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Implied Volatility and Rebalancing Timing:

Market cycles and the relationship between implied volatility indices and stock index returns.

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Niklas Holst and Harald Rønning

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AUTHOR(S)		SUPERVISOR:
Candidate number:	Name:	Peter Molnar
1055 …………………	Harald Rønning ………………………………………	
1060 …………………	Niklas Holst ………………………………………	

Abstract

This paper studies market timing based upon the level of the VIX and compares VIX based portfolio rotations with modern rebalancing practices. The thesis analyses the outcomes of the different rebalancing and trading strategies, and compare them through different performance measures. The study finds that on average, rebalancing strategies based on the level of the VIX does not have significant positive returns compared to the standard dynamic rebalancing scheme that are used today by nearly every professional mutual fund manager.

Preface

This study constitutes the shared work and the final part of our master's degree program with a main profile in applied finance at the UIS Business School, University of Stavanger.

The theme of the thesis was decided by different factors. Our initial interest in the subject were inspired by our interest in the effect rebalancing can have on a portfolio return and risk characteristics. Later in our thought process we decided to incorporate volatility indices, and thus we decided to combine timing and rebalancing. The market cap in volatility based products are increasing massively, and we believe that including VIX level based rebalancing schemes makes our paper original.

While working with the subject, we learned a lot in terms of the volatility market. The thesis includes interesting sections from previous literature on market timing, the volatility market, allocation strategy and rebalancing. In addition, we have learned about rebalancing through extensive portfolio theory. The overall process of learning a new subject such as the volatility market in addition to analyzing and simulating data through excel and Stata has been both challenging and exciting for us. We hope that the reader will find our paper interesting and worth the read.

Finally, we would like to thank our supervisor, Associate Professor Peter Molnar, for applying his extensive knowledge in the volatility market to us. In addition, Peter has given us valuable feedback and guidance through the writing process.

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1. Introduction

1.1 Background and Motivation

Dynamic rebalancing is the most popular form of rebalancing today, and ensures a “sell high” and “buy low” portfolio mechanism. With the rise of volatility based products as an asset class we were intrigued to see to which degree volatility based rebalancing schemes would perform in a long time-series. *Moran (Dash & Moran, 2005)* notes that a portfolio that allocates 10% in the VIX and 90% in the S&P 500 and continues to rebalance the portfolio weekly would have outperformed the S&P 500 by 5% while reducing the standard deviation by 25%, the study was based on data from 1986 to 2003.

When deciding on a specific research question, we wanted to fill what we believe to be a hole in previous research on the topic. There exists some research on the topic, but to the best of our knowledge, there is no research combining rebalancing and market timing based on the VIX in a similar framework. It seems to be a recurring theme that the VIX has a market timing ability, but to what extend an investor may use this to his or her advantage remains untested in several areas. This is why we decided to compare VIX based asset rotations to popular rebalancing schemes. Empirical evidence and previous literature find significant positive results from using VIX level based trading strategies, however, the strategies used today are reserved for professional institutions with sophisticated market analysis tools. As we are assuming the stand point of an average investor, our focus has been to find patterns and results to analyse, based on more primitive market timing models.

The paper assumes the stand point of an average international investor that does not have access to any private information. The methodology of the paper takes aim in simulating different approaches to rebalancing by incorporating market timing based on the level of the VIX. Due to the limited data available on international volatility indices, the paper uses the VIX as the volatility index, the S&P 500 as the equity index and 10 year US T-bills as the risk-free alternative. We will discuss existing theory and literature on volatility indices and market timing, in addition to asset allocation and rebalancing specifically. We will use existing research and models that focuses on the VIX level as a trigger for market timing and rebalancing, and incorporate this in our framework. By reviewing the results from the different strategies, we can see if there are basic rebalancing models based upon the VIX that can be more effective than the traditional dynamic rebalancing scheme.

Finally, we will use different performance metrics to evaluate which rebalancing and allocation strategies that are best suited for the average investor.

1.2 Thesis structure

In the first part of the paper, we will review existing literature and previous research that explores the subject of volatility indices and the market timing ability. Following, we will look at some research and empirical studies on VIX based trading strategies and hedges. In chapter 3, we will dive into some modern portfolio theory by looking at allocation strategies and rebalancing schemes. We aim to review some theory on the topic of rebalancing, and combine that with the existing theory on volatility indices and market timing.

In chapter 4, we will discuss the data we used in the excel model. This chapter will discuss the different asset classes and the decision behind why we chose that particular data set. In addition, we will look at some descriptive statistics for the different asset classes. This part includes both statistics regarding our own data and the general traits of the different asset classes.

Chapter 5 represents the methodology part of our thesis. In this chapter, we try to explain to the best of our ability our overall approach. This part focuses on the approach used to create the different rebalancing strategies. Our methodology also introduces the reader to the different performance measures used to evaluate our results. We will look at some descriptive statistics for the different strategies and explain the details and rationale behind the different strategies.

Following the methodology, we analyze the results in chapter 6. In this part, we briefly cover the returns generated by each strategy. Next, we take a closer look at the rebalancing effectiveness and timing ability of the different strategies by discussing the positive or negative impact of the rebalancing dates. We use these results to evaluate the performance of the different strategies through different performance measures. The performance level of each strategy is evaluated through four different performance metrics; Sharpe Ratio, Treynor Ratio, Jensen`s Measure and M^2 Measure. Finally, we discuss the overall ranking of the strategies, and what contributed to the specific rankings.

Chapter 7 represents the conclusion of the paper.

In the end, we have added a list of our references and an appendix containing regression data for the different rebalancing strategies.

1.3 Research question

Our literature review is meant to highlight the fact that researchers are not able agree upon a particular optimal rebalancing strategy. In addition, the surge of volatility indices and products gives a new perspective on rebalancing timing. Using a deductive research strategy, we formulize an active rebalancing strategy that use the level of the VIX as a metric for timing. The changes made to the portfolio using this strategy is dependent that the VIX shows some kind of predictability of the S&P 500. We test these strategies and compare with a dynamic rebalancing strategy that use yearly rebalancing with a 5% threshold.

Research question:

How will rebalancing strategies using implied volatility as a tool for market timing perform, when compared to dynamic rebalancing?

2. Literature Review

For the last decade, investments in volatility markets has increased dramatically. Implied volatility indices, such as the famous VIX index, measure of the implied volatility of the underlying. In case of the VIX index, it is the volatility implied but 30-day options on the S&P 500 as an underlying asset. Traders believe the VIX is subject to a mean reverting process and make trades based upon the VIX, see *Whaley (2013).* In general, implied volatility increases when the market is bearish, when investors believe that the asset's price will decline over time, and decreases when the market is bullish, when investors believe that the price will rise over time. This is due to the common belief that bearish markets are riskier than bullish markets. Implied volatility is a way of measuring the investor's sentiment to the market. For instance, implied volatility rose to the extreme during the financial crisis in 2008.

Alexander and Korovilas (2011) analyzes the relationship between the VIX and the S&P 500, and highlights the hazards when adding volatility products as hedge in portfolios. The large negative correlation between daily returns on the S&P 500 and those on the VIX, averaging about -0.7 before the banking crisis, became even more negative (-0.85) during the crisis. Based on the relationship, they investigate whether this can be used to trade volatility products to effectively hedge a portfolio. In conclusion, they warned against using volatility as a hedge due to its long term expected negative return and pricing structure, stating that only investors who are experienced within the volatility trading branch should consider volatility products as a hedge.

Today, there is more than 30 VIX exchange traded products (ETPs) listed on the market and generating around $ 2.6 billion average daily trading volume. *Whaley (2013)* discuss properties of these derivatives. First, he concludes that VIX ETPs is not suitable buy-and-hold investment, because through time the investors are almost guaranteed to lose money. One example of this among the findings of Whaley is that VIX ETPs benchmarked to the VIX short-term total return futures index dropped the value by nearly 94% during a five-year period (January 2009 to the end of 2013). Thus, if an investor considering using VIX ETPs as a buy-and-hold investment, the person must have a thoughtful strategy, which demand daily rebalancing and are subject to a host of management fees and expenses, or simply sell that investment.

A recently published article*, Bordonado, Molnár, and Samdal (2017)* examines the most traded VIX-exchanged products (ETP) focusing on their performance, price discovery, hedging and trading strategy. They analyze the two most traded ETPs, and concluded that the older and more traded the ETP leads the price of direct and levered ETPs, and the younger and less traded ETPS leads the price in case of inverse ETPs. The paper also contains a trading strategy which are based on buying VIX direct and inverse ETPs and hedging the position with S&P 500 ETF. As we know, are the direct VIX ETPs strongly negatively correlated with S&P 500, and thus they investigated the opportunity to use these indices as an instrument for hedging or diversification to an equity portfolio. They conclude that the diversification benefits with this type of indices are too low, the negative expected return is simply too high. However, the hedging possibilities are little more interesting. The analysis suggests that the investors often are willing to pay a premium for VIX exposure, because most of the investors are risk averse and need insurance, and therefore impose time-decay on investors looking for volatility exposure using other products too. It is this time-decay function that rise the trading opportunities for the VIX ETPs. The strategy is then to buy the inverse VIX ETPs when the term structure is sufficiently in contango, which in term of theirs results are highly profitable and robust to transactions cost. Thus, at the end they conclude that the ability for hedging tools with VIX exchange are poor, but it creates many different opportunities for investors seeking high profits with willingness to take some risk.

As mentioned before, the direct VIX ETPs are strongly negatively correlated with S&P 500, therefore it reacts in the opposite direction compared with equity returns. Especially in crises we can identify this negatively correlation. *Manda (2010)* investigated the stock market volatility during the recent financial crisis (2008). She revealed that the financial crises of 2008 changed the whole dynamics in the market. Firstly, we could identify a stronger correlation between the asset class, and most of the asset class experienced significant pullbacks. The S&P lost about 56% of its value from October 2007 peak to March 2009, and the VIX Index had more than tripled its value. Suddenly had the market turn upside down, becoming extremely volatile, and most of the investors had lost money. The volatility of the stock market, measured by the volatility of S&P 500, increased from 13.4% to 43.6% during the crises. We have seen a similar effect also in an earlier crisis, when in 1987 VIX reached its highest level ever during the major stock market decline. This support the idea that VIX index might be an important indicator to follow, in general, and particularly during the crises. The VIX index is often referred to as the "Fear Index" when it spikes during market turmoil or periods of extreme uncertainty.

However, if the investor wants to use the VIX and minimize some of the risk, a possible idea is to rebalance the portfolio after publicly available information that helps to predict the market. Such information is based on the idea that we can use implied volatility for style and size strategies, which have the ability to time the price movements in the market. *Copeland and Copeland (1999)* examine this subject, and investigated the possibility of making a potential trading rule based on the assumption that an implied volatility index has market timing ability. They build their study around two previous studies. First, *Merton (1980)* investigated equilibrium expected market return and concluded that the market risk premium is positively correlated with variance of the market portfolio. The reason is a generally reasonable assumption that in capital market equilibrium, where the representative investor is risk-averse, will the investor expect a much higher return if the investor has to bear more risk. The second study, *French, Schwert, and Stambaugh (1987),* investigated the relation between stock returns and market volatility. They revealed that if the predicable volatility of stock return were positively related to the expected market risk premium, would a positive unexpected change in volatility create a future discount rate that goes up and current spot price would have fallen.

Furthermore, the paper contains evidence that unexpected change in the volatility of stock returns are negatively related to the unexpected stock market return, with other words would unexpected increase in volatility create an unexpected negative return. Based on these theories, they prepared two strategies that use changes in the implied volatility of options on stock market index futures as market timing signals, and explore empirical relationships between timing and style, and size. In the first strategy, the investor will replace the portfolio of growth stocks into value stocks, if the expected future volatility went up. Such a strategy is based on the assumption that investors are losing their confidence in growth stock when the uncertainty in the market is rising. The second strategy is based on the idea that the size of the companies in the portfolio constitute a decisive role. Portfolios involving large-cap stocks perform often better when expected volatility increased, and vice versa. Thus, if the implied volatility decreased, the investor will form a portfolio with small-cap stocks, and if the implied volatility increased, the portfolio will be shifted into large-cap stocks.

