An Empirical Study of CAPM, the Fama-French three-factor and the Fama-French five-factor Model

A Study Performed on the Swedish Stock Market

Bachelor's Thesis in Financial Economics

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Abstract

This thesis aims to add further research about the *Fama-French five-factor model* and its ability to explain average returns on the Swedish Stock Market. Additionally, the study also investigates and compares the performance of *CAPM*, the *Fama-French three-factor model* and the *Fama-French five-factor model*. The study rejects all three models ability to explain average returns of the *Size-B/M*, *Size-OP*, and of the aggregated portfolios. In contrast, only the *Fama-French three-factor model* was rejected in terms of explaining the average returns of the *Size-Inv* portfolio, indicating that *CAPM* and the *Fama-French five-factor model* can be used as explanatory models for portfolios sorted on *size* and *investments*. Due to the ambiguous results, the study could not conclude whether one model is preferable the others which may be the explanation behind why *CAPM* is still widely used despite years of criticism. Even though the *Fama-French three-* and *five-factor models* were invented relatively near in time, the study did not indicate that these models are superior to *CAPM*.

Keywords: CAPM ◆ Fama-French ◆ Asset pricing ◆ Swedish Stock Market
JEL Classification: G12 ◆ G31

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1 Introduction

In the world of finance and business, a common choice is whether to invest or not to invest in a firm or an internal business project. A question that most investors ask themselves when faced with this choice is what return, given the risk, they should expect. Pricing assets is fundamental and an essential part of sophisticated investors', small enterprises', banks', fortune 500 companies' and private persons' investment decision process. Fund managers price assets as a determinant of risk and performance while companies may price assets to evaluate internal business projects or a potential merger, and banks may use it to price debt correctly. Accurately predicting the expected return of an investment is a difficult task, thus several models have been developed to help us understand how asset prices are determined.

In the 1960's, Treynor (1961, 1962), Sharpe (1964) , Lintner (1965) and Mossin (1966) developed the *Capital Asset Pricing Model (CAPM)* in which a security is priced in proportion to its "systematic risk" or market beta. Since the development of this revolutionary framework, multiple empirical tests have been made to validate *CAPM*.
Lintner (1965) tested returns on 301 common stocks from 1954 to 1963 and found that *CAPM* could not be verified due to an attenuation bias. Fama and MacBeth (1973) continued to test *CAPM* and found that it is both consistent and not consistent. In opposite to the criticizers, Richard Roll published Roll's critique (1977) in which he argues that *CAPM* would hold if we were able to observe a comprehensive market portfolio, meaning that it includes assets such as real estates, human capital, and so on. These papers implied that a significant relationship exists between asset betas and the expected excess returns, which is consistent with *CAPM*, but it also implied that more variables seem to affect the expected excess return.

Later on, Fama and French (1993) published a paper in which they argued that the *size* and *book-to-market ratio* of a firm better explain the variation in average returns. They had observed that two classes of stocks seemed to outperform the market, small capitalization firms and high book-to-market firms. In light of this, the *Fama-French three-factor model* was developed. The model is an extended version of *CAPM* in the form of two more risk factors, a *size* factor and a *book-to-market* factor.

The *book-to-market* factor in the *Fama-French three-factor model* captured the effect of investments and profitability indirectly, but available evidence suggested that the model overlooked variation in returns related to profitability and investments. Due to this evidence, Fama and French (2015) developed the *Fama-French five-factor model*, in which two additional risk factors were added, *operating profitability* and *investments*. Fama and French's theoretical starting point for the *Fama-French five-factor model* is the dividend discount model, which states that the value of a stock today depends on future dividends, in combination with theories from Miller and Modigliani's paper (1961) in which they discuss how the dividend policy affects the value of a firm. The theoretical proof in combination with the empirical evidence suggesting that the *Fama-French three-factor model* lefts profitability and investment unexplained, made them add these two additional risk factors.

Even though multiple models have been developed since the 1960s, *CAPM* is still the standard pricing model for most professionals, implying that *CAPM* is a superior pricing model. In a study by Graham and Campbell (2002), 392 CFOs was surveyed about how they make capital budgeting and capital structure decisions. They found that 73.5% of the respondents always or almost always use *CAPM* to estimate the cost of equity. confirming that *CAPM* is still widely used and that it may be a superior asset pricing model. Another potential explanation for *CAPM*'s popularity may be its simplicity compared to multi-factor pricing models such as the *Fama-French five-factor model*. One further reasonable explanation, is that *CAPM* is used mainly because of its long history as a recognized asset pricing model, and not necessarily for its accuracy.

Results from previous empirical studies comparing *CAPM*, the *Fama-French three-factor model* and the *Fama-French five-factor model* varies a lot, and it seems hard to conclude that one model is preferable to the others. Some criticize *CAPM* for its simplicity and argues that one explanatory variable could not possibly explain all the movements on the market. Further, many criticize the underlying assumptions of the model. Some argue that multi-factor models are better due to the inclusion of additional causes of risk such as corporate fundamentals of a firm and/or macroeconomic related risks other than the market risk. These additional variables are also the main reason of the criticism. Some argue that the additional variables captures anomalies that are weak or circumstantial, meaning that the variables varies in contrast to the market risk which is always relevant. For example, the *book-to-market* factor has been considered as not relevant in some recent studies.

One thing is certain, to be able to allocate capital as efficiently as possible, it is crucial to understand how assets are priced and to price them correctly. Otherwise, investors and companies may invest in value-destroying or less value-creating projects and firms. Due to the importance of asset pricing, this thesis aims to add further research and understanding of the risk factors influencing average returns. In the next sections, the study will be narrowed down into more specific questions.

1.1 Purpose

The purpose of this thesis is to test the performance of *CAPM*, the *Fama-French three-factor model* and the *Fama-French five-factor model* in terms of explaining the average returns of Swedish stocks. Both *CAPM* and the *Fama-French three-factor model* have been widely tested compared to the relatively new *Fama-French five-factor model*. The focus of the thesis is to add further empirical research of the *Fama-French five-factor model*'s performance in the Swedish stock market and to investigate whether one of the three models is preferred to the others.

1.2 Research Questions

As mentioned in the purpose, this thesis aims to add further empirical research on asset pricing on the Swedish Stock Market. The thesis will do so by investigating the following two research questions.

(I) ***Can CAPM, the Fama-French three-factor model and the Fama-French five-factor model explain average returns on the Swedish stock market?***

(II) ***Are any of the models superior in explaining average returns on the Swedish stock market?***

The study will compare and investigate how accurate the three pricing models are in explaining average returns by testing if the alpha (α) is significantly indistinguishable from zero. Alpha is a term used in investing and represents a strategy's ability to beat the market and is also referred to as excess return or abnormal returns. In the thesis, alpha refers to the intercept of the regressions conducted and will be used as an indicator of each model's performance and an important factor when comparing the models. Further, alpha can be interpreted as the constant unexplained part of the average returns.

The factors in table 1 are the five explanatory variables in the study and will be further explained in the following section. In table 2, an overview of each model's components is provided which basically means adding additional explanatory variables to *CAPM*.

Factor	**Abbrev.**	**Captures**
Market	***MKT***	Systematic risk which cannot be eliminated by diversification.
Size	***SMB***	The effect of market capitalisation.
Book-to-market	***HML***	The effect of a company being fundamentally cheap or not.
Profitability	***RMW***	The effect of relative profitability of the firm.
Investments	***CMA***	The effect of a high or low CAPEX.

