1,00	-0,10
PE	-0,22	-0,23	-0,11	-0,10	1,00

Table 12, Accounting factors - correlation matrix.

	SmB	HmL	HYmLY
SmB	1,00	0,01	-0,40
HmL	0,01	1,00	0,14
HYmLY	-0,40	0,14	1,00

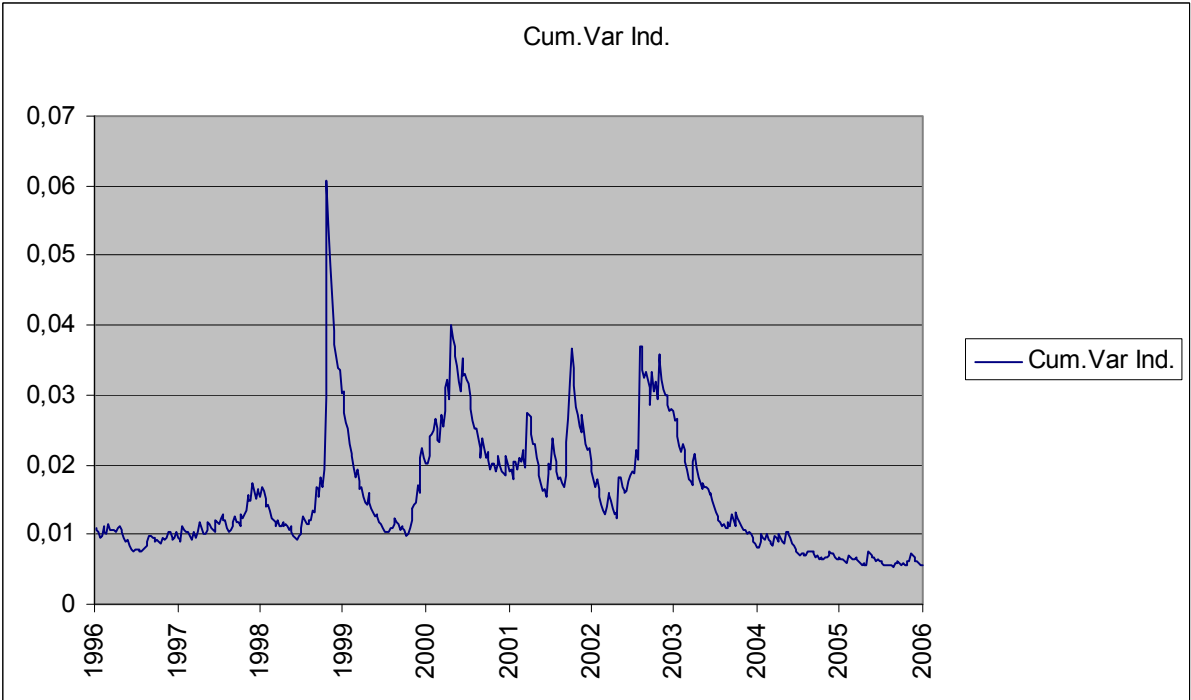**Table 13, Intersected accounting factors - correlation matrix.**

	IND1	IND2	IND3	IND4	IND5	IND6	IND7	IND8	IND9	MOM	Rw	Rso	FEX	SmB	HmL	HYmLY
IND1	1,00	0,74	0,43	0,27	0,56	0,43	0,38	0,36	0,29	0,06	0,49	0,44	*-0,02*	*-0,19*	0,00	*-0,14*
IND2	0,74	1,00	0,55	0,35	0,73	0,57	0,54	0,43	0,46	0,05	0,61	0,58	*-0,01*	*-0,25*	*-0,06*	*-0,25*
IND3	0,43	0,55	1,00	0,19	0,55	0,49	0,42	0,38	0,38	0,06	0,43	0,48	*-0,05*	*-0,19*	*-0,11*	*-0,26*
IND4	0,27	0,35	0,19	1,00	0,37	0,22	0,22	0,23	0,24	*0,00*	0,40	0,22	*-0,02*	*-0,09*	0,02	*-0,11*
IND5	0,56	0,73	0,55	0,37	1,00	0,63	0,61	0,49	0,48	0,04	0,62	0,63	*-0,01*	*-0,23*	*-0,08*	*-0,34*
IND6	0,43	0,57	0,49	0,22	0,63	1,00	0,68	0,57	0,47	0,03	0,54	0,59	*-0,03*	*-0,16*	*-0,26*	*-0,59*
IND7	0,38	0,54	0,42	0,22	0,61	0,68	1,00	0,52	0,40	0,03	0,57	0,68	*-0,02*	*-0,17*	*-0,14*	*-0,45*
IND8	0,36	0,43	0,38	0,23	0,49	0,57	0,52	1,00	0,37	0,00	0,40	0,48	0,01	*-0,15*	*-0,18*	*-0,38*
IND9	0,29	0,46	0,38	0,24	0,48	0,47	0,40	0,37	1,00	0,04	0,43	0,35	0,01	*-0,21*	*-0,16*	*-0,28*
MOM	0,06	0,05	0,06	*0,00*	0,04	0,03	0,03	0,00	0,04	1,00	0,06	0,03	0,09	*-0,05*	*-0,02*	*-0,03*
Rw	0,49	0,61	0,43	0,40	0,62	0,54	0,57	0,40	0,43	0,06	1,00	0,07	*-0,01*	*-0,15*	*-0,12*	*-0,31*
Rso	0,44	0,58	0,48	0,22	0,63	0,59	0,68	0,48	0,35	0,03	0,07	1,00	*-0,02*	*-0,19*	*-0,10*	*-0,35*
FEX	*-0,02*	*-0,01*	*-0,05*	*-0,02*	*-0,01*	*-0,03*	*-0,02*	0,01	0,01	0,09	*-0,01*	*-0,02*	1,00	*0,00*	*-0,05*	*0,00*
SmB	*-0,19*	*-0,25*	*-0,19*	*-0,09*	*-0,23*	*-0,16*	*-0,17*	*-0,15*	*-0,21*	*-0,05*	*-0,15*	*-0,19*	*0,00*	1,00	0,01	*-0,40*
HmL	0,00	*-0,06*	*-0,11*	0,02	*-0,08*	*-0,26*	*-0,14*	*-0,18*	*-0,16*	*-0,02*	*-0,12*	*-0,10*	*-0,05*	0,01	1,00	0,14
HYmLY	*-0,14*	*-0,25*	*-0,26*	*-0,11*	*-0,34*	*-0,59*	*-0,45*	*-0,38*	*-0,28*	*-0,03*	*-0,31*	*-0,35*	*0,00*	*-0,40*	0,14	1,00

Table 14, All factors included in the model of the economy – correlation matrix.