Copeland and Copeland (1999) suggested that VIX index would be a leading indicator, because of the evidence that value stock outperform portfolios of growth stocks following an increase in the VIX index *(Boscaljon, Filbeck, & Zhao, 2011).* The results were based on 75-day moving average index with a one-percent change in VIX as a signal to time the market by rotating between styles or size. In 2011, *Boscaljon et al. (2011)* did a similar test, with data from 1990 to 2008 that corresponds with the Chicago Board Options Exchange new VIX index. They investigated the effectiveness of the market volatility index (VIX) provided by the Chicago Board Options Exchange in timing shifts for style asset allocation. The result was interesting, because they found some evidence that supported *Copeland and Copeland (1999)* initial finding, but for holding periods that lasted less than 30 days there was no evidence supporting their initial results. Only statistically significant for periods longer than 30 days, especially during periods with increasing in the uncertainty in the market. Thus, based on the results they concluded that for longer holding periods the investor might have some opportunities to gain some profit by rebalancing their portfolios between value and growth stocks based on changes in the VIX index.

Following, is a theory and literature chapter that covers the topic of rebalancing. For structural reasons, we will return on the topic of using the VIX as a trigger/timing later in the thesis. In chapter 5 section 4 we will combine rebalancing and VIX timing as a theoretic foundation for our strategies in the excel model.

3. Asset Allocation and Portfolio rebalancing

A study by *Ibbotson and Kaplan (2000)* shows that asset allocation determines 90% of the portfolios variability in returns over time. The asset allocation of a portfolio describes the investors risk preferences and the investors expected return. Assuming the investor is rational and a long-term investor, the investor would prefer to keep the same strategic asset allocation for the complete investment duration. As a portfolio usually consists of different instruments that will produce different returns over time, the investor will have to "rebalance" the portfolio when it has drifted from its target asset allocation in order to keep the intended risk and return characteristics of the investment. This form of rebalancing is the practice that is used by most investors. Research suggest there are no optimal rebalancing form in terms of range and threshold *(Jaconetti, Kinniry Jr, & Zilbering, 2010).*

Strategic asset allocation involves assigning weights to different asset classes based on the investors risk tolerance and return objectives. The strategy assumes a rational investor that is risk averse. Strategic asset allocation use rebalancing to reallocate assets if the portfolio drifts too far away from the asset allocation target. The overall goal of this strategy is to add discipline to a long-term portfolio strategy by reallocating assets to the original target.

Tactical Asset Allocation allows investors to make deviations from the target asset allocation in the short term based upon expectations for the macro economy. Different approaches have been used to find correlations between asset classes and macro economy. *Fama and Schwert (1977)* found that government debt instruments, bonds and bills, are complete hedges against expected inflation. The expected nominal returns on these instruments vary directly with the expected inflation rate so that their expected real returns are unrelated to the expected inflation rate. Historically, investment grade bonds perform poorly in low interest rate market, as it is usually an indicator of poor economy. Furthermore, the study showed a negative correlation between common stocks and expected inflation for the same period. Even though they discovered empirical evidence that showed stocks correlate negatively with expected inflation, they did not manage to find good enough evidence to support a trading strategy.

If we look at the market the past 40 years, the volatility of the average stock return has drastically outpaced total market volatility. *Irvine and Pontiff (2009)* performed a study about idiosyncratic return volatility compared with the market volatility. They found out that idiosyncratic return volatility has dramatically increased and estimated that the difference keeps increasing by 6% each year. They argue that these findings are attributable to the more intense economy-wide competition, and used the various cross-sectional and time-series test to support this idea. If we look at the return on assets, they discovered a negative correlation related to idiosyncratic volatility in the cross-section, when the return has declined over our sample period. This support their explanation. With increased volatility will also the risk increase. This is one of the reason why rebalancing is a relevant topic. "Portfolio rebalancing is a powerful risk control strategy" wrote *Tokat and Wicas (2007)* in their article. They revealed that a portfolio must be rebalanced, if you want to ensure that a portfolio's risk and return characteristics remain consistent over time. The reason is that a rebalancing strategy solves this risk by formalized guidelines on how often the portfolio should be monitored. It would also disclose how far from its target an asset allocation can deviate before it's rebalanced, and with periodic rebalancing, should you restore a portfolio to its target or to some intermediate allocation. How you want to approach this strategy depends on a number of factors such as the market environment and asset-class characteristics. Every portfolio may be unique, therefore the specific guidelines to the portfolio may be unique. Each guideline answers fundamental question about the rebalancing strategy, like; how often, how much and how far, and thus it has an important impact on investor's characteristics when it comes to risk and return and returns preferences. Different market returns patterns may create different opportunities for tactical rebalancing. Generally, there is no doubt about the benefits of rebalancing, however, there is hardly any agreement on the optimal rebalancing strategy.

Although rebalancing suggests a split or an even balance between two things, stocks and bonds does not need to be split in order to rebalance a financial portfolio. Defining rebalancing in financial terms is the reallocation of assets to a defined makeup. By buying or selling assets, the portfolio manager is able to keep the strategic asset allocation of the portfolio in the long term. For example, let's say a portfolio manager sets an allocation of 50% stocks and 50% bond. The difference in return characteristics would imply that the stock allocation would increase over time. The investor will then sell stocks and buy bonds, in order to keep the strategic long-term weights. Thus, we can say that rebalancing a portfolio comes down to realigning the weightings of a portfolio of assets to the desired level of asset allocation. Rebalancing a portfolio centered on a fixed asset allocation has proved to be valuable. By implementing a rebalancing mechanism, the investor is able to sell "high" and buy "low", without effort. This is a good approach that takes advantage of the time variations in the risk premium. As a result, the portfolio volatility will decrease and whereas the return does not have to decrease.

As discussed above, the strategy of maintaining a fixed asset allocation in the long term is beneficial in terms of return and volatility. More often than not, the investor rebalances their portfolio in order to maintain their desired level of risk. When analyzing portfolios with a long history, we see that rebalancing significantly reduces historic volatility. As a result of higher expected long-term performance, the share percentage of stocks will increase over time in a portfolio that does not have a rebalancing scheme.

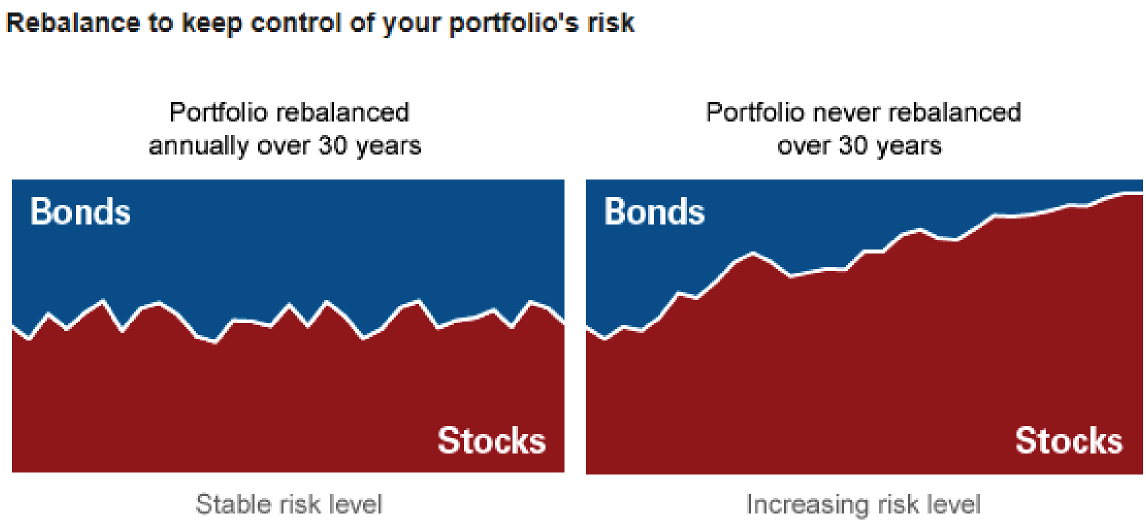

Figure 1 The effect of rebalancing over 30 year's periods (Vanguard)

Typically, it can be difficult for an investor to sell "winning shares", as it can be in conflict with an investor's instinct. However, it reflects one of the most logical approaches to the market in general; "buy low, sell high". For most people, passive rebalancing is therefore preferred and implemented as a mechanism that sells high performing asset classes and buys lower performing asset classes. The mechanism will "trigger" depending on the rules set by the investor. There are different ways to use this mechanism, and the different strategies for rebalancing often depends on the asset allocation strategy of the portfolio.

Using a threshold is a natural way of rebalancing a portfolio. The threshold may be a fixed deviation of the original strategic weights. If the threshold is 5%, in a 60/40 allocation, this means that if the equity stake rise to more than 65% of the portfolio, the fund will be rebalanced. If the equity share be reduced to 55% the portfolio is rebalanced. Another strategy is calendar rebalancing. As the name suggest, this strategy involves setting a date for observation, and if the portfolio allocation has deviated from the strategic weights at that date, the fund will be rebalanced. The observation frequency is usually either monthly, annually or semi-annually. More commonly though, a combination of the two is used to rebalance a portfolio. By using both, we can eliminate the downside of each of the strategies. Transaction costs limits the tightness of the threshold. For example, let's say that the portfolio has an annual volatility of 20%. If we were to observe it monthly and use a threshold of 1%, there would be a lot of transactions involved. The turnover would not be worth the increase in risk adjusted return as the costs would outweigh. Remember, the key element of rebalancing is keeping the long-term target asset allocation.

Active rebalancing, also known as opportunistic rebalancing, is where the goal is to reduce the risk and add more return by controlling the portfolio drift and capture unique opportunities and buy-low/sell high, as asset class performances drift relative to each other. The general idea behind it, involves frequently look at the index, but only rebalance when it's profitable to do so. *Daryanani (2008)* investigated this strategy. The paper studies show that opportunistic rebalancing return benefits can be more than doubled compared with traditional annual rebalancing. Over a 13-year baseline period (1992-2004) has the benefits from opportunistic rebalancing far exceeded the cost associated with trading, taxes and observing. A strategy like this require that the investor has a good plan before the investment, and enough time to frequently analyze the index after the investment is done. The paper demonstrated a guideline to succeed in such a strategy. It is important to have wider rebalance bands (up to 20%), analyze the portfolio biweekly, only rebalance asset classes that are out of balance and often profitable to increase the number of uncorrelated classes used in portfolios.

Often the traditional periodic rebalancing is too mechanical and the frequent rebalancing would often generate too much transaction cost. *Masters (2003)* analyze these issues, and the goal was to devise an easily implemented rebalancing strategy that was consistent with a portfolio's underlying assumptions and preferences. The approach was to set bands around the target allocations and whenever those limits are exceeded you would rebalance. He also demonstrated a way to calculate the rebalance cost, including both direct trading expenses and indirect market impact. The idea was to have linear cost function of rebalancing, were selling twice as much of an asset will cost roughly twice as much. The cost would be illustrated with a two-way cost of rebalancing including market impact. The main focus and the fundamental is then to create a set of rules on when and how far the rebalance helps, so we can eliminate the temptation to delay rebalancing and minimize the costs associated with too-frequent periodic rebalancing, and also create more flexibility. *Jaconetti et al. (2010)* highlighted that the main purpose of rebalancing is to maintain the risk-and-return characteristics of the portfolio. The article compels investor to use reasonable monitoring and a 5% threshold to manage their portfolio, and that rebalancing costs could become significant if the rotations are exceeding a yearly frequency.

4. Data

In this chapter, we will take a deeper look at the data set used both in our portfolio and for the implied volatility. We will discuss in detail the decisions behind why we included the data we did and for what purpose. Secondly, detailed information explaining the data will also be presented in this chapter, such as, correlation, returns and risk. The implications of the data statistics and previous research will be used to base our strategies in the rebalancing model.

We used *DataStream* by Thompson Reuters to download the data (VIX, SPX & 10year T-bills) into the excel worksheet. The bonds are represented by US 10 year T-bills, and the index in the Thompson Reuters DataStream is "US BENCHMARK 10 YEAR DS GOVT. INDEX - CLEAN PRICE INDEX".