Table 1: Risk factors considered in the models

Model	**Intercept**	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**
CAPM	α	***MKT***	-	-	-	-
Fama-French Three-factor Model	α	***MKT***	***SMB***	***HML***	-	-
Fama-French Five-factor Model	α	***MKT***	***SMB***	***HML***	***RMW***	***CMA***

Table 2: Structure of the three models

1.3 Limitations of the study

a) Due to lack of financial figures for earlier periods, the time-period in the study is set from **2007** to **2019**.

b) The firms in the analysis need to have available data for all variables for at least one of the years in the sample period.

1.4 Thesis Structure

The remaining part of the thesis is structured in the following order: The next section explains the fundamental asset pricing theories and how they have been developed. In the third section, *Previous Research*, Fama and French's most groundbreaking asset pricing papers are discussed. The fourth and firth section,*Data* and *Method*, presents how the data have been retrieved and the regression process. In the *Empirical Results* section, the regression output is presented. Finally, the thesis ends with a discussion of the results and a final conclusion.

2 Theoretical Framework and Previous Research

2.1 The Efficient Market Hypothesis

The Efficient Market Hypothesis emerged as a big financial theory in the mid-60s. In 1965, Eugene Fama argued for the random walk hypothesis and Paul Samuelson published a paper that proved if markets are efficient, prices will exhibit random-walk behavior. Five years later, Eugene Fama (1970) published *Efficient Capital Markets: A review of theory and empirical work* in *the Journal of Finance*. In this paper, Fama performed several empirical tests to see whether the efficient markets model stands up well or not. He concluded, with a few exceptions, that there is empirical evidence supporting the theory of efficient markets. The main idea is that an "efficient" market always fully reflects available information, meaning that prices quickly and correctly react to new information. It also implies that higher returns are only achievable by taking on more risk, i.e., there is no free lunch. Further, the theory is divided into three different subgroups. *Weak*, *Semi-strong*, and *Strong* form.

- *Weak* form implies that investors cannot outperform the market by predicting prices using historical data, meaning that current prices reflect all information contained in past prices. Some trading strategies are challenging the weak form by exploiting effects of serial correlation or periodic patterns, e.g., the January effect.

- *Semi-strong* efficiency suggests that current market prices reflect the information contained in publicly available information and past market prices. Thereby, implying that fundamental analysis (use of financial statements, industry information, and so on.) cannot help investors outperform the market. Phenomena such as the Neglected Firm Effect, Post-Earnings-Announcement drift, First-day underpricing IPOs, Long-run underperformance of IPOs and Return predictability all challenge the *Semi-strong* form of efficiency.

- *Strong* form, the final level of efficiency, indicate that market prices fully reflect information in past market prices, publicly available information, and private information. If true, this implies that investors cannot outperform the market by trading on information that not been publicly disclosed yet (insider information). The Strong form has been challenged by evidence supporting that prices actually move before public announcements which suggest that insider trading exist and that it can yield extra returns. If the *Strong* form holds, it indicates that future returns cannot be predicted by any information, implying that market prices evolve according to a random walk.

2.2 Modern Portfolio Theory (MPT)

Trying to understand the underlying factors of how stock prices are determined have been of significant interest since the beginning of stock trading. The basis for a theory that predicting stock price behavior took place in the mid-1900s. Till then, investors had used simple principles based on experience and by learning through from other investors. Investors knew that they need to diversify to reduce risk in their portfolios but, a formal framework of how to do this had not yet been developed. Modern portfolio theory or mean-variance analysis is a model that explains how rational investors can use diversification to optimize their returns at a given level of risk. One of the pioneers in modern portfolio theory is Harry M. Markowitz (1952), whom released a classic paper *Portfolio Selection* in *the Journal of Finance*. In this paper, Markowitz explains how investors can reduce the risk in their portfolio and keep returns constant, i.e., maximize their return at a given level of risk. The mean-variance portfolio theory (MPT) had been created, mean because it is based on the expected return (mean) and variance since the proxy of risk is based on the standard deviation (square root of the variance) of the stocks in the portfolio. Further, the model uses the statistical concept covariance to be able to catch the effect of how n number of stocks intercorrelate:

$$\text{Expected Return} = \sum X_i \mu_i \tag{1}$$

$$\text{Portfolio Variance} = \sum \sum X_i X_j \sigma_{ij} \tag{2}$$

Before this mathematical/statistical framework, investors had already used diversification as a tool to reduce the risk in portfolios. One can argue that Harry M. Markowitz formalized this behavior and developed a mathematical framework that explained how creating a diversified portfolio can help investor maximize returns at a given level of risk.

The critical insight is that stocks should not be evaluated based on itself; instead it should be evaluated based on how it contributes to the risk and return of a portfolio. In his paper, Markowitz assumes that investors are risk-averse, meaning that they prefer a less risky portfolio to a riskier portfolio for a given level of return, implying that an investor will take on more risk only if expected return increases. The framework also implies that investors take on the right kind of diversification, meaning that investors should avoid investing in stocks with high covariances among themselves. Markowitz suggests that this can be accomplished by holding assets in different industries. Harry M. Markowitz's contribution to portfolio theory is a fundamental part of today's education within finance. Markowitz's concepts and theories are the foundation of many theories and models being used in the finance industry still today.

The theory can be further explained by the *efficient frontier*, see figure 1a, which is the set of portfolios that offers the highest expected return for a defined level of risk or the lowest risk for a given level of expected return. The *efficient frontier* is a curved line because there is a diminishing marginal return on taking on more risk; the concept is illustrated in figure 1a. As a rational investor, one would always be on the curved line since being on that line means maximizing returns at the preferable risk. Not choosing a portfolio on the efficient frontier would be sub-optimal because one can choose a portfolio with the same expected return but with a lower risk. Later on, a riskless asset was included which implied that investors could create a portfolio of a *riskless asset* and *n risky assets*, meaning no short sell constraint. The combination of *risk-free* and *risky assets* results in a new mean-variance efficient portfolio which will be a straight line starting from the intercept in the figure below (at the return of the risk-free rate). The line will be tangent to the *efficient frontier* line, and the *tangency portfolio* is the portfolio on the line with the highest Sharpe (1964) ratio.
The optimal portfolio obtained when a riskless asset is added must be above, or at least coincident with the *efficient frontier* obtained for the *n risky assets* by themselves. The *tangency portfolio* is the case where the two coincide. The vertical intercept represents a portfolio of 100% risk-free assets, the tangency portfolio represents holdings of 0% risk-free assets and 100% of the portfolio at the tangency point, and portfolios above the tangency point represents leverage portfolios (i.e. negative holdings of the risk-free

asset).

Due to the requirement of solving a variance-covariance matrix for all included assets Markowitz proposed a *single index model* as a possible solution to simplify the use of the mean-variance portfolio theory. As of today, solving these equations would not be a problem but in the 1950s this was very time consuming. The idea of a *single index model* was further researched during the 1960s and finally resulted in the Capital Asset Pricing Model, which is the next theory to be described.

2.3 Capital Asset Pricing Model

The Capital Asset Pricing Model takes the Markowitz framework one step further by explaining the equilibrium asset prices under the key assumption that all market participants behave according to the Markowitz model. CAPM is primarily based on the work of Treynor (1961, 1962), Sharpe (1964), Lintner (1965), and Black (1972). In the Markowitz framework, we consider a single investor who faces a given investment opportunity set (universe of assets with some risk/return characteristics). Further, the investor is a price-taker which means that he or she can only buy assets available in the market, without affecting their prices. Based on this theoretical world, the investor selects an optimal portfolio, in line with his or her investment objectives. But as we all know, prices are not exogenous, instead they are determined by the equilibrium of all market participants, i.e. at the point where the participants are ready to exchange assets. To obtain the CAPM equilibrium, there are several underlying assumptions, which are summarized in Table 3.