The stocks are represented by the S&P 500 and is listed in the Thompson Reuters database as "S&P 500 COMPOSITE - PRICE INDEX"

The VIX is the volatility index representing options and futures on the expected volatility of the S&P 500 and is labeled in the Thompson Reuters database as "CBOE SPX VOLATILITY VIX (NEW) - PRICE INDEX"

4.1 Choosing asset classes

In order to capture the essence of the thesis, which is to test if implied volatility can be legitimately used as a tool for rebalancing timing, we thought it is best to only include the underlying stock index S&P 500 and a risk-free alternative. From an investor perspective, the allocation between risky and "safe" investment assets are the most important portfolio decision. The allocation that is perhaps the most popular for risk aversive investors, is the 60/40 allocation. *Valensise (Mariathasan, Valensise, & Laud, 2016)*, head of Barings' multi-asset group points out that investors who used this allocation in the last 30 years would have averaged a return of about 9% annually, and a volatility of 8,5%, making the average portfolio with such a strategy very attractive for any long-term investor.

4.2 The Volatility Index

As we are studying market timing using the S&P 500 as a reference, the volatility index is the VIX. This index has the longest history out any volatility index. As a result, it captures several market cycles. This is an important factor as repetition in different market cycles will give legitimacy to the statistical approach. We can look at the VIX index as a combination of two components: the expected volatility for the S&P 500 and a volatility risk premium. The VIX index is calculated by using the midpoint of real-time S&P 500® Index (SPX) option bid/ask quotes. The VIX index is often referred to as the premier indicator of market investor sentiment, as it represents the volatility of the S&P 500. According to CBOE*(CBOE, 2014)* the VIX measures the level of expected volatility of the S&P500 over the next 30 days that is implied in the bid/ask quotations of SPX options. The calculation can be derived from the formula 1.

$$\sigma^2 = \frac{2}{T}\sum_t \frac{\Delta K_i}{K_i^2} e^{RT} \underset{\smile}{Q}(K_i) - \frac{1}{T}\left[\frac{F}{K_0} - 1\right]^2 \qquad (1)$$

Where:

σ	${}^{\text{VIX}}/_{100} \rightarrow \text{VIX} = \sigma \text{ x } 100$
T	Time to expiration
F	Forwards index level derived from index option prices
K_0	First strike below the forward index level, F
K_i	Strike price of i^{th} out-of-the-money option; a call if $K_i > K_0$ and a put if $K_i < K_0$; both put and call if $K_i = K_0$.
ΔK_I	Interval between strike prices – half of the difference between the strike on either side of K_I: $\Delta K_I = \frac{K_{i+1} - K_{i-1}}{2}$
R	Risk-free interest rate expiration
Q(K_i)	The midpoint of the bid-ask spread for each option with strike K_i.

A VIX formula was already presented by *Whaley (2013)* for CBOE on January 19, 1993. The formula above however, is more precise. It was introduced in 2003 and derived *by CBOE and Goldman Sachs(CBOE, 2014)*. They changed the underlying from S&P100 (OEX) to S&P500 (SPX). This is the VIX that we use today, and it is also known as the "new" VIX. The VIX historical close can be traced back to January 1990 until today. Our data will therefore consist of closing prices from January 1990 to January 2017, thus we have a dataset that is 27 years long.

Implied Volatility Data:

CBOE Volatility Index	02.01.1990 – 02.01.2017	Daily observations

4.3 Risky Assets: Equity

The S&P 500 will obviously be representing the equities in our portfolio as it is the underlying of the volatility index we chose. We assume the point of view of an American investor, thus having indices and data in USD currency is of great help. The S&P 500 also represents the overall US stock market in the sense that it is a collection of the top 500 market cap companies listed on the NYSE or NASDAQ index. It is one of the most followed equity indices today, and many believe it to be the best representation of the American stock market and thus, American investor sentiment. With the S&P 500 being so representative of the financial economy in the US, it can capture the different market cycles that has happened through the years.

Equity Data:

Standard & Poor's 500	02.01.1990 – 02.01.2017	Daily observations

4.4 Risk free assets

When we are analyzing strategies for rebalancing against each other, we first and foremost look at the risk return the different strategies yield. Different bond indices could be used in a 60/40 portfolio, including both investment grade bond and high yield. However, choosing between these alternatives would bring several challenges into our problem, as the results of the strategies in question may vary by large margins depending on the indices used as the bond alternative.

Therefore, we thought it best to use American T-bills, as it best represents the risk-free rate and is already in US currency. Having every part of our time series data in the same currency implies that we may completely ignore currency risk and currency shifts. As we are using a 27year long dataset and assume the role of a long term American investor, we chose to use the 10-year US Treasury-bill as our risk-free alternative.

5. Methodology

The rebalancing model in our thesis is a based on a combination between our initial results in terms of volatility, return and correlation of the three-time series, and the research/models of previous researchers.

5.1 Time series correlation

Our results for the correlation between the VIX and the log returns of SPX are in line with the findings of *Alexander and Korovilas (2011)*. For the 27-year long time series the correlation is -0.7129.

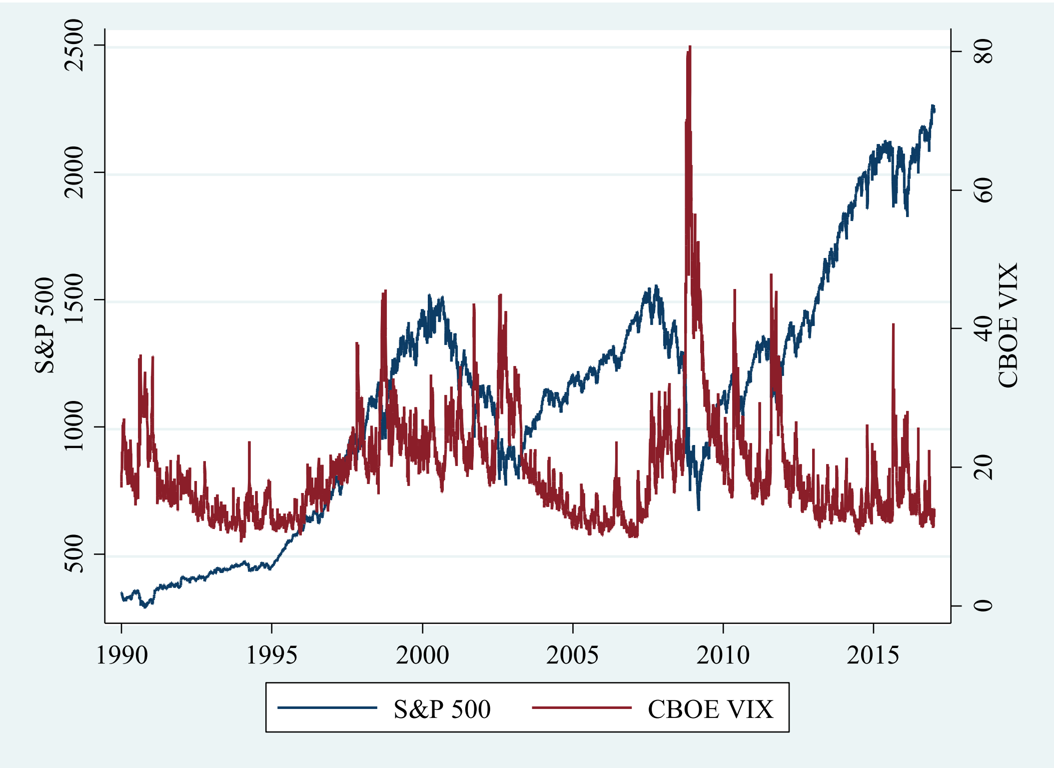

Figure 2 Correlation between CBOE VIX & log return of SPX. Daily data from 1990-2017.

During the financial crisis, the negative correlation is at a higher level, see *figure 3*. From January 2008 until December 2010, we measured the correlation at -0.7875 for the period.

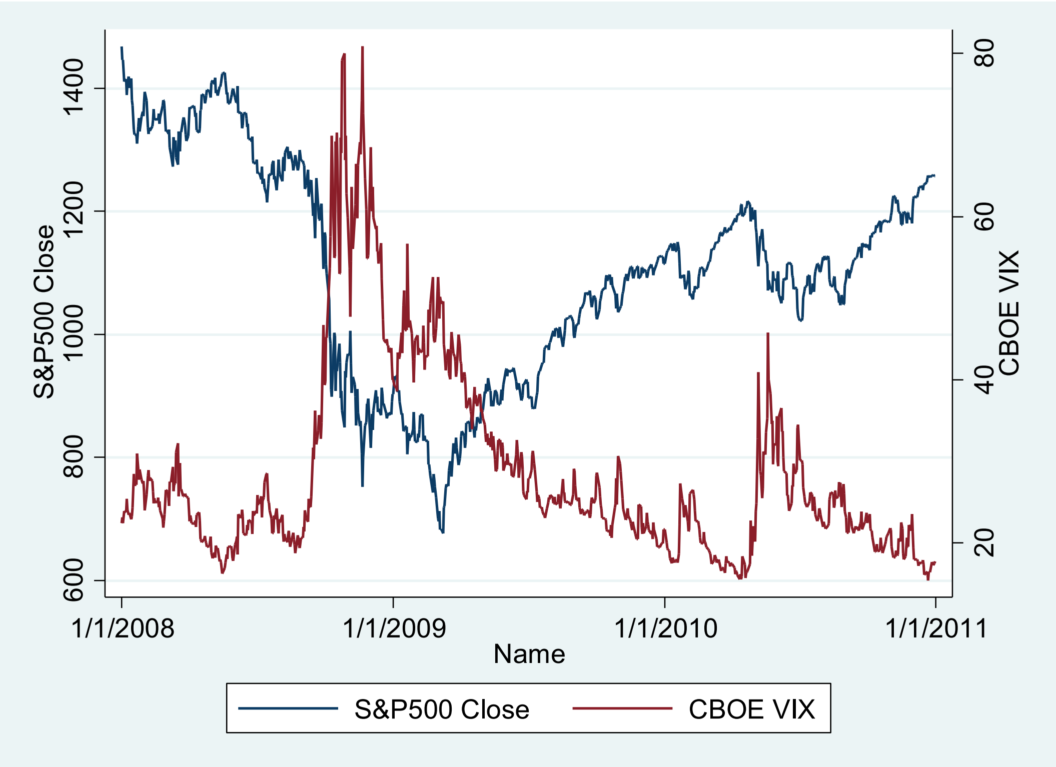

Figure 3 Correlation between CBOE VIX & log return of SPX during the financial crisis.

When we observe price levels of the SPX and T-bills, there is a common trend. However, correlation between the returns of SPX and the returns of T-bills is -0.1921 for the period, suggesting that while both time series have a positive total return, they generate their return at different times, partly inversely of each other. When studying *figure 4*, we see a clear pattern of negative correlation in terms of returns, especially when the volatility of the stock market increases.

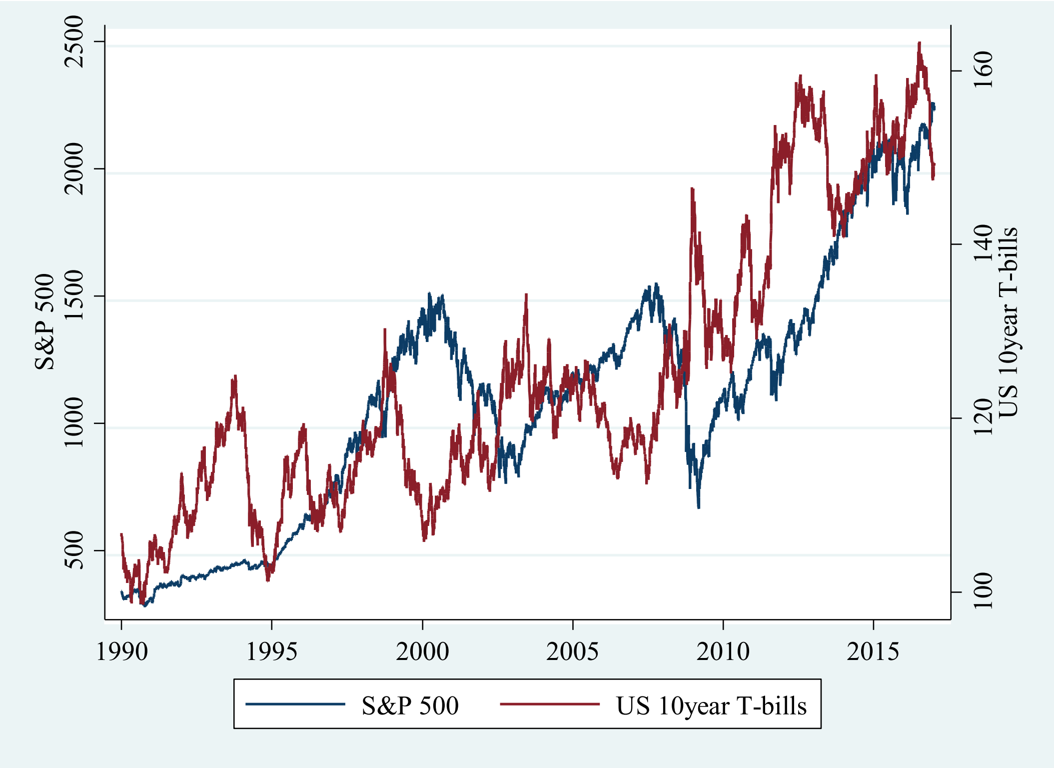

Figure 4 Correlation between 10-year treasury bills & S&P 500 price level. Daily data from 1990-2017

We can see an immediate increase in the closing prices of T-bills when stock market dramatically decreases. This is displayed both during the market crash ending in 2002 and in the financial crisis of 2008. During the period of the latter, the correlation of the SPX and 10year T-bills are -0.3810, which is roughly double of the correlation in the 27-year long dataset. The financial crisis is measured from January 2008 to the end of December 2010.

5.2 Historical Risk and Return

We use daily historical closing prices to find the historical return and volatility. The historical data and statistics is used as the foundation, or rationale for our strategies. When we are incorporating traditional rebalancing and VIX based rebalancing strategies on the data, both the return and risk of the portfolio will change, and we can analyze the top performer. That is the point of it all, anyway.

The historical volatility is measured as the standard deviation of the log returns close price. The natural log of the closing prices can be measured by the following formula.

$$r_n = \ln(C_n/C_{n-1}) \tag{2}$$

ln = natural log

C_n = closing price

C_{n-1} = previous day closing price

Next, we had to calculate the standard deviation of the returns we got in step 1. Standard deviation is the square root of variance, and is calculated as follows:

$$\sigma^2 = \sqrt{\frac{\sum_{i=1}^{n}(r_i - r_{avg})^2}{n-1}} \tag{3}$$

In financial markets, it is normal to look at volatility and returns in annualized form. We get the annualized volatility by multiplying the 1-day volatility by the square root of the number of trading days in a year – which in our case is 252.

S&P 500:

This time series is the daily closing prices of the SPX from 1990 to 2017. We use the historical data of S&P 500 as the equity part of our portfolio. The annual volatility of the S&P 500 was measured at 17.60 %. The annual return was measured at 11.38%. Both statistics are descriptive of a medium to high risk portfolio. Many models and academics use 15% as a standard measure for normal stock volatility.

At 11, 38 % the S&P 500 would be a very profitable investment during the 27-year period. The test portfolio increased from 1 Mill USD to just over 4 Million USD, quadrupling the initial investment over the time frame. The stock market average return being between 8-9 %, the SPX has delivered a high relative return.

US 10 year T-bills

US 10 year T-bills had a sharp decrease following the 2016 US presidential election. The risk-free rate for the 27-year period were measured at 1,09 % with a volatility of 7,21%. T-bills also appears to display a mean reverting price pattern, and does not follow the price pattern to that of stocks. This is a key feature for hedging in periods of uncertainty. The T-bills portfolio only increase by approximately 30% over 27 years. It also contains a considerable amount of volatility, dropping by over 10 percentage points within a year on several occasions. As a result, it is a sub-optimal buy and hold investment. However, the negative correlation with SPX makes it useful as a hedge in times of uncertainty, and we can clearly see positive spikes when the stock market decreases.

5.3 Performance measures description

As our task revolves in ranking different strategies we want to use more performance metrics than historical returns alone. As such we will now describe these metrics where we will highlight the benefits and limitations of each metric, see *Marantika and Nurfiana (2016), Treynor (1962),Sharpe (1966)* and *Modigliani and Modigliani (1997)*.

Sharpe Ratio:

$$\frac{\bar{r}_p - r_f}{\sigma_p} \tag{4}$$

Where:

$\bar{r}_p$: Expected portfolio return

r_f: Risk free rate

σ_p: Portfolio standard deviation

Sharpe ratio measures the amount of return earned per unit of risk. As such, the higher the Sharpe ratio, the better an investment's return have been relative to the amount of investment risk. The main advantage of the Sharpe Ratio is that it measures risk and return relative to itself. Meaning it avoids the Alpha and Beta drawback, two measures relative to each other normally used in fund analysis. As the benchmark is often not comparable to a fund, it is often advantageous to measure the investment to other funds, rather than an index. The disadvantage of the Sharpe Ratio is that it does not take the overall market performance into effect. It is also based upon historical data of return and risk. It is simply not meaningful in other circumstances then comparing raw numbers with other funds or indexes.

Treynor Ratio: $$\frac{r_i - r_f}{\beta_i} \quad (5)$$

Where:

r_i: Portfolio return

r_f: Risk free rate

β_i: Portfolio beta

Like the Sharpe Ratio, Treynor Ratio reflects excess returns per unit of risk. However, by dividing on beta rather than portfolio SD, we get the systematic risk rather than total risk. This metric is good when comparing the portfolio to the market. The beta was calculated from a CAPM regression:

$$\bar{r_p} = r_f + \beta_p \, (\bar{r}_m - r_f) \quad (6)$$

$\beta_p = portfolio\ beta$

$r_f = Risk\ free\ rate$

$\bar{r}_m = expected\ market\ return$

It reflects the excess return of the portfolio relative to its benchmark. Unfortunately, this ratio could be easily manipulated by using a benchmark that is a poor fit to the portfolio. As a lower beta indicates a higher score, we question the usefulness of this ratio when comparing the funds. This also a problem for us, as the allocation of $VIX/\overline{VIX} > 1.5|1.25\ (2)$ and $VIX/\overline{VIX} > 1.3|1.15\ (2)$ use a higher stock allocation than the rest. However, it is a good metric for comparing the other strategies.

Jensen's Alpha:

$$\alpha_p = \bar{r}_p - \left[\, r_f + \beta_p \left(\bar{r}_m - r_f \right) \right] \quad (7)$$

Where:

$\bar{r}_p$ = Expected total portfolio return

r_f = Risk free rate

β_p = Portfolio beta

$\bar{r}_m$ = Expected market return

A risk adjusted performance measure that reflects the average return on a portfolio over and beyond that predicted by the capital asset pricing model (CAPM), given the portfolio beta and the average market return. The advantage of Jensen's Alpha is that it can compare fund managers, including not only returns, but risk as well. It shows raw numbers that based on historical data can tell us how the investment fund managers have performed.

M^2 measure:

Step 1: Calculate Sharpe ratio

Step 2: Multiply Sharpe ratio with the annual standard deviation of benchmark (S&P 500)

Step 3: Add the risk-free rate

$$M^2 = \frac{\bar{r}_p - r_f}{\sigma_p} * \sigma_{bench} + r_f \tag{8}$$

Where:

σ_{bench}: Standard deviation of benchmark

The M^2, or Modigliani squared focuses on the total volatility as the measure for risk, but its risk adjustment leads an easy-to-interpret difference on return relative to its benchmark. For instance, P* is the adjusted portfolio where it has been adjusted to the degree where it has the same standard deviation. Let us assume the active portfolio P has a standard deviation 1,5 times its benchmark. In order to achieve the same amount of risk, we would adjust and put 1/3 of the assets in to T-bills which would give us the same risk as the benchmark. As such the M^2 approach can directly compare the returns of the active portfolio relative to its benchmark. The M^2 approach is easy to interpret and compare. It directly shows how the fund manager performs given risk equal to that of its benchmark. It is useful when comparing performance of an active fund or strategy relative to the market or benchmark. However, the M^2 approach is not a good measurement to compare funds that track various indexes. In our case, some strategies have a higher allocation than others, which might make this metric less applicable to our comparison.

5.4 Previous research and models

Numerous studies have found compelling evidence that implied volatility measurements such as the VIX index are effective in predicting future market volatility for the next 30 days. *Low (2004).* finds evidence that risk is semi dimensional. The study finds that extreme drops in prices lead to rapid increases in risk, while extreme price increases lead to gradual reductions in risk. From previous research, we have been through the fact that trading based on signals from the VIX index works best in times with high volatility. When creating a trading/rebalancing strategy based on the VIX, we are looking at patterns between the VIX, S&P 500 and USBONDS during periods of crisis. When we discussed how to formulate a rebalancing strategy based upon the VIX index ability to predict future volatility, we had to first formulate what high and low volatility implies for the market. In times where the volatility increases by a large amount over a short period of time, it is due to a dramatic fall in stock prices. In times where the expected volatility is low there is a positive investor sentiment, and stock prices are steadily rising *(see figure 2).*

Following the methodology of *Copeland and Copeland (1999),* we examine the impact of percentage changes in the VIX index as a market signal. The percentage changes in the VIX is calculated by subtracting the 75-day moving average of the VIX index from the Day 0 VIX index and then dividing this difference by the 75-day moving average. This eliminates some of the daily "noise" of the VIX index and identifies the percentage changes in the VIX index that are relatively large compared to a 75-day moving average. This percentage change in the VIX index is used as a trading signal to switch between value and growth portfolios. For percentage increases in the VIX index, a long value and short growth portfolio is formed. Similarly, when the VIX index decreases a significant percentage from the 75-day moving average, a long growth and short value portfolio is formed.

Copeland and Copeland (1999) found a significant difference in correlation comparing the VIX to growth and value stocks respectively and developed a simple trading strategy based on that research. In our thesis, the focus is between low risk bonds (T-bills) and stocks (SPX). *Copeland and Copeland (1999)* used a % intraday movement of the VIX compared to its 75-day moving average as a signal to rotate between growth and value stocks. They use different percentages, but overall conclude that high percentages and longer holding periods yields the better results.

Where they shifted their portfolio towards value over growth when a dramatic increase in the VIX occurred, we will shift our portfolio towards bonds (risk free assets) in the same event.

In the relationship between implied and historical volatility, the latter serve as a baseline, while fluctuations in implied volatility is a measure of the relative values of the option premiums. This relationship is often referred to as the volatility risk premium. As investor are buying VIX ETP`s to hedge their portfolios, there is a volatility risk premium for the seller. We calculated the average difference between implied volatility and 1-month historical volatility to be 30%. When creating VIX based trading strategies, this is something that could be beneficial to account for.

We discussed what we expected in terms of results. Analyzing descriptive statistics and previous research we assume that using the VIX ability for volatility prediction will produce a hedge against significant drops in the S&P 500 price in times of great market uncertainty. In summary, we construct a simple balanced portfolio consisting of S&P 500 and T-bills, and rotate between them following an increase or a decrease in the VIX index, much like how *Copeland and Copeland (1999)* rotated between growth and value using the level of the VIX as their indicator.

5.5 Rebalancing schemes and trading strategies

In this chapter, we will describe the theory and excel model used to create each strategy. Some of the rebalancing/rotation strategies have several different allocation strategies. In our opinion, these rotation strategies have specific characteristics, such as timing variables, that may cause a large difference in performance based upon the allocation strategy. The different allocation strategies are indicated with a number in the label/name of the rotation strategy. We are not including transactions costs in this thesis. The overall cost of rebalancing is not significant with the rebalancing frequency being low in a long-time frame.

Label: S&P500

S&P 500 is a representation of the US stock market for the 27-year period. We justify including this time series as we will use it as a comparative tool for the results we are about to discover. The time value of being invested in the stock market is undeniable, especially when the time period is as long as 27 years. We believe it will be interesting to compare the risk adjusted return of the SPX against our portfolios using different allocation and rebalancing strategies.

The series is calculated in excel simply by multiplying portfolio value of day t-1 with 1+Log Return day t.

Excel label: T-bills
We include T-bills as it represents our risk-free rate in the US market for the 27-year period.

Excel label: 60/40 no rebalance
A strategy based on the purpose of allocating the capital in different assets to create diversification and balance the risk. We chose a popular allocation strategy, 60/40 allocation between stocks and bonds, with the aim of being relevant for most investors. This allocation strategy is perhaps the most popular for normal risk aversive investors, and the overall risk of such a portfolio is usually considered to be low to medium. This strategy ignores one of the most essential tools in terms of asset allocation strategies, as it does not maintain the initial stock and bond weights during the time series. As the portfolio is not rebalanced during the 27-year time frame, the portfolio will drift away from the original asset allocation target by a considerable amount, as there is a large difference in the returns gained from stocks compared to the bonds. Intuitively, this will increase the overall volatility of the portfolio. When we had calculated the log returns of SPX and 10year T-bills we simply created the time-series, starting with 600 000 USD in SPX and 400 000 USD in T-bills. It is interesting to see how the most basic investment strategy compares to different strategic and tactical asset allocation schemes over the time period, and it helps to put our results in perspective.