Table 3: CAPM Assumptions

I.	No transaction costs to buy or sell assets
II.	Assets are infinitely divisible No size constraints
III.	No taxes on capital gains or dividends
IV.	Investors are small and influence prices only at an aggregated level
V.	All investors care only about expected returns and volatility (Markowitz framework)
VI.	Unlimited short sales of assets are allowed
VII.	Unlimited lending/borrowing at the riskless rate
VIII.	All investors care about mean and variance over the same period
IX.	All investors have homogenous beliefs
X.	All assets are tradeable, including human capital

As mentioned earlier, investors hold a proportion of risky asset given by the *tangency portfolio* (maximizing the *Sharpe ratio*). Further, they adjust their exposure by borrowing/lending the riskless asset. Depending on the ratio of riskless and risky assets, the investors move along the *Capital Allocation Line (CAL)* and selects the most suitable combination of expected return and risk. Assumption V states that individuals will hold risky assets in the same proportions as the *tangency portfolio*. If the market is composed only of these individuals, it implies that the *tangency portfolio* will equal the *market portfolio*.

Formal determination of the market equilibrium (*market portfolio*)

I. Investor k has wealth W_k and invests $W_{f,\,k}$ in the riskless asset and $(W_{\mathrm{k}} - W_{f,\,k})$ in the *tangency portfolio*.

II. The market equilibrium enforces that aggregate demand should equal supply.

(a)

$$\sum_{k=0}^{k} w_{f,k} = 0 \tag{3}$$

(b)

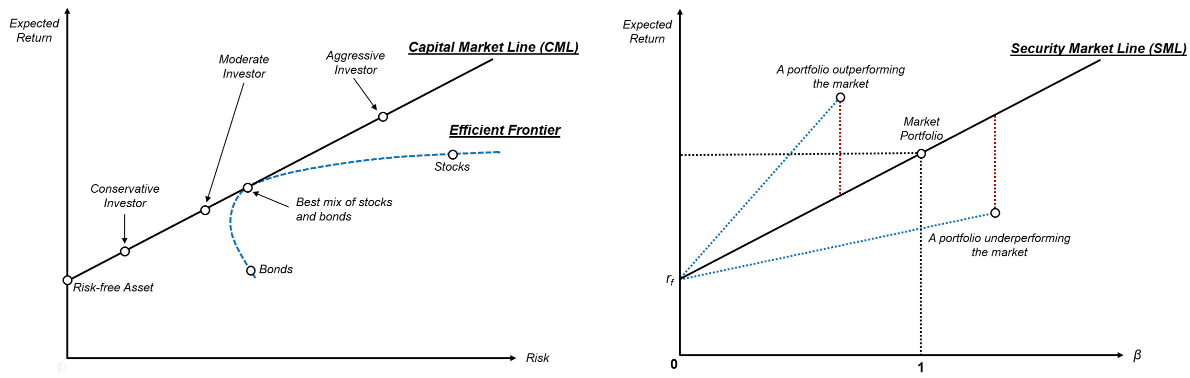
$$\sum_{k=1}^{K} (W_k - W_{f,k}) (\mathbf{w}_T)_i = MCAP_i \overset{yields}{\longrightarrow} = MCAP_M \mathbf{w}_M \tag{4}$$

(c)

$$\begin{gathered} \left(\sum_{k=1}^{K} W_k\right) w_T - \left(\sum_{k=1}^{K} W_{f,k}\right) w_T = MCAP_M \mathrm{w}_M \\ MCAP_M \mathrm{w}_T = MCAP_M \mathrm{w}_M \\ \mathrm{w}T = \mathrm{w}_M \end{gathered} \tag{5}$$

This implies that the market portfolio is the *tangency portfolio* of all risky assets in the market. As illustrated by 1a, the *Capital Allocation Line* for the *market portfolio* is called the *Capital Market Line*.

The final concept regarding *CAPM* is the *Security Market Line (SML)*. The expected excess return of an asset is proportional to the market expected excess return. The coefficient of proportionality, β_i, depends on the relative volatility of the asset with regard to the market volatility and the correlation between asset i and market returns where only the risk correlated with the market is rewarded. The *Security Market Line* is a graphical representation, see figure 1b, of the relation between the β of an asset and its expected return.



(a) *Capital Market Line* (b) *Security Market Line*

Interpretation of the graph is that the asset i contributes to the portfolio risk proportionally to its covariance with the portfolio itself. Equation 6 represents the *CAPM* formula:

$$CAPM : R_i = R_f + \beta_i \left(\mathrm{R}_M - \mathrm{R}_f\right) \tag{6}$$

The risk of a security can be divided into *systematic risk* and *idiosyncratic risk*. *Systematic risk* means that the risk of the security is correlated with the market risk, meaning that it contributes to the total portfolio risk and therefore should be rewarded in terms of expected excess return. *Idiosyncratic risk* is not correlated with the market, meaning that it does not contribute to the total portfolio risk and thereby should not be rewarded. Further, the *Security Market Line* can be used to demonstrate if an asset is overpriced or under-priced relative to expected return calculated using *CAPM*. In the *CAPM* world, all assets are correctly priced, meaning they are positioned on the *Security Market Line*. An asset above the *Security Market Line* means that the expected return of the asset is above the fair value according to *CAPM*, implying that the price of the asset is too low, i.e., underpriced. In contrast, if the asset is below the *Security Market Line*, the expected return is lower than predicted by *CAPM*, meaning that the price of the asset is too high, i.e., overpriced.

Famous researchers such as Lintner (1965), Black (1972), and Fama and MacBeth (1973) have made several empirical tests of the model and it has been widely criticized for a long time. Eugene F. Fama, rewarded with the Nobel Prize due to his empirical analysis of asset prices, and his research partner Ken French declared in their paper *The Capital Asset Pricing Model: Theory and Evidence* (2004) that *CAPM* should not be used in practical applications due to the lack of empirical data supporting the model.

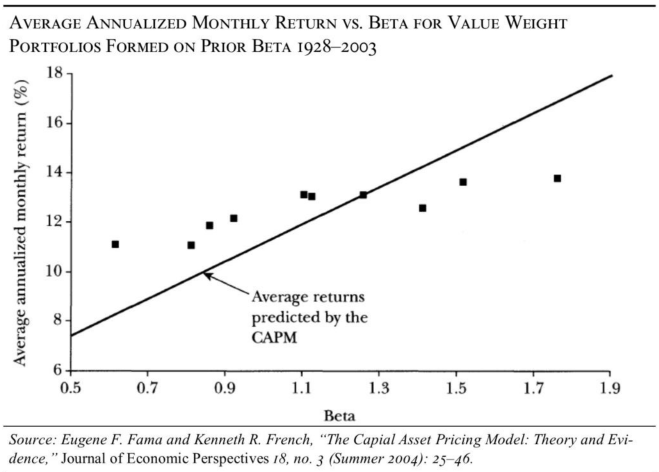


Figure 2: Graph from Fama's and French's faomous paper *The Capital Asset Pricing Model: Theory and Evidence*

As figure 2 illustrates, Fama and French concluded that market risk is not the only factor rewarded in the market. The bias implies that there are omitted variables that could further explain expected returns. This will be further explained in the next section.

2.4 Fama-French Three-factor Model

In their empirical testing of CAPM, Fama and French (1993) observed that small firms and high book-to-market firms seemed to outperform the market consistently. Therefore, two additional variables were added, a *size factor (**SMB**)* and a *the book-to-market factor (**HML**)* which resulted in the *Fama-French Three-factor Model*:

$$R_{i,t} - R_f = \beta_{i,MKT} MKT_t + \beta_{i,SMB} SMB_t + \beta_{i,HML} HML_t + \varepsilon_{i,t} \tag{7}$$

The *Size factor (**SMB**)* is the difference between the return of a portfolio of small capitalisation stocks and a portfolio of large capitalisation stocks. On average, small firms have had a historical positive β_{SMB}, because of the higher risk premium versus large capitalisation firms, which on average have negative exposure to ***SMB***.