Label: Dynamic
We wanted to test a strategy which reduces the downside risk and ensures that the investment is allocated according to the financial plan. We chose a strategy that combine calendar and threshold strategy. This way, we are only forced to rebalance when there is a significant shift in our strategic weights at a certain point in time. Our goal is to demonstrate the benefit of strategic asset allocation.

Our portfolio starts with a 60/40 allocation between S&P 500 and T-bills. Our observation is at the beginning of the year, every year. This is known as yearly calendar rebalancing. We also included a threshold of 5%. If equity stake rises more than 65% of the portfolio after a year, the portfolio was rebalanced. The same situation if the equity stake reduced to 55% of the portfolio after a year. Combining calendar and threshold rebalancing is commonly referred to as dynamic rebalancing. Professional asset managers have increased the observations per year over time, as the statistical tools and data has become more precise. However, as pointed out by *Jaconetti et al. (2010)* in Vanguard, the risk adjusted returns to be gained by rebalancing with a higher frequency is small or insignificant. In the excel model, we simply rebalanced the portfolio at the beginning of each year, if the five percent threshold we set was breached.

Label: $VIX/\overline{VIX} > 1.5|1.25$ (1) & $VIX/\overline{VIX} > 1.3|1.15$ (1)
The allocation we use for this series is 60% of the portfolio is made up from S&P 500 and 40% 10year US T-bills. The rebalancing framework is inspired by the mode from *Copeland and Copeland (1999)* that rotates the portfolio between asset classes based on dramatic intraday movements in the VIX compared to its 75day moving average. We know from previous research that movements in the VIX are more dramatic when rising then falling, working opposite to that of stocks. By pulling out of the market in times of great uncertainty, we believe we can decrease the overall volatility of the portfolio, without dramatically lowering the return.

When intraday VIX close increases by 50% compared to its 3-month average, the investor will pull out all risky assets. The investor will then "rebalance" the portfolio when the intraday VIX decreases by 25% compared to its 3month average. We also test this with 30% trigger for pull-out and 15% for buying back the risky assets so that the strategy itself is tested for different trigger points.

Label: $VIX/\overline{VIX} > 1.5|1.25$ (2) & $VIX/\overline{VIX} > 1.3|1.15$ (2)
The style rotation occurs at the same dates and is based on the same movements in the VIX as strategy 2. In this case, the asset allocation is 100/0 between stocks and bonds from the start, and rotate to 100% in T-bills, when 3-month moving average is 50% and 30% larger than the VIX level. The explanation behind the strategy assumes that stocks will produce higher returns in times of low volatility and that bonds will increase when the volatility increases dramatically. This also tests for the VIXs ability to predict the stock and bond market simulating a portfolio with a different risk profile.

Label: $VIX/\overline{VIX} > 1.5|1.25$ (3) & $VIX/\overline{VIX} > 1.3|1.15$ (3)
Similar to $VIX/\overline{VIX} > 1.5|1.25$ (1), 60% of the portfolio is made up from S&P 500 and 40% 10year US T-bills. The strategy rotates the portfolio based on dramatic movements in the VIX. This model incorporates a modern asset allocation strategy called dynamic asset allocation.

Dynamic asset allocation rotates the strategic weights based on macro economy factors. Dynamic asset allocation for a balanced fund is always invested in both stocks and bonds, but are weighted differently based on the macro economy. In this allocation strategy, we will rotate from 60/40 to 40/60. When intraday VIX close increases by 50% and 30% compared to its 3-month average we rotate to 40% stocks and 60% bonds. We rebalance the portfolio when intraday VIX decreases by 25% and 15% compared to its 3month average.

Label: VIX level (1)

This strategy assumes that the rebalance/rotation should be based upon the VIX level, rather than a dramatical change in the intraday level compared to a moving average. If for example, the level of the VIX increases from 10 to 15 it would pass the 50% threshold in the Copeland inspired strategies we used earlier. However, the VIX level would still be very low when compared to the historical average. As a result, we decided to use a strategy that uses the total average, rather than a moving average. The average of the VIX is 19.66 for our time series. A 100% in intraday VIX level compared to the total average of 19.66 will trigger a pull out, and shift all allocation towards bonds for a minimum of 30 holding days. Thus, it will trigger if intraday VIX level > (19.66 * 2 = 39.31). The portfolio will shift back towards a 60% stocks and 40 % bonds allocation when half of the reversion to the mean process is completed. Thus, a 50% decrease from 39.31, meaning it will trigger if intraday VIX level < 39.31 – (19.66 * 0.5) = 29.48

Label: $VIX/HVOL > 1.3$ (1), $VIX/HVOL > 1.3$ (2) & $VIX/HVOL > 1.3$ (3)

In this strategy, we measured the 1-month realized volatility and compared it to the VIX. The volatility risk premium in terms of the VIX and realized/historical volatility for the S&P 500 were measured at approximately 30% for the 27year period. In order for this strategy to be similar to the others in terms of number of rotations we added a second contingent based on the VIX level strategy. So, IF: Implied Volatility/Historical Volatility > 1.3 and Implied Volatility > Average Implied Volatility * 1,50. This strategy rotates when the VIX rises beyond a certain point, and when the VIX is higher than historical volatility plus volatility risk premium. The allocation strategy is represented by (1), (2) and (3), and is equal to the allocation strategies used in the $VIX/\overline{VIX}$ rotation strategies.

Label summary:

When reading the through from this point on, we will use a lot of shortened label names. As a result, we wish to highlight the label meaning for the different rebalancing and allocation strategies, see *table 1* and *table 2*.

Allocation label	*Description*
(1)	*Tactical allocation model, starts with 60% stocks and 40%T-bills, rotates to 100% T-bills on rotation trigger, before reallocating to original weights upon second trigger.*
(2)	*Tactical allocation model, starts with 100% stocks and 0% T-bills, rotates to 100% T-bills on rotation trigger, before reallocating to original weights upon second trigger.*
(3)	*Dynamic allocation model, starts with 60% stocks and 40%T-bills, rotates to 40% stocks and 60% T-bills on rotation trigger, before reallocating to original weights upon second trigger.*
No allocation label	*Strategic allocation model, starts with 60% stocks and 40% bonds and reallocates to original weights on every trigger.*

Table 1: Allocation label summary

Rotation/Rebalancing Strategy	*Rotation/Rebalancing Trigger*
No label	*There is no trigger for rebalancing.*
Dynamic	*The trigger is based upon yearly observations with a 5 % drift threshold.*
$VIX/\overline{VIX} > 1.5 \vert 1.25$	*The trigger is based upon an 50% increase in intraday VIX level compared to VIX level 75-day moving average. Second trigger is activated half-way through the mean-reverting process of the VIX level.*
$VIX/\overline{VIX} > 1.3 \vert 1.15$	*The trigger is based upon an 30% increase in intraday VIX level compared to VIX level 75-day moving average. Second trigger is activated half-way through the mean-reverting process of the VIX level.*

VIX level	*The trigger is based upon an 100% increase in the intraday VIX level compared to the total average. Second trigger is activated half-way through the mean-reverting process of the VIX level.*
VIX/HVOL	*This trigger has two contingent that must be fulfilled in order to activate. The first being the intraday VIX level must be 30% higher than the realized 1-month volatility. Secondly, the intraday VIX level must be 50% higher than the VIX total average level. Second trigger is when the intraday VIX level has dropped below 150% of the total average, and 125% of the 1-month realized volatility.*

Table 2: Rotation/rebalancing label summary

6. Results

6.1 Historical returns

In order to answer our problem question, we need to look at the historical performance of each strategy. The historical returns for each strategy are illustrated in figure 5.

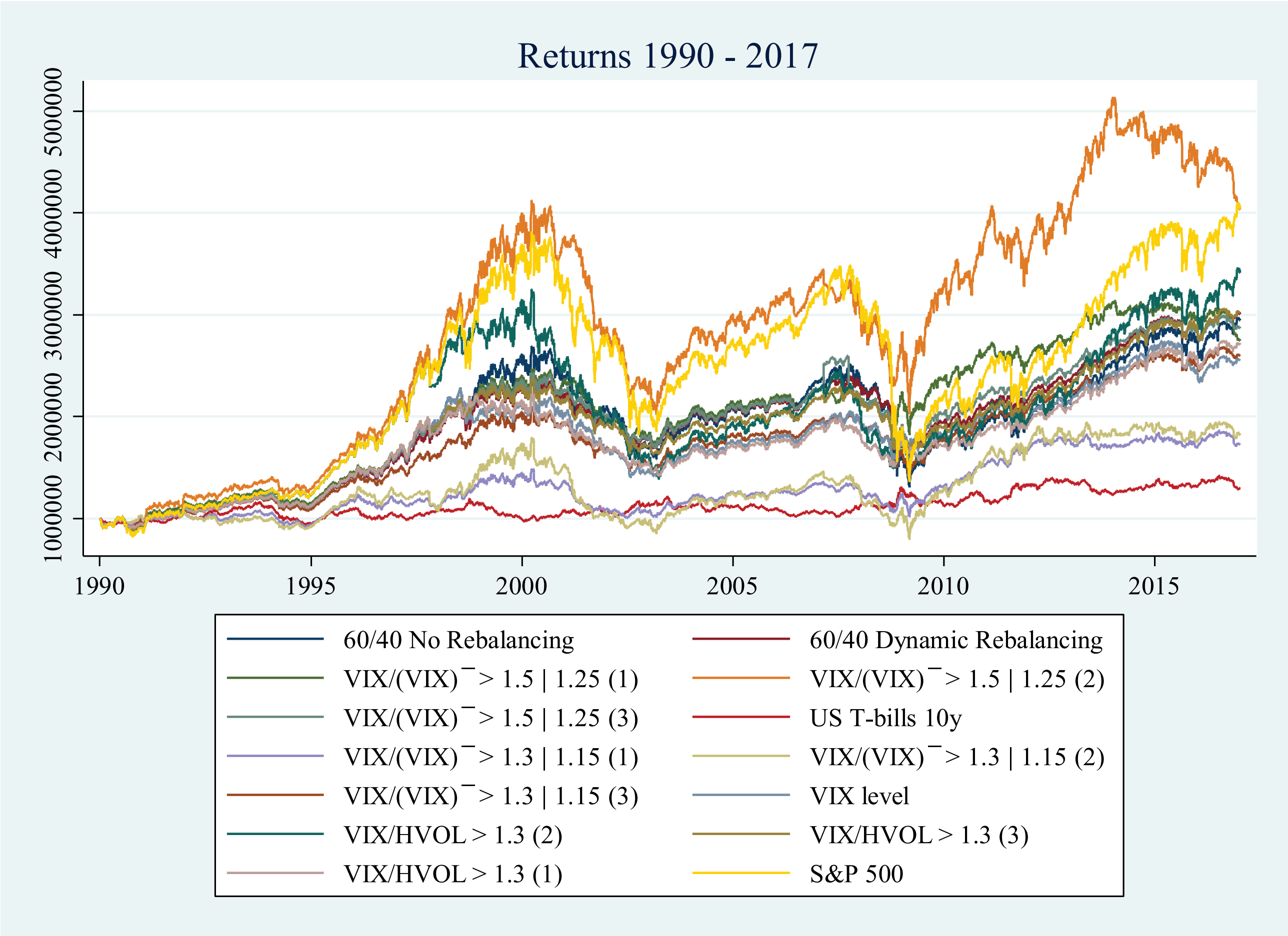

Figure 5 Historical returns for each strategy

There is not a large difference in performance in general when we are looking at the strategies. The obvious strategy that stand out is $IX/\overline{VIX} > 1.5|1.25\ (2)$. This strategy uses a higher stock allocation in general compared to the others, this also why the returns achieved are significantly higher compared to the rest, see chapter 5.2. The annual geometric return of the $VIX/\overline{VIX} > 1.5|1.25\ (2)$ strategy was 11.36 %, only 0,02% lower than S&P 500, but with a considerable lower standard deviation at 14,01 %. This is in line with the theory that due to a negative correlation, rotating to T-bills can be useful as a hedge in bad times.

The dynamic rebalancing strategy had an annual return of 7,48 %. This is not very surprising, as some version of dynamic rebalancing is used by almost every mutual fund manager today. The mechanism provided by this strategy forces the investor to sell "high" and buy "low". As timing, the market has proven time and time again to be virtually impossible, the rebalancing mechanism is maybe as close as we can get. The allocation is also significantly closer to the target compared to not rebalancing at all. When we compare the two, the annual return was 7,27 % for a 60/40 portfolio with no rebalancing. In addition, the dynamic rebalancing strategy has a considerable lower standard deviation, as a result of not having a drift towards risky assets over time.

Strategy	*Total Return* (02.01.1990 – 02.01.2017)
Dynamic	202 %
$VIX/\overline{VIX} > 1.5 \vert 1.25$ (1)	176 %
$VIX/\overline{VIX} > 1.5 \vert 1.25$ (2)	307 %
$VIX/\overline{VIX} > 1.5 \vert 1.25$ (3)	188 %
$VIX/\overline{VIX} > 1.3 \vert 1.15$ (1)	73 %
$VIX/\overline{VIX} > 1.3 \vert 1.15$ (2)	83 %
$VIX/\overline{VIX} > 1.3 \vert 1.15$ (3)	161 %
VIX level	156 %
VIX/HVOL >1.3 (1)	172 %
VIX/HVOL >1.3 (2)	244 %
VIX/HVOL >1.3 (3)	203 %
S&P 500	307 %

Table 3: Strategy: Total return

We can observe a pattern of rebalancing strategies based upon the VIX that may work better than others. Most notably, by looking at *table 3*, there is a clear difference in the returns of the moving average strategies that uses different thresholds, $VIX/\overline{VIX} > 1.5|1.25$ (1), (2) & (3) outperforms $VIX/\overline{VIX} > 1.3|1.15$ (1), (2) and (3) respectively. The $VIX/\overline{VIX} > 1.5|1.25$ (1) strategy gave the investor a respectable 176% return, while the equivalent lower threshold $VIX/\overline{VIX} > 1.3|1.15$ (1) had a total return of only 73%. Similarly, $VIX/\overline{VIX} > 1.3|1.15$ (2) had 83%, which is less than a third of $VIX/\overline{VIX} > 1.5|1.25$ (2). $VIX/\overline{VIX} >$

$1.5|1.25$ (3) also outperformed $VIX/\overline{VIX} > 1.3|1.15$ (3), with total return of 188% against 161%. When we are using higher thresholds, it clearly yields better results in this framework.

The *VIX/HVOL* strategies are not too different from the higher threshold moving average strategies in terms of returns. They all give a respectable return over the time frame. $VIX/\overline{VIX} > 1.5|1.25$ (1) and *VIX/HVOL >1.3 (1)* have almost identical total return. The interesting thing to note here, is the difference between the second and third allocation strategy, when we compare the two style rotation models. $VIX/\overline{VIX} > 1.5|1.25$ (2) is higher than *VIX/HVOL >1.3 (2),* however, *VIX/HVOL >1.3 (3)* is higher than $VIX/\overline{VIX} > 1.5|1.25$ (3). This also goes to show that testing the different rotation styles using different allocation strategies and thresholds is important in order to attain a holistic analysis.

When studying the returns for the different strategies, it is also interesting to see what is causing the difference in returns. Firstly, by using T-bills we are implementing an asset class that is unattractive as a long-term investment due to the low annual returns it produces. Therefore, strategies that on average allocate more towards stocks are likely to produce higher returns over the period.

Strategy	*%Stocks*
S&P 500	*1,00*
VIX/HVOL >1.3 (2)	*0,85*
$VIX/\overline{VIX} > 1.5|1.25$ (2)	*0,83*
60/40 No Rebalancing	*0,75*
$VIX/\overline{VIX} > 1.3|1.15$ (2)	*0,70*
Dynamic Rebalancing	*0,61*
$VIX/\overline{VIX} > 1.3|1.15$ (3)	*0,61*
VIX/HVOL >1.3 (3)	*0,61*
VIX level	*0,60*
$VIX/\overline{VIX} > 1.5|1.25$ (3)	*0,59*
$VIX/\overline{VIX} > 1.5|1.25$ (1)	*0,53*
VIX/HVOL >1.3 (1)	*0,55*
$VIX/\overline{VIX} > 1.3|1.15$ (1)	*0,42*

Table 4: Asset allocation - Stock and bond weights

Table 4 shows the obvious downside to our comparisons is the difference in allocation. We could have chosen to leave out the 100/0 or 0/100 allocation that is used in $VIX/\overline{VIX} > 1.5|1.25$ (2), *VIX/HVOL >1.3* (2) and $VIX/\overline{VIX} > 1.3|1.15$ (2), but we wanted to see the benefits of the strategy using different allocations to see the difference in results.

6.2 Rotation and Rebalancing - Timing

In this chapter, we review specific rebalancing periods and how it affected performance. This chapter will include number of rotations for each strategy and explain the benefits and cons by rebalancing at those dates.

Strategy	*Number of Rebalancing periods*	*Total return in periods*	*Average return per period*	*Stock allocation in periods*	*Number of days in periods*
Dynamic Rebalancing	26	NA	NA	NA	NA
$VIX/\overline{VIX} > 1.5\|1.25$ (1)	19	22,99%	*1,21%*	0%	1173
$VIX/\overline{VIX} > 1.5\|1.25$ (2)	19	22,99%	*1,21%*	0%	1173
$VIX/\overline{VIX} > 1.5\|1.25$ (3)	19	30,17%	*1,59%*	40%	1173
$VIX/\overline{VIX} > 1.3\|1.15$ (1)	39	22,41%	*0,58%*	0%	2137
$VIX/\overline{VIX} > 1.3\|1.15$ (2)	39	22,41%	*0,58%*	0%	2137
$VIX/\overline{VIX} > 1.3\|1.15$ (3)	39	63,67%	*1,63%*	40%	2137
VIX level	7	19,23%	*1,37%*	0%	655
VIX/HVOL >1.3 (1)	27	12,43%	*0,46%*	0%	1064
VIX/HVOL >1.3 (2)	27	12,43%	*0,46%*	0%	1064
VIX/HVOL >1.3 (3)	27	23,36%	*0,87%*	40%	1064
S&P 500	0	NA	NA	NA	NA

Table 5: Rotation and rebalancing statistics

When analyzing how effective the “flight to quality” rotations were, we need see the numbers for each rotation. In table 5, we have summarized the returns given by the rotation periods. The difference in the overall returns for the different strategies can largely be explained by these statistics.

The rotation timing in the Moving average strategies are negatively affected by a lower threshold. The average returns for $VIX/\overline{VIX} > 1.5|1.25$ (1) and $VIX/\overline{VIX} > 1.5|1.25$ (2) are 1,21% per period, while the returns of $VIX/\overline{VIX} > 1.3|1.15$ (1) and $VIX/\overline{VIX} > 1.3|1.15$ (2)

were only 0,58% for the same periods. In addition, the latter strategies are spent almost twice as many days invested in bonds only. $VIX/\overline{VIX} > 1.3|1.15\ (1)$, $VIX/\overline{VIX} > 1.3|1.15\ (2)$ and $VIX/\overline{VIX} > 1.3|1.15\ (3)$ suffered a lot from daily noise. There are several occasions where the VIX level have high daily increases which is not a result of an incoming long-term down-turn in the stock market. There have been several "daily crashes" during the course of our time-series. With lower trigger points, the strategy will rotate more often as a result of "false" market signals or corrections. As the rotation strategy uses a less "attractive" investment alternative in terms of long-term returns, a rotation into T-bills based upon false signals will in most cases decrease the return of the strategy. The S&P 500 fell 64.63, or 6.86% on October 27, 1997, a mini-crash that was a result of economic crisis in Asia. However, on October 28, most of the losses from the previous day were recovered. The portfolios that follow this "flight to quality" allocation used in the VIX based strategies, will not be in the stock market during this "recovery" period, as the trigger forces the strategies to rotate from stocks to T-bills. As previously mentioned, we force the strategies on a 30-day holding period that were in line with the *Copeland and Copeland (1999)* model, and also makes sure it doesn't become a day trading strategy. As a result, the moving average strategies and VIX level will be able to hedge during a consistent market drawback, but will lose returns given by the market when the drawback is short-term (less than 30days). The $VIX/HVOL$ strategies suffer from the same problem, but is timing the rotations even less accurately. The rotation periods only accumulated returns of 0,46% per period on average for (1) and (2).

Surprisingly, the strategies with allocation (3) performs on average better in the rotation periods. As a result, we can say that a "flight to quality" rotation based upon our VIX strategies are on average ineffective. However, in terms of total returns, we cannot so easily draw the same conclusion. As we discussed in the last chapter, the total returns $VIX/\overline{VIX} > 1.5|1.25\ (1)$ and $VIX/\overline{VIX} > 1.5|1.25\ (2)$ are higher than $VIX/\overline{VIX} > 1.5|1.25\ (3)$, even though $VIX/\overline{VIX} > 1.5|1.25\ (3)$ on average performs better in the rotation periods. This can easily be explained by looking at specific periods. A large decrease in a portfolio will greatly affect the long-term returns. This will also suggest that portfolios containing stocks during a market crash will be more prone to having the long-term return greatly decreased. While a high increase will give a similar long-term boost to returns. For example, $VIX/\overline{VIX} > 1.5|1.25\ (1)$ and $VIX/\overline{VIX} > 1.5|1.25\ (2)$ outperforms $VIX/\overline{VIX} > 1.5|1.25\ (3)$ in the middle of the financial crisis by a large margin. From 17.09.2008 – 19.12.2008 the price of T-bills increased by 11,15%, thus dramatically increasing the returns of $VIX/\overline{VIX} > 1.5|1.25\ (1)$ and $VIX/\overline{VIX} >$

1.5|1.25 (2). During the same rotation period, the S&P 500 dropped by 26,41 %, resulting in $VIX/\overline{VIX} > 1.5|1.25\ (3)$ decreasing by 4,24 %. Overall though, this section highlights the fact that our VIX based strategies are inaccurate in terms of rotation timing.

6.3 Performance Evaluation

The performance measures are highlighted in table 6. The table summarizes the descriptive statistics and the performance according to each metric. We refer to the appendix where output regression data is listed for each strategy.

	Performance Summary										
Portfolio	Dynamic	VIX/(VIX)$^{-}$ > 1.5 | 1.25 (1)	VIX/(VIX)$^{-}$ > 1.5 | 1.25 (2)	VIX/(VIX)$^{-}$ > 1.5 | 1.25 (3)	VIX/(VIX)$^{-}$ > 1.3 | 1.15 (1)	VIX/(VIX)$^{-}$ > 1.3 | 1.15 (2)	VIX/(VIX)$^{-}$ > 1.3 | 1.15 (3)	VIX level	VIX/Hvol > 1.3 (1)	VIX/Hvol > 1.3 (2)	VIX/Hvol > 1.3 (3)
Annual Return	0,0748	0,0652	0,1136	0,0697	0,0272	0,0309	0,0595	0,0579	0,0636	0,0904	0,0752
Beta	0,5441	0,3724	0,5511	0,4798	0,2377	0,4411	0,4476	0,4207	0,3376	0,5325	0,5061
Stanard dev.	0,1007	0,0915	0,1401	0,0992	0,0866	0,1301	0,0894	0,0987	0,0899	0,1326	0,0922
Performance measures											
Sharpe ratio	0,6345	0,5928	0,7331	0,5918	0,1875	0,1531	0,5439	0,4761	0,5858	0,5990	0,6974
Treynor	0,1174	0,1456	0,1863	0,1224	0,0683	0,0452	0,1086	0,1116	0,1560	0,1492	0,1270
Jensens Alpha	0,0079	0,0159	0,0460	0,0094	-0,0082	-0,0255	0,0025	0,0037	0,0179	0,0246	0,0122
M squared	0,0087	0,0014	0,0261	0,0012	-0,0699	-0,0760	-0,0072	-0,0191	0,0002	0,0025	0,0198
Ranking											
Sharpe ratio	3	4	1	5	10	11	8	9	7	6	2
Treynor	7	4	1	6	10	11	9	8	2	3	5
Jensens Alpha	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
M squared	3	5	1	6	10	11	8	9	7	4	2
Average	4,33	4,33	1,00	5,67	10,00	11,00	8,33	8,67	5,33	4,33	3,00
Rank	**3**	**3**	**1**	**7**	**10**	**11**	**8**	**9**	**6**	**3**	**2**

Table 6: Performance measures (risk free rate is annual return of US T-bills)

We include these metrics in our thesis as we believe there are several factors that come to play when evaluating performance. An investor is in most cases sensitive to risk, thus metrics that include risk in various ways is a part of our evaluation. $VIX/\overline{VIX} > 1.5|1.25\ (2)$ scored the highest in every metric. The performance metrics are highly dependent on returns and standard deviation. The Sharpe ratio and M^2 measure is based in these metrics exclusively. In addition, a lower beta will also increase the Treynor ratio for each strategy, as it measures systematic risk.