The *book-to-market factor (**HML**)* is the difference between the return of a portfolio of stocks with a high book-to-market ratio, i.e., *value stocks*, and a portfolio of low book-to-market ratio, i.e., *growth stocks*. On average, *value stocks* have positive exposure to this factor, thus a higher risk premium than *growth stocks*, which on average have negative exposure to ***HML***.

2.5 Fama-French Five-Factor Model

Novy-Marx (2013), Titman, Wei, and Xie (2004) and additional researchers found evidence regarding the Fama-French three-factor model being incomplete because it is missing much of the variation in average returns related to *investments* and *profitability*. Novy-Marx argued that profitable firms generate significantly higher average returns than unprofitable firms, despite having, on average, lower book-to-markets and higher market capitalization. Further, Titman, Wie, and Xie presented evidence suggesting that firms that substantially increases capital investments afterwards achieve negative benchmark-adjusted returns. This gave grounds for the Fama-French five-factor model (2015), which includes two additional variables that capture the effect of *investments (**CMA**)* and *profitability (**RMW**)*.

$$\mathrm{R}_{i,t} - R_f = \alpha_i + \beta_{i,MKT} MKT_t + \beta_{i,HML} HML_t + \beta_{i,SMB} SMB_t + \beta_{i,RMW} RMW_t + \beta_{i,CMA} CMA_t + \varepsilon_{i,t} \tag{8}$$

In the equation, $\boldsymbol{RMW_t}$ is the difference between the returns on diversified portfolios of stocks with robust and weak *profitability*. $\boldsymbol{CMA_t}$ is the difference between the returns on diversified portfolios of the stocks of low and high investment firms, also known as conservative firms and aggressive firms. If the five factors capture all variation in average returns the intercept a_i is zero.

3 Data

3.1 The sample

The data sample used in the thesis was obtained from Bloomberg and Riksbanken, and consist of seven different financial figures. The following five figures were downloaded for each stock: *Total Return Index*, *Market Capitalization*, *Book Value of Equity*, *Total Assets* and *Operating Income* and as a proxy for the *Market Return* the *OMX Stockholm Benchmark Index* was downloaded as well. The stock universe was obtained by withdrawing all companies that have been listed on the Stockholm Stock Exchange since 1996 until today by using the *Equity Screening Function* in Bloomberg. Data was downloaded from the time period **1997 − 2019**. The raw data sample consisted of 915 Bloomberg tickers. One variable, *STIBOR 1m* was downloaded from Riksbanken's statistical database. The figures from Bloomberg are summarized in Table 4. The calendar year data is from December 31st and the monthly stock prices from the last trading day each month.

Model Factor	**Bloomberg Figure**	**Bloomberg Field**
Return	*Total Return Index*	CUST_TRR_RETURN_HOLDING_PER
Size	*Current Market Cap*	CUR_MKT_CAP
Book Value	*Total Equity*	TOTAL_EQUITY
Investments	*Total Assets*	BS_TOTAL_ASSET
Profitablity	*EBIT*	EBIT

Table 4: Bloomberg Input

3.2 Cleaning the data

The initial data set contained multiple tickers with data errors or that did not contain any of the relevant financial figures for the whole period. In the cleaning process the following tickers or data were removed:

(I) *Tickers that do not contain any data for the entire period.*

(II) *Tickers categorized as Indexes, ETFs or Preferred stocks.*

(III) *Data points that are classified as outliers.*

(IV) *Tickers that do not contain the necessary financial figures for at least one test year.*

After the cleaning process, the data points in Table 5 was obtained for the annual accounting figures necessary to calculate the financial ratio that are used to create the factor portfolios and the regression portfolios. As can be seen, the number of observations improves by time which must be considered when deciding the time frame. If comparing the *indata from Bloomberg* with the *Financial ratios*, it can be seen that the *Financial ratios* contain less data points than the *indata from Bloomberg*. It makes sense since the *Financial ratios* are calculated by combining the figures from Bloomberg or by calculating the difference between periods which requires a match of the indata figures.

	Indata from Bloomberg				***Financial Ratios***		
Year	**Market Cap**	**Total Equity**	**Total Assets**	**EBIT**	**Book-to-market**	**Profitability**	**Investments**
1998	241	170	64	169	110	167	2
1999	289	195	99	192	138	190	53
2000	382	213	123	208	196	205	56
2001	382	205	142	200	200	197	87
2002	371	223	167	212	218	205	111
2003	352	219	178	208	209	206	138
2004	352	287	251	278	259	275	163
2005	386	306	288	304	279	299	169
2006	433	332	325	329	305	323	246
2007	496	365	367	362	340	356	276
2008	521	414	390	418	388	392	310
2009	506	428	387	427	400	413	349
2010	506	422	390	417	398	403	363
2011	500	398	375	397	377	382	361
2012	467	379	359	377	359	365	353
2013	441	381	359	378	363	368	341
2014	441	387	371	383	373	376	339
2015	445	403	382	397	386	388	344
2016	446	404	384	396	393	389	355
2017	452	415	399	409	404	402	368
2018	446	397	393	392	393	385	373

Table 5: Summary of Financial Figures for Factor Construction

3.3 Constructing the Fama French Factors

The Fama-French Factors can be constructed using different breakpoints. At Kenneth French's official website, the ***SMB***, ***HML***, ***RMW*** and ***CMA*** factors are constructed using either **2 x 3**, **5 x 5** or **10 x 10** portfolios. In the thesis, the portfolios are constructed using the **2 x 3** method, see figures 3a, 3b, and 3c for a graphic explanation. Fama and French (2015) investigated if one method is more preferable and concluded that **2 x 3** factor portfolios is the best approach which support the use of **2 x 3** factor portfolios in our analysis.

3.3.1 Variables

Before constructing the Fama-French factors, all variables must be defined:

- ***Size***
  As a measure of *size* the *Market Capitalization* for each stock has been used. In similar studies performed on other markets, Price (P) multiplied by the number of Outstanding Shares have been used. Since it gives the same result and removes one calculation step, *Market Capitalization* is used in this study. As can be seen in Table 4, the *Market Capitalization* was obtained from Bloomberg.

- ***Book-to-market (B/M)***
  Book Equity was downloaded from Bloomberg using the TOTAL_EQUITY function. The *Book-to-market* ratio was calculated by dividing *Book Equity* by *Market Capitalization* for each individual stock.

- ***Operating Profitability (OP)***
  Operating Profitability was calculated by dividing *Operating Income* by *Book Equity*. *EBIT* was used as a proxy for *Operating Income* since it overlooks the capital structure and tax rates of the firms which make the firms more comparable. One could argue for the use of *EBITDA* but due to lack of available data points for *EBITDA*, *EBIT* was the better option.

- ***Investments (Inv)***
  The final variable, *Investments*, is the change in *Total Assets* between (t – 1) and (t - 2) divided by *Total Assets* at time (t – 2).

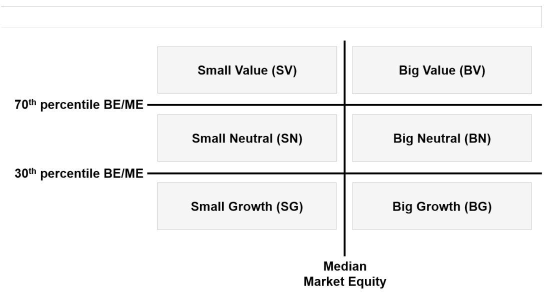
3.3.2 Factor Construction

Next step, after defining the variables, is to construct the factors ***SMB***, ***HML***, ***RMW*** and ***CMA*** from which the returns can be calculated. The portfolios were sorted at the end of [December] each year. Since the *INV* variable is calculated using financial data from *t-2* the first actual portfolio construction year is December 1998. The actual time period is consequently December 1998 to December 2018 which corresponds to 240 monthly return data points.