6.3.1 Sharpe ratio

Looking at the performance summary (table 6) we can identify the effectiveness of the different strategies across different objective performance metrics. Sharpe ratio is the most common metric for risk adjusted returns. Comparing the dynamic rebalancing strategy to the others of similar stock allocation, we see that $VIX/HVOL > 1.3\ (3)$ is the only rotation strategy that performs better. The Sharpe for dynamic rebalancing was 0,6345 which is higher than the other strategies with the exception of $VIX/\overline{VIX} > 1.5|1.25$ (2) and $VIX/HVOL > 1.3$ (3). $VIX/\overline{VIX} > 1.5|1.25$ (2) has the highest Sharpe ratio with 0,7331 and $VIX/\overline{VIX} > 1.3|1.15$ (2) has the lowest with 0,1531. It is interesting to see the difference in Sharpe, given that the two different rotation styles had the same allocation strategy. The only thing that separated the two strategies where the threshold for rotation trigger. This is evidence that the style rotation from stocks to bonds and vice versa works better if the trigger is set high. This is in line with previous research calming the VIX can predict the market more accurately in bad times.

6.3.2 Treynor ratio

As we mentioned when we described the performance measures in 5.3, the Treynor ratio is a measure of systematic risk. With the benchmark being S&P 500, the strategies will score higher the more the returns deviate (negatively correlate) with the benchmark. Naturally, strategies that follow the moving average model of style rotation will have a lower Beta than the dynamic rebalancing strategies, which is mostly why the $VIX/\overline{VIX} > 1.5|1.25$ and $VIX/HVOL > 1.3$ strategies have a higher Treynor ratio than dynamic rebalancing. As this model use systematic risk, we can also measure how the strategies can handle times of high volatility or crisis. This is something we feel adds relevant information to how the strategies performed, which is why we decided to include this metric. $VIX/\overline{VIX} > 1.5|1.25$ (2) has the highest Treynor ratio with 0,1863 (table 6). This can be explained by the high returns given by the strategy. $VIX/\overline{VIX} > 1.5|1.25$ (1) has the second highest Treynor ratio with 0,1456. $VIX/\overline{VIX} > 1.5|1.25$ (1) also has the highest returns during the financial crisis, in which we have dated from 01.01.2008 to 31.12.2010 (table 6).

Strategy	*Returns* (01.01.2008 – 31.12.2010)
Dynamic	-13,12 %
$VIX/\overline{VIX} > 1.5\|1.25$ (1)	16,42 %
$VIX/\overline{VIX} > 1.5\|1.25$ (2)	13,83 %
$VIX/\overline{VIX} > 1.5\|1.25$ (3)	-2,16 %
$VIX/\overline{VIX} > 1.3\|1.15$ (1)	15,93 %
$VIX/\overline{VIX} > 1.3\|1.15$ (2)	15,73 %
$VIX/\overline{VIX} > 1.3\|1.15$ (3)	-2,88 %
VIX level	-0,42%
VIX/HVOL >1.3 (1)	-1,69 %
VIX/HVOL >1.3 (2)	-9,23 %
VIX/HVOL >1.3 (3)	-9,00 %
S&P 500	-35,17 %

Table 7: Strategy return during financial crises

A beta below zero, suggests that the strategy has a lower risk than the benchmark which is certainly an advantage during the financial crisis as the benchmark decreased by 35,17 %. The $VIX/\overline{VIX} > 1.3|1.15$ strategies are the only strategies with lower Treynor ratio than dynamic rebalancing in this metric, which is a result of the low total return. We see all the VIX based rotation strategies has higher returns than the dynamic rebalancing strategy during the crisis, proving that rotating to bonds can be a successful hedge during times of very high volatility, see table 7. Rotating to different asset classes during economic downturns is nothing new. This strategy is mentioned by *Næs, Skjeltorp, and Ødegaard (2011)* in their study of liquidity in the stock market during different business cycles, where they discover that investors usually rotate to risk free investments during financial down turns. This strategy is called “flight to quality”.

6.3.3 Jensen's Measure

Although there are some differences in the alpha, none of the Alphas are statistically significantly different from zero and should therefore be disregarded in the evaluation. We will discuss the small differences in alpha and what they may indicate. However, we did not include these differences in the overall ranking as they are not significant.

We use Jensen's Alpha to measure performance rather than the alpha from CAPM, as Jensen's Alpha is better suited to account for the risk. Similar to Treynor ratio, Jensen's Alpha also use beta as a measure of risk. When we are evaluating either different portfolios, strategies or funds it is important to account for risk. Given two investment opportunities with the same expected return, the investment with the lower risk will be the preferred choice. Jensen's Alpha is one of the ways to determine if the strategy is providing the proper amount of return given the level of risk relative to the benchmark. As we are using a 100% equity index as our benchmark, it is unlikely that high or even significant alphas will occur in most of the cases. Dynamic rebalancing, $VIX/\overline{VIX} > 1.5|1.25$ (1), (3) and $VIX/\overline{VIX} > 1.3|1.15$ (3) achieved an alpha of approximately 1%, each deviating by a small amount (see table 6). The $VIX/HVOL$ strategies had an alpha of approximately 1,5%. The other strategies had 0 or negative alpha. $VIX/\overline{VIX} > 1.5|1.25$ (2) have an alpha of 4,6 %. As the Treynor Measure also reflected, this may indicate that the $VIX/\overline{VIX} > 1.5|1.25$ (2) strategy is able to successfully hedge during bad times, as the returns relative to the risk is higher than that of the benchmark.

6.3.4 M^2 Measure

We use Modigliani risk-adjusted performance or M^2 Measure as measure of the risk-adjusted returns of the different strategies relative to the S&P 500. As all our strategies uses S&P 500 in the portfolio, this measure can evaluate which is able to beat the benchmark in terms of risk adjusted returns. Once again, $VIX/\overline{VIX} > 1.5|1.25$ (2) is the number 1 ranking strategy in the category with an M^2 Measure of 0,0261. The M^2 Measure is in units of percentage returns; thus, it is easier to interpret than dimensionless measures such as Sharpe ratio. In the case of $VIX/\overline{VIX} > 1.5|1.25$ (2), this strategy gives 2,61 % more risk adjusted return than the S&P 500 per year. In addition, the *VIX/HVOL >1.3 (3)* strategy has 1,98% higher risk adjusted return per year than the benchmark. The M^2 Measure is directly derived from Sharpe ratio. As a result, the strategies with positive M^2 also have a higher Sharpe ratio than S&P 500. To summarize, this means that dynamic rebalancing, the $VIX/\overline{VIX} > 1.5|1.25$ strategies and the *VIX/HVOL >1.3* strategies all have a higher Sharpe ratio than S&P 500. Those with negative M^2 had a lower Sharpe ratio than S&P 500. The M^2 Measure helps us put that relationship into a more interpretable context.

6.3.5 Summarizing performance

To summarize the performance evaluation, we will use the ranking system from table 6. The clear winner is the $VIX/\overline{VIX} > 1.5|1.25$ (2) strategy. This strategy is as mentioned based on opportunistic rebalancing or tactical allocation, which tries to take advantage of business cycles based upon some kind of macroeconomic intuition or calculation such as the Top-down computation. In our case, this intuition is based on intraday movement in the intraday VIX level compared to its 3-month moving average. The $VIX/\overline{VIX} > 1.5|1.25$ (2) strategy achieves rank 1 in all our metrics, mainly due to the high returns compared to the other strategies. We want to emphasize that $VIX/\overline{VIX} > 1.5|1.25$ (2), $VIX/\overline{VIX} > 1.3|1.15$ (2) and *VIX/HVOL >1.3 (3)* use a different allocation strategy compared other strategies, which could have a large impact on the returns either way. However, as $VIX/\overline{VIX} > 1.3|1.15$ (2) had the lowest score in all our metrics, we have evidence that basing opportunistic rebalancing on primitive VIX level model achieves significantly better results with high trigger points. This is also supported by the other Moving average strategies. $VIX/\overline{VIX} > 1.5|1.25$ (1) and $VIX/\overline{VIX} > 1.5|1.25$ (3) ranks third and seventh place, while $VIX/\overline{VIX} > 1.3|1.15$ (1) and $VIX/\overline{VIX} > 1.3|1.15$ (3) had the two lowest ranks.

Dynamic rebalancing achieves a high score on most of the metrics. In terms of objective risk adjusted returns measured by Sharpe ratio and M^2, it places third, only beaten by $VIX/\overline{VIX} > 1.5|1.25$ (2) which uses a significantly higher on average stock allocation and *VIX/HVOL >1.3 (3).* Overall it places fifth, beaten by $VIX/\overline{VIX} > 1.5|1.25$ (1), $VIX/\overline{VIX} > 1.5|1.25$ (2), *VIX/HVOL >1.3 (2)* and *VIX/HVOL >1.3 (3).* The explanation for the low scores in Treynor ratio, is as mentioned a result of having a higher Beta, and a lower ability to hedge when the stock market decreases.

Overall the summary of the performance measures is indicative that a rebalancing scheme based upon the VIX can work, but that our model needs several adjustments. In terms of our research question, our analysis highlight indications that strategies using a "flight to quality" style rotation based on the VIX, could outperform the dynamic rebalancing model under some circumstances. The dynamic rebalancing scheme is not the highest performing rebalancing method in terms of risk adjusted return if we account for average stock allocation. However, while dynamic rebalancing was placed fifth in the ranking, the objective risk adjusted return measure given my Sharpe ratio and M^2 is more indicative of the overall performance due to biasness in the benchmark. Thus, the dynamic rebalancing strategy was only outperformed by *VIX/HVOL >1.3 (3)* in terms of rebalancing strategies that had a similar average stock allocation in the time-series.

In conclusion, our performance review shows that combining the *VIX/HVOL >1.3* and $VIX > \overline{VIX} * 1{,}50$ rotation model with a dynamic allocation model is something that should be investigated further. In addition, the $VIX/\overline{VIX} > 1.5|1.25$ (2) strategy suggests that being fully invested in equities while rotating to a Bond portfolio only when the intraday VIX level dramatically increases from its moving average can be profitable if the trigger is set to a high percentage. As we discussed in the analysis, the VIX based rotation strategies perform significantly better when the volatility is high. During the financial crisis, all the VIX strategies outperformed the dynamic rebalancing model, which is suggestive of an increase in the VIX predictability of the underlying S&P 500 during a market crash.

7. Conclusion

The previous literature and studies on style rotation based on VIX found significant results for profit gains. However, these results were based on different asset classes than what we are using in our study. We find that using style rotation with a “flight to quality strategy” can give the investor significant risk-adjusted profit margins, however, the framework or “overall strategy” needs to stay true to several principals. Firstly, when using a “flight to quality” rotation based upon the intraday VIX compared to the 75-day moving average, the trigger threshold needs to be set at a high level. The optimal trigger point is uncertain, and could be an interesting topic for further investigation and studies. In addition, we find that using implied volatility/ realized volatility in combination with an intraday VIX level threshold could be a profitable rebalancing strategy if the investor accounts for the volatility risk premium, as shown by the excess returns compared to dynamic rebalancing that resulted from some the implied volatility / historical volatility strategies.

However, as we are measuring several different strategies based upon the VIX and comparing it to a single strategy with dynamic rebalancing, we believe the objective approach would be to review the VIX based strategies as one strategy in the overall conclusion. Thus, we find that on average, the VIX based strategies perform worse than dynamic rebalancing in terms of risk adjusted return and performance. The dynamic rebalancing model came in at shared third in our performance summary, and is the easier strategy to implement for the average investor. In this thesis, the strategy is both proven to give a small return benefit, and also decreases the portfolio volatility, which is in line with previous research.