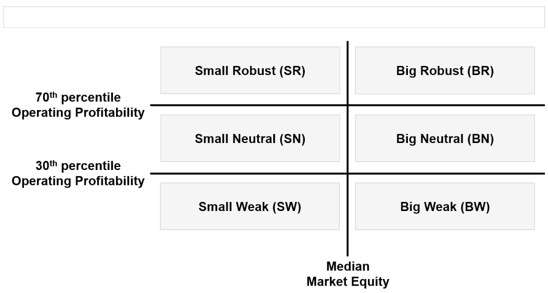
The first step in the process was to define the yearly breakpoints for each variable. As can be seen in 3a, 3b, and 3c, the median market cap was used as the yearly breakpoint for size. For the other variables, the 30$^{\text{th}}$ and 70$^{\text{th}}$ percentile was used as yearly breakpoints. After defining the breakpoints, the stocks in the sample were divided into the following portfolios by using the factor calculations presented in Table 6:

- **6 Size-B/M Portfolios (3a)**
- **6 Size-OP Portfolios (3b)**
- **6 Size-Inv Portfolios (3c)**

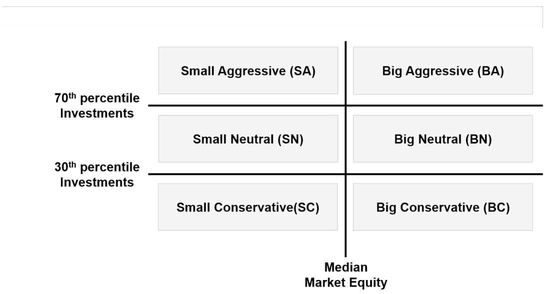
Figure 3: **2 x 3** Construction of Fama-French Factors



(a) ***SML & HML***



(b) ***RMW***



(c) ***CMA***

Factor	Yearly Breakpoints	Factor Calculation
Size	*Median*	$\text{SMB}_{B/M} = (SV + SN + SG)/3 - (BV + BN + BG)/3$
		$\text{SMB}_{OP} = (SR + SN + SW)/3 - (BR + BN + BW)/3$
		$\text{SMB}_{Inv} = (SC + SN + SA)/3 - (BC + BN + BA)/3$
		$\text{SMB} = \left(SMB_{B/M} + SMB_{OP} + SMB_{Inv}\right)/3$
B/M	*30*$^{\text{th}}$ and *70*$^{\text{th}}$ percentile	$\text{HML} = (SV + BV)/2 - (SG + BG)/2$
OP	*30*$^{\text{th}}$ and *70*$^{\text{th}}$ percentile	$\text{RMW} = (SR + BR)/2 - (SW + BW)/2$
Inv	*30*$^{\text{th}}$ and *70*$^{\text{th}}$ percentile	$\text{CMA} = (SC + BC)/2 - (SA + BA)/2$

Table 6: Factor Calculations

Further, each portfolio was value-weighted to be able to calculate the monthly portfolio returns. Finally, by using the 18 portfolio returns, the monthly return of each Fama-French factor was determined. A correlation test was conducted to see whether the data sample represent a valid proxy for the true data set. The test was conducted between the *OMX Stockholm Benchmark Index* and a value-weighted market portfolio from the data sample. The correlation test resulted in a correlation of **0.9203** which could be considered as sufficient. Further, Table 7 presents some descriptive statistics for each factor. The *Market premium* is equivalent for all models. The ***SMB***-factor is negative, on average, for both the three-factor and five-factor model, which implies a negative small cap premium. It is a fairly big difference between the three-factor model's and five-factor model's *SMB*-factor which make sense since adding two additional control variables may capture some of the effects generated by ***SMB***. The ***HML****-factor* and ***RMW***-factor is positive implying a positive *value premium* and a positive *profitability premium*

3.4 Constructing the Regression Portfolios

The regressions were run on 3 x 16 regression portfolios constructed similar to the Fama-French factor portfolios. Instead of 2 x 3 portfolios, they were constructed using the lower quartile, the median, and the upper quartile of each factor, see figure 4. The portfolios are created by combining *size* with *B/M*, *OP* and *Inv* separately. This method generates 16 *Size-BE/ME* portfolios, 16 *Size-OP* portfolios, and 16 *Size-Inv* portfolios, thereby generating 48 regression portfolios in total.

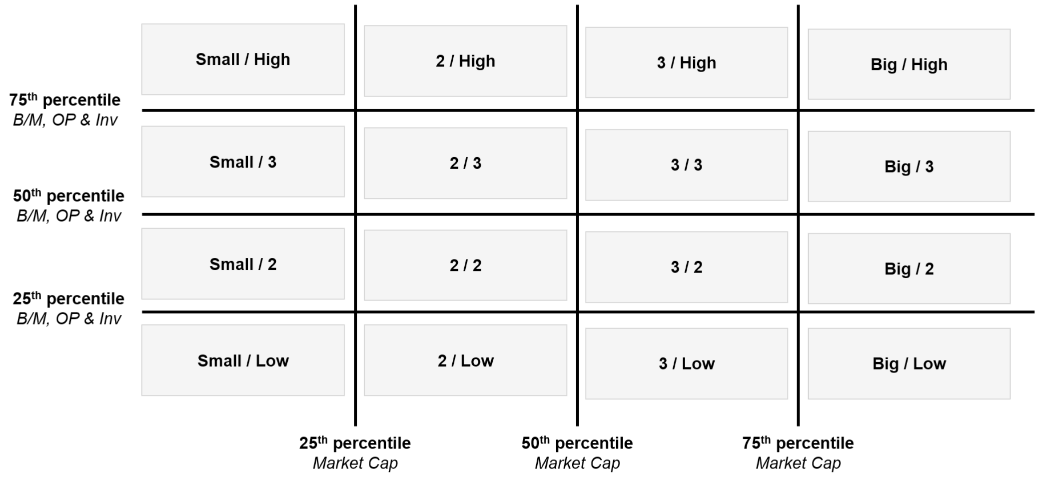


Figure 4: **4 x 4** Construction of Regression Portfolios

3.5 Descriptive Statistics - Indata

This section aims to provide an overview of the data that has been used in the analysis. In the first subsection, statistical information regarding the right-hand-side explanatory variables is disclosed. The second subsection provides statistics about the dependent variables also referred to as the regressions portfolios.

3.5.1 Factors

Monthly (%)	$\mathbf{R_f}$	**MKT**	**SMB**	**HML**	**RMW**	**CMA**
Average Return	0.17	0.60	0.03	0.05	1.51	-0.29
Standard deviation	0.14	4.86	3.48	3.20	4.18	2.25

Table 7: Descriptive Statistics Factors

3.5.2 Regression Portfolios

Table 8: Average excess returns, standard deviation and number of stocks

	Excess Return					*Standard deviation*					*Number of stocks*			
Panel A: Size-B/M														
	Low	**2**	**3**	**High**		**Low**	**2**	**3**	**High**		**Low**	**2**	**3**	**High**
Small	-0.14	-0.06	0.30	1.58	**Small**	6.45	6.46	8.23	8.44	**Small**	15	14	17	26
2	0.56	0.27	0.45	-0.34	**2**	5.06	5.04	4.78	4.76	**2**	24	21	23	24
3	0.56	0.58	0.12	0.66	**3**	5.47	4.92	5.26	5.27	**3**	25	24	26	25
Big	0.59	0.41	0.61	0.98	**Big**	4.81	4.82	4.80	5.62	**Big**	23	35	28	18
Panel B: Size-OP														
	Low	**2**	**3**	**High**		**Low**	**2**	**3**	**High**		**Low**	**2**	**3**	**High**
Small	0.02	0.68	1.35	0.87	**Small**	5.68	5.99	7.26	5.55	**Small**	40	16	6	9
2	-0.47	-0.04	0.81	0.80	**2**	4.45	3.62	3.88	3.86	**2**	32	24	16	20
3	-0.42	-0.05	0.58	1.07	**3**	5.89	4.16	4.18	4.04	**3**	13	28	33	25
Big	-0.29	0.47	0.27	0.64	**Big**	6.92	4.14	3.66	4.07	**Big**	5	24	35	35
Panel C: Size-Inv														
	Low	**2**	**3**	**High**		**Low**	**2**	**3**	**High**		**Low**	**2**	**3**	**High**
Small	0.50	0.23	0.99	-0.12	**Small**	7.50	7.18	8.60	8.26	**Small**	26	8	7	14
2	0.16	0.77	-0.10	-0.17	**2**	4.74	4.34	5.13	5.51	**2**	25	17	15	23
3	-0.13	0.55	0.55	0.65	**3**	5.26	4.94	4.75	5.30	**3**	18	24	23	25
Big	0.27	0.39	0.68	0.21	**Big**	4.81	4.67	4.73	5.20	**Big**	14	33	36	19

4 Method

This chapter will explain further how the pricing models were tested. Going back to our purpose, we aim to find empirical evidence for the pricing models' effectiveness in the Swedish stock market. Firstly, time series regressions were conducted where the pricing models are tested against our regression portfolios. To reach a conclusion regarding the effectiveness of the pricing models, a Gibbons-Ross-Shanken (1989) test is performed to test whether the alphas of the regressions differ significantly from zero.

4.1 Regression Analysis

The objective of our work is to test the usage of the Fama French multi-factor models and gather empirical evidence either against or in favor of our hypothesis. The regression analysis is where the empirical testing is performed. 48 time-series regressions has been conducted on the regression portfolios created in earlier sections. The dependent variables used in the regressions are the monthly returns of our regression portfolios. All portfolio returns are value-weighted and measured in excess of the corresponding risk free rate of return. The one month *STIBOR* is used as a proxy for the risk free rate of return. The *STIBOR 1M* decreases significantly during the analyzed period, from above 4% to down below 0% as of 2019. The explanatory variables of our regressions are ***MKT***, ***SMB***, ***HML***, ***RMW*** and ***CMA***. Their definitions can be found in section 4.3. The result of the regression is an intercept α_i and a coefficient β_i for each of the independent variables. The remaining difference between our models estimate and the observed returns are explained by the error term ε_i.

Throughout the regression some underlying OLS assumptions where questioned. The error terms should exhibit homoscedasticity, a time series plot of the residuals indicate that their variance has increased during the economic crises in our period. We believe that the ***MKT*** factor should absorb most of this systematic failure but no model has yet proven to predict crises so this observation was expected. However, beyond the crises the error terms seems to exhibit homoscedasticity and their expected value is zero. To counter these moments of increased variance robust standard errors were used.

These are the final regression models used in the study:

CAPM:

$$r_i - r_f = \alpha_i + \beta_{,MKT} MKT + \varepsilon_j \tag{9}$$

Fama-French three-factor:

$$r_i - r_f = \alpha_i + \beta_{,MKT} MKT + \beta_{i,SMB} SMB + \beta_{i,HML} HML + \varepsilon_j \tag{10}$$

Fama-French five-factor:

$$r_i - r_f = \alpha_i + \beta_{,MKT} MKT + \beta_{i,SMB} SMB + \beta_{i,HML} HML + \beta_{i,RMW} RMW + \beta_{i,CMA} CMA + \varepsilon_j \tag{11}$$

4.2 Gibbons-Ross-Shanken

In order to test the second hypothesis a GRS test was performed. The test was initially developed by Gibbons, Ross and Shanken (1989). The test is used to study the alpha intercepts from the regressions of our models, thus enabling a comparison of the models. The GRS test is a statistical test of the hypothesis that all alphas would be jointly equal to zero ($\alpha_i = 0 \forall i$). Thus, not rejecting the null hypothesis indicates our model is efficient in pricing capital assets. The formula below defines the test statistic and its corresponding f-value. $\hat{\alpha}$ is a N * 1 vector of our estimated intercepts, Σ-hat represents an unbiased estimate of the residual covariance matrix and $\overline{\mu}$ is a L * 1 vector of the factor portfolios' sample means. Finally, the Ω residual is an unbiased estimate of the factor portfolios' covariance matrix.

GRS Formula:

$$fGRS = \frac{T}{N} \times \frac{T-N-L}{T-L-1} \times \frac{\hat{\alpha}' \times \Sigma^{-1} \times \hat{\alpha}}{1 + \overline{\mu}' \times \hat{\Omega}^{-1} \times \overline{\mu}} \sim F(N, T-N-L) \tag{12}$$

The test was performed on each of the models. An initial general test was performed for all portfolios for each pricing model. Then we branched the test further to explicitly test the pricing models against each category of portfolio. Testing each model against the 16x3 value-weighted portfolios derived from *Size-B/M*, *Size-OP* and *Size-Inv*. The output of this test is one f-test and one asymptotically valid chi-square test. The reasoning behind the chi-squared part of the GRS test is that as the number of observations move towards infinity stock-returns have been known to exhibit a chi-squared distribution rather than the normal distribution. These underlying assumptions of the tests are important. Therefore, the distributions were examined closely. After examining the distributions of the error terms it was concluded that the distribution is close to normal and thus the f-test output is applicable.

5 Empirical Results

5.1 Descriptive Statistics Regressions

In this chapter a summary of descriptive statistics from our regressions will be presented and compared across the pricing models and risk factors. We have divided the results into our three portfolio types in order to compare the pricing models in each area of risk. *Alpha* ($\hat{\alpha}$), *Alpha t-statistic* ($t(\hat{\alpha})$) and *Adjusted* R^2 will function as our main metrics for comparison across the models and across the risk factors. R^2 naturally increases by the number of explanatory variables which would bias the comparability of our metrics since our models have various number of explanatory variables. However, the *Adjusted* R^2 is modified for comparison between models of varying number of explanatory variables. The adjusted version of R^2 should then increase only if the added explanatory variables of Fama and French improves the model more than would be expected by chance. Further the $\hat{\alpha}$ from our regressions will indicate how much of our observations are left unexplained after our predictions and the t-statistic of this metric will indicate its significance. In the following sections, 5.1.1, 5.1.3 and 5.1.5 we will test the following hypothesis to determine the significance of the regression alpha to see whether the models succeeds in explaining the average returns of the specific portfolio.

$$\begin{aligned} \mathbf{H_0} &= \boldsymbol{The\ regression\ alphas\ are\ indistinguishable\ from\ zero} \\ \mathbf{H_1} &= \boldsymbol{The\ regression\ alphas\ are\ distinguishable\ from\ zero} \end{aligned} \tag{13}$$

Finally, in section 5.1.4, we compare the jointly significance of all alphas from each model, meaning that we test the models ability to explain average returns on all portfolios instead of looking at a specific portfolio. This corresponds to the following hypothesis:

$$\begin{aligned} \mathbf{H_0} &= \boldsymbol{The\ regression\ alphas\ are\ jointly\ indistinguishable\ from\ zero} \\ \mathbf{H_1} &= \boldsymbol{The\ regression\ alphas\ are\ jointly\ distinguishable\ from\ zero} \end{aligned} \tag{14}$$

5.1.1 Size-B/M Portfolios

This segment evaluates the statistics from our regressions on the portfolios formed on *size* and *book-to-market* characteristics where the high column in table 9, on the next page, refer to portfolios of high *book-to-market ratio* while the low column represent low *book-to-market* portfolios. Same principle applies to the small and big rows. The second and third columns and rows in between the extremes represent the other breakpoints of the portfolios created in section 5.1.1 of the thesis.

In table 9, the alpha values and their respective t-statistic are displayed alongside the Adjusted R^2 from each regression. Considering the general absence of significant alpha values our models perform unexpectedly well in explaining our portfolio returns within the *Size-B/M* universe. *CAPM* exhibits only one significant alpha in the high *book-to-market* and second *size*-quartile. Meanwhile the Fama and French model exhibits more significant alphas, two each in the high *book-to-market* region of which one is the same portfolio as *CAPM* failed to describe. The Fama and French models do also struggle with explaining another common portfolio in the third *book-to-market* quartile. Further examination of these problematic portfolios leaves no indications as to why this pattern arises. None of the models show significant alpha values in the second and lowest quartile-column of *book-to-market.* On average the Fama and French models display a higher Adjusted R^2 where the *Fama-French five-factor model* marginally outperforms the *three-factor model.*

5.1.2 Table - Size-B/M Portfolios

Alpha ($\hat{\alpha}$)					***T-statistic*** ($\hat{\alpha}$)					***Adjusted R^2***				
CAPM														
	Low	**2**	**3**	**High**		**Low**	**2**	**3**	**High**		**Low**	**2**	**3**	**High**
Small	-0.004	-0.003	-0.001	0.013	**Small**	-0.81	-0.65	-0.19	1.91	**Small**	0.11	0.11	0.16	0.06
2	0.003	0.001	0.001	-0.007	**2**	0.68	-0.26	0.38	**-2.53**	**2**	0.24	0.34	0.30	0.46
3	0.001	0.001	-0.004	0.002	**3**	0.33	0.45	-1.24	0.61	**3**	0.43	0.55	0.56	0.56
Big	0.001	-0.002	0.001	0.004	**Big**	0.35	-1.06	0.38	1.62	**Big**	0.80	0.88	0.85	0.76
Fama-French Three-factor Model														
	Low	**2**	**3**	**High**		**Low**	**2**	**3**	**High**		**Low**	**2**	**3**	**High**
Small	-0.005	-0.004	-0.002	0.013	**Small**	-1.01	-0.84	-0.33	1.94	**Small**	0.28	0.28	0.40	0.17
2	0.002	-0.002	0.001	0.008	**2**	0.69	-0.50	0.30	**-3.70**	**2**	0.56	0.58	0.47	0.72
3	0.001	0.001	-0.004	0.002	**3**	0.23	0.43	**-2.21**	0.82	**3**	0.77	0.83	0.82	0.86
Big	0.001	-0.002	0.001	0.004	**Big**	0.46	-1.19	0.50	**2.16**	**Big**	0.88	0.90	0.89	0.85
Fama-French Five-factor Model														
	Low	**2**	**3**	**High**		**Low**	**2**	**3**	**High**		**Low**	**2**	**3**	**High**
Small	-0.006	0.001	0.003	0.020	**Small**	-1.25	0.28	0.49	**3.01**	**Small**	0.30	0.31	0.41	0.22
2	0.004	0.001	0.003	0.007	**2**	1.52	0.30	0.86	**-3.28**	**2**	0.60	0.60	0.48	0.72
3	0.002	0.001	-0.005	0.003	**3**	0.75	0.33	**-2.20**	1.56	**3**	0.78	0.81	0.80	0.84
Big	0.000	-0.001	0.001	0.003	**Big**	0.04	-0.88	0.44	1.66	**Big**	0.88	0.90	0.89	0.84

Table 9: Regression statistics for the *Size-B/M* portfolios

5.1.3 Size-OP Portfolios

Table 10 shows the summary statistics derived from regression on our portfolios formed from *size* and *profitability* measures. The high columns refer to diversified portfolios of high *profitability* and the opposite is true of the low column while the small and big rows remain the same as in our previous table. In the *profitability* area *CAPM* and the *Fama-French three-factor model* shows a decrease in performance while the *Fama-French five-factor model* improves its performance relative to the *book-to-market*-portfolios and outperforms the two other models. The right-most portfolios unveil high t-statistics in the *profitability* section as they did in the *book-to-market* section. In addition a tendency toward more significant alphas in the average *size* region is revealed in this section. The most problematic portfolio in this section was the one mimicking stocks of high *profitability* and *size* between the 50^{th} and 75^{th} quartile (t = 3.09, 4.32, 3.15).

5.1.4 Table - Size-OP Portfolios

CAPM

	Alpha ($\hat{\alpha}$)				***T-statistic ($\hat{\alpha}$)***				***Adjusted R^2***			
	Low	**2**	**3**	**High**	**Low**	**2**	**3**	**High**	**Low**	**2**	**3**	**High**
Small	-0.002	0.004	0.012	0.006	-0.51	0.89	**2.06**	1.47	0.12	0.12	0.01	0.11
2	-0.007	-0.003	0.005	0.005	**-2.21**	-1.49	**2.01**	**1.99**	0.22	0.44	0.45	0.39
3	-0.008	-0.004	0.002	0.007	**-1.96**	**-1.96**	0.80	**3.09**	0.29	0.54	0.61	0.54
Big	-0.008	0.000	-0.001	0.002	-1.60	-1.60	-1.28	1.46	0.31	0.78	0.86	0.90

Fama-French Three-factor Model

	Alpha ($\hat{\alpha}$)				***T-statistic ($\hat{\alpha}$)***				***Adjusted R^2***			
	Low	**2**	**3**	**High**	**Low**	**2**	**3**	**High**	**Low**	**2**	**3**	**High**
Small	-0.003	0.004	0.012	0.006	-0.68	0.90	**2.10**	1.47	0.31	0.28	0.13	0.20
2	-0.008	-0.004	0.004	0.005	**-2.99**	**-2.14**	**2.49**	**2.30**	0.51	0.67	0.69	0.60
3	-0.009	-0.005	0.001	0.007	**-2.57**	**-3.35**	1.04	**4.32**	0.53	0.84	0.86	0.79
Big	-0.008	0.000	-0.001	0.002	-1.62	0.14	-1.44	1.49	0.33	0.78	0.89	0.90

Fama-French Five-factor Model

	Alpha ($\hat{\alpha}$)				***T-statistic ($\hat{\alpha}$)***				***Adjusted R^2***			
	Low	**2**	**3**	**High**	**Low**	**2**	**3**	**High**	**Low**	**2**	**3**	**High**
Small	0.003	0.006	0.008	0.007	0.74	1.36	1.30	1.51	0.38	0.29	0.17	0.18
2	-0.004	-0.003	0.004	0.004	-1.64	-1.44	**2.32**	1.75	0.59	0.68	0.69	0.60
3	0.000	-0.005	0.001	0.005	-0.09	**-2.96**	0.57	**3.15**	0.69	0.82	0.85	0.78
Big	0.006	0.002	-0.001	0.000	1.51	1.02	-1.32	0.11	0.64	0.79	0.89	0.91

Table 10: Regression statistics for the *Size-OP* portfolios

5.1.5 Size-Inv Portfolios

Table 11 shows the summary statistics derived from regressions on our portfolios formed from *size* and *investment* levels. The high columns refer to diversified portfolios with aggressive *investments* and the opposite is true of the low column while the small and big rows remain the same as in our previous tables. In this section all models outperform their previous measures in terms of number of significant alpha values. There is one portfolio that stands out, the portfolio consisting of small equities with fairly conservative investments, where all three models struggle to describe the average returns. When observing *Adjusted* R^2 the Fama and French models slightly outperform *CAPM* in that regression but none of the *Adjusted* R^2 are above 0.05.

5.1.6 Table - Size-Inv Portfolios

	Alpha ($\hat{\alpha}$)					***T-statistic ($\hat{\alpha}$)***					***Adjusted R^2***			
CAPM														
	Low	**2**	**3**	**High**		**Low**	**2**	**3**	**High**		**Low**	**2**	**3**	**High**
Small	0.002	0.001	0.007	-0.004	**Small**	0.32	0.17	1.03	0.61	**Small**	0.11	0.02	0.06	0.07
2	-0.002	0.005	-0.004	-0.006	**2**	-0.48	1.55	-1.11	-1.53	**2**	0.29	0.35	0.25	0.34
3	0.006	0.001	0.001	0.002	**3**	-1.82	0.29	0.44	0.66	**3**	0.47	0.61	0.54	0.44
Big	-0.003	-0.002	0.001	-0.003	**Big**	-1.49	-1.36	0.98	-1.49	**Big**	0.81	0.91	0.89	0.73
Fama-French Three-factor Model														
	Low	**2**	**3**	**High**		**Low**	**2**	**3**	**High**		**Low**	**2**	**3**	**High**
Small	0.001	0.001	0.007	-0.005	**Small**	0.25	0.12	1.02	-0.76	**Small**	0.30	0.05	0.11	0.22
2	-0.002	0.004	-0.005	-0.006	**2**	-0.82	1.72	-1.52	**-1.96**	**2**	0.59	0.55	0.50	0.54
3	-0.006	0.000	0.001	0.002	**3**	**-3.03**	0.20	0.38	0.78	**3**	0.77	0.85	0.76	0.79
Big	-0.003	-0.002	0.001	-0.004	**Big**	-1.47	-1.43	1.18	-1.67	**Big**	0.81	0.92	0.91	0.77
Fama-French Five-factor Model														
	Low	**2**	**3**	**High**		**Low**	**2**	**3**	**High**		**Low**	**2**	**3**	**High**
Small	0.008	0.003	0.008	-0.005	**Small**	1.61	0.41	1.08	-0.71	**Small**	0.38	0.05	0.11	0.24
2	0.001	0.004	-0.003	-0.004	**2**	0.44	1.64	-0.84	-1.39	**2**	0.66	0.55	0.54	0.57
3	-0.005	0.000	0.001	0.002	**3**	**-2.44**	0.03	0.63	1.11	**3**	0.80	0.84	0.75	0.79
Big	-0.001	-0.001	0.000	-0.004	**Big**	-0.39	-0.98	0.08	**-2.02**	**Big**	0.82	0.92	0.92	0.79

Table 11: Regression statistics for the *Size-Inv* portfolios

5.1.7 Model Comparison Tests (GRS)

Table 12: Comparison of the three asset-pricing models

Summary GRS-statistics					
Size-B/M					
	fGRS	***pGRS***	***Avg.*** $\lvert\hat{\alpha}\rvert$	***Avg. Dev.***	***Avg. Adj.*** R^2
CAPM	**1.95**	**0.02**	0.0030	0.0030	0.45
Three-Factor Model	**2.08**	**0.01**	0.0030	0.0030	0.64
Five-Factor Model	**2.55**	**0.00**	0.0038	0.0035	0.65
Size-OP					
	fGRS	***pGRS***	***Avg.*** $\lvert\hat{\alpha}\rvert$	***Avg. Dev.***	***Avg. Adj.*** R^2
CAPM	**3.94**	**0.00**	0.0049	0.0049	0.42
Three-Factor Model	**3.89**	**0.00**	0.0049	0.0048	0.58
Five-Factor Model	**2.68**	**0.00**	0.0037	0.0033	0.62
Size-Inv					
	fGRS	***pGRS***	***Avg.*** $\lvert\hat{\alpha}\rvert$	***Avg. Dev.***	***Avg. Adj.*** R^2
CAPM	1.70	0.05	0.0031	0.0031	0.42
Three-Factor Model	**1.78**	**0.04**	0.0030	0.0030	0.59
Five-Factor Model	1.46	0.13	0.0032	0.0032	0.61
All portfolios					
	fGRS	***pGRS***	***Avg.*** $\lvert\hat{\alpha}\rvert$	***Avg. Dev.***	***Avg. Adj.*** R^2
CAPM	**2.57**	**0.00**	0.0036	0.0037	0.43
Three-Factor Model	**2.57**	**0.00**	0.0036	0.0037	0.60
Five-Factor Model	**2.19**	**0.00**	0.0035	0.0034	0.63

Table 12 shows the summary statistics from the GRS tests which is used for model comparison, thereby enabling a test of the second research question. Panels one through three displays our output from GRS tests performed in each section of the 16x3 portfolios. The last panel is a summary of a GRS test performed on all 48 portfolios simultaneously. As is evidenced by our low p-values, at a significance level of 0.05, all GRS-test rejected the null hypothesis that the alphas are jointly indistinguishable from zero except two portfolios. The GRS test performed on *CAPM* and the *Fama-French five-factor model* in the *Investment* (***Inv***) universe failed to reject the null hypothesis. This supports

CAPM and the *Fama-French five-factor model*, since not rejecting means that it cannot be confirmed the the models failed to give a complete prediction of the sample returns. Yet, strictly comparing p-values across models would not necessary indicate power over another test. If we look further at the *Adjusted* R^2 column it's obvious that the *Fama-French five-factor model* outperforms *CAPM* in terms of explanatory power in all areas and marginally beat the same statistics from the *Fama-French three-factor model* as well. However, adding more risk factors derived from premiums estimated within the sample and then sorting the sample in accordance with these factors would naturally have this effect. The metrics are somewhat trivial in terms of comparability. Observing the joint GRS from the last panel, all portfolios, indicates that the *Fama-French five-factor model* is closest to a complete description of the portfolio returns (2.19). Yet another contradictory outcome of the GRS test is the average absolute $\hat{\alpha}$. In the last panel the Fama-French five-factor model marginally exhibits the lowest alpha intercept on average.

6 Conclusion and Discussion

The thesis aimed to provide further research about the pricing models and their ability to explain average returns on the Swedish Stock Market. The study was divided into three portfolio sets (3x16) based on the risk areas Fama and French has identified in their previous research, resulting in three different portfolios, *Size-B/M*, *Size-OP*, and *Size-Inv*. As an indication of efficiency, the alphas from each regression were tested to see how much average return the models leave unexplained. Looking further into the GRS statistics, enabled us to compare the model's performance in various areas of risk and by various characteristics.

As anticipated, the GRS test rejects the hypothesis of all alphas being indistinguishable from zero on all 48 portfolios, implying that all models are insignificant in explaining average returns. The rejection means there is still a variation in the average returns that the models cannot capture. The *Fama-French five-factor model* and *CAPM* did, however, stand their ground in one of the tests in the *Size-Inv* universe where the GRS test failed to reject the null hypothesis indicating high explanation in this particular area and portfolio set. The overall outcome of the hypothesis testing and regression statistics were ambiguous. While the GRS test helped to summarize the regressions into a clear and dense manner, the resulting statistics were ambiguous and somewhat difficult to digest into which model is the most useful. While one model exhibited a higher *Adjusted* R^2 another displayed lower alphas and strictly relating these would be like comparing apples and oranges to some extent.

Besides the market factor, all factors considered in these models are focused on the idiosyncratic risk of equities such as investments and size. Since investment decisions often are affected by macroeconomic factors, perhaps including a pricing model that includes more specific systematic risk factors would diversify the comparison group further and might suggest a more satisfying result. But we hand over this intriguing task to future researchers.

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