Even though the overall conclusion landed on dynamic rebalancing to be the preferred choice, we believe that achieving additional risk adjusted return is possible with a tactical allocation approach using the VIX as an indication for rebalancing. When applying VIX based rebalancing schemes, we believe the approach should be reserved to professional investors with experience in volatility markets, and the data analytical tools necessary to find the optimal trigger points for rebalancing. In terms of the average investor, we do not believe our results are evidence that amateur investors should use VIX based rebalancing methods over the dynamic rebalancing method. Dynamic rebalancing still yields a significant increase in risk adjusted returns and the timing effect for taking advantage of market cycles is bullet-proof.

8. References

Alexander, C., & Korovilas, D. (2011). The hazards of volatility diversification. doi:doi.org/10.2139/ssrn.1752389

Bordonado, C., Molnár, P., & Samdal, S. R. (2017). VIX Exchange Traded Products: Price Discovery, Hedging, and Trading Strategy. *Journal of Futures Markets, 37*(2), 164-183. doi:10.1002/fut.21786

Boscaljon, B., Filbeck, G., & Zhao, X. (2011). Market timing using the VIX for style rotation. *Financial Services Review, 20*(1), 35-44. https://search.proquest.com/docview/881048319?accountid=136945

CBOE. (2014). *The CBOE Volatility Index - VIX®*. Retrieved from http://www.cboe.com/micro/vix/vixwhite.pdf

Copeland, M. M., & Copeland, T. E. (1999). Market timing: Style and size rotation using the VIX *Financial Analysts Journal* (Vol. Vol. 55,No2, pp. 73-81). http://www.jstor.org/stable/4480156

Daryanani, G. (2008). Opportunistic Rebalancing: A New Paradigm for Wealth Managers. *Journal of Financial Planning, 21*(1). doi:dx.doi.org/10.2469/dig.v38.n3.33

Dash, S., & Moran, M. T. (2005). VIX as a companion for hedge fund portfolios. *The Journal of Alternative Investments, 8*(3), 75-80. doi:DOI: 10.3905/jai.2005.608034

Fama, E. F., & Schwert, G. W. (1977). Asset returns and inflation. *Journal of financial economics, 5*(2), 115-146. doi:doi.org/10.1016/0304-405X(77)90014-9

French, K. R., Schwert, G. W., & Stambaugh, R. F. (1987). Expected stock returns and volatility. *Journal of financial economics, 19*(1), 3-29. doi:doi.org/10.1016/0304-405X(87)90026-2

Ibbotson, R. G., & Kaplan, P. D. (2000). Does Asset Allocation Policy Explain 40, 90, or 100 Percent of Performance? *Financial Analysts Journal, 56*(1), 26-33. doi:10.2469/faj.v56.n1.2327

Irvine, P. J., & Pontiff, J. (2009). Idiosyncratic Return Volatility, Cash Flows, and Product Market Competition. *Review of Financial Studies, 22*(3), 1149-1177. doi:10.1093/rfs/hhn039

Jaconetti, C. M., Kinniry Jr, F. M., & Zilbering, Y. (2010). Best practices for portfolio rebalancing. *Vanguard*, 16. https://www.vanguard.com/pdf/icrpr.pdf

Low, C. (2004). The fear and exuberance from implied volatility of S&P 100 index options. *The Journal of Business, 77*(3), 527-546. doi:10.1086/386529

Manda, K. (2010). *Stock market volatility during the 2008 financial crisis.* Citeseer.

Marantika, A., & Nurfiana, N. (2016). *RISK AND TURNOVER FROM INVESTING IN EQUITY MUTUAL FUND PERFORMANCE.* Paper presented at the Prosiding International conference on Information Technology and Business (ICITB).

Mariathasan, J., Valensise, M., & Laud, S. (2016, November 2016). Asset Allocation: The 60/40 question. *Investment Pensions Europe*.

Masters, S. J. (2003). Rebalancing. *The Journal of Portfolio Management, 29*(3), 52-57. doi:10.3905/jpm.2003.319883

Merton, R. C. (1980). On estimating the expected return on the market: An exploratory investigation. *Journal of financial economics, 8*(4), 323-361. doi:doi.org/10.1016/0304-405X(80)90007-0

Modigliani, F., & Modigliani, L. (1997). Risk-adjusted performance. *The Journal of Portfolio Management, 23*(2), 45-54. doi:10.3905/jpm.23.2.45

Næs, R., Skjeltorp, J. A., & Ødegaard, B. A. (2011). Stock market liquidity and the business cycle. *The Journal of Finance, 66*(1), 139-176. doi:10.1111/j.1540-6261.2010.01628.x

Sharpe, W. F. (1966). Mutual fund performance. *The Journal of Business, 39*(1), 119-138. http://www.jstor.org/stable/2351741

Tokat, Y., & Wicas, N. W. (2007). Portfolio rebalancing in theory and practice. *The Journal of Investing, 16*(2), 52-59. doi:10.3905/joi.2007.686411

Treynor, J. L. (1962). Jack Treynor's' Toward a Theory of Market Value of Risky Assets'. doi:dx.doi.org/10.2139/ssrn.628187

Vanguard. Retrieved from https://investor.vanguard.com/investing/portfolio-management/rebalance

Whaley, R. E. (2013). Trading Volatility: At What Cost? *The Journal of Portfolio Management, 40*(1). doi:10.2139/ssrn.2261387

9. Appendix

9.1 Regressions

Dynamic Rebalancing:

SAMMENDRAG (UTDATA)

Regresjonsstatistikk	
Multippel R	0,995460374
R-kvadrat	0,990941356
Justert R-kva	0,99094007
Standardfeil	0,000706528
Observasjon	7045

Variansanalyse

	fg	*SK*	*GK*	*F*	*Signifkans-F*
Regresjon	1	0,38459309	0,38459309	770446,411	0
Residualer	7043	0,00351574	4,9918E-07		
Totalt	7044	0,38810883			

	Koeffisienter	*Standardfeil*	*t-Stat*	*P-verdi*	*Nedre 95%*	*Øverste 95%*	*Nedre 95,0%*	*Øverste 95,0%*
Skjæringspu	2,16574E-05	8,4182E-06	2,57268808	0,0101115	5,1552E-06	3,816E-05	5,1552E-06	3,816E-05
X-variabel 1	0,578904318	0,00065953	877,750768	0	0,57761144	0,5801972	0,57761144	0,5801972

$VIX/\overline{VIX} > 1.5|1.25$ (1):

SAMMENDRAG (UTDATA)

Regresjonsstatistikk	
Multippel R	0,77528776
R-kvadrat	0,601071111
Justert R-kva	0,601014469
Standardfeil	0,00387204
Observasjon	7045

Variansanalyse

	fg	*SK*	*GK*	*F*	*Signifkans-F*
Regresjon	1	0,15909914	0,15909914	10611,7756	0
Residualer	7043	0,10559357	1,4993E-05		
Totalt	7044	0,26469271			

	Koeffisienter	*Standardfeil*	*t-Stat*	*P-verdi*	*Nedre 95%*	*Øverste 95%*	*Nedre 95,0%*	*Øverste 95,0%*
Skjæringspu	4,67898E-05	4,6135E-05	1,0141844	0,31052961	-4,3649E-05	0,00013723	-4,3649E-05	0,00013723
X-variabel 1	0,372355613	0,00361463	103,013473	0	0,36526985	0,37944138	0,36526985	0,37944138

$VIX/\overline{VIX} > 1.5|1.25$ (2):

SAMMENDRAG (UTDATA)

Regresjonsstatistikk	
Multippel R	0,774174828
R-kvadrat	0,599346665
Justert R-kva	0,599289778
Standardfeil	0,006272296
Observasjon	7045

Variansanalyse

	fg	SK	GK	F	Signifkans-F
Regresjon	1	0,4144958	0,4144958	10535,7879	0
Residualer	7043	0,27708359	3,9342E-05		
Totalt	7044	0,69157939			

	Koeffisienter	Standardfeil	t-Stat	P-verdi	Nederste 95%	Øverste 95%	Nedre 95,0%	Øverste 95,0%
Skjæringspu	6,0557E-05	7,4734E-05	0,81030257	0,41779368	-8,5944E-05	0,00020706	-8,5944E-05	0,00020706
X-variabel 1	0,600988436	0,00585508	102,643986	0	0,58951072	0,61246615	0,58951072	0,61246615

$VIX/\overline{VIX} > 1.5|1.25$ (3):

SAMMENDRAG (UTDATA)

Regresjonsstatistikk	
Multippel R	0,969252832
R-kvadrat	0,939451053
Justert R-kva	0,939442456
Standardfeil	0,00168913
Observasjon	7045

Variansanalyse

	fg	SK	GK	F	Signifkans-F
Regresjon	1	0,3117821	0,3117821	109276,116	0
Residualer	7043	0,0200948	2,8532E-06		
Totalt	7044	0,3318769			

	Koeffisienter	Standardfeil	t-Stat	P-verdi	Nederste 95%	Øverste 95%	Nedre 95,0%	Øverste 95,0%
Skjæringspu	2,37558E-05	2,0126E-05	1,18036457	0,23789511	-1,5697E-05	6,3208E-05	-1,5697E-05	6,3208E-05
X-variabel 1	0,521232681	0,00157677	330,569381	0	0,51814173	0,52432363	0,51814173	0,52432363

$VIX/\overline{VIX} > 1.3|1.15$ (1):

SAMMENDRAG (UTDATA)

Regresjonsstatistikk	
Multippel R	0,70461554
R-kvadrat	0,496483059
Justert R-kva	0,496411567
Standardfeil	0,003901616
Observasjon	7045

Variansanalyse

	fg	SK	GK	F	Signifkans-F
Regresjon	1	0,10571512	0,10571512	6944,61278	0
Residualer	7043	0,10721283	1,5223E-05		
Totalt	7044	0,21292794			

	Koeffisienter	Standardfeil	t-Stat	P-verdi	Nederste 95%	Øverste 95%	Nedre 95,0%	Øverste 95,0%
Skjæringspu	-1,5161E-05	4,6487E-05	-0,32612642	0,7443384	-0,00010629	7,5968E-05	-0,00010629	7,5968E-05
X-variabel 1	0,303511111	0,00364209	83,3343433	0	0,29637152	0,3106507	0,29637152	0,3106507

$VIX/\overline{VIX} > 1.3|1.15$ (2):

SAMMENDRAG (UTDATA)

Regresjonsstatistikk	
Multippel R	0,706153019
R-kvadrat	0,498652086
Justert R-kva	0,498580902
Standardfeil	0,00638232
Observasjon	7045

Variansanalyse

	fg	*SK*	*GK*	*F*	*Signifkans-F*
Regresjon	1	0,28534698	0,28534698	7005,12867	0
Residualer	7043	0,28688963	4,0734E-05		
Totalt	7044	0,57223662			

	Koeffisienter	*Standardfeil*	*t-Stat*	*P-verdi*	*Nederste 95%*	*Øverste 95%*	*Nedre 95,0%*	*Øverste 95,0%*
Skjæringspu	-3,69592E-05	7,6045E-05	-0,48601946	0,62696849	-0,00018603	0,00011211	-0,00018603	0,00011211
X-variabel 1	0,498646403	0,00595778	83,6966467	0	0,48696736	0,51032545	0,48696736	0,51032545

$VIX/\overline{VIX} > 1.3|1.15$ (3):

SAMMENDRAG (UTDATA)

Regresjonsstatistikk	
Multippel R	0,968671106
R-kvadrat	0,938323712
Justert R-kva	0,938314955
Standardfeil	0,001611594
Observasjon	7045

Variansanalyse

	fg	*SK*	*GK*	*F*	*Signifkans-F*
Regresjon	1	0,27829375	0,27829375	107149,994	0
Residualer	7043	0,01829233	2,5972E-06		
Totalt	7044	0,29658608			

	Koeffisienter	*Standardfeil*	*t-Stat*	*P-verdi*	*Nederste 95%*	*Øverste 95%*	*Nedre 95,0%*	*Øverste 95,0%*
Skjæringspu	1,39812E-05	1,9202E-05	0,72811215	0,46656914	-2,366E-05	5,1623E-05	-2,366E-05	5,1623E-05
X-variabel 1	0,492445048	0,00150439	327,337737	0	0,48949598	0,49539411	0,48949598	0,49539411

VIX level:

SAMMENDRAG (UTDATA)

Regresjonsstatistikk	
Multippel R	0,80126908
R-kvadrat	0,64203214
Justert R-kva	0,64198131
Standardfeil	0,00401
Observasjon	7045

Variansanalyse

	fg	*SK*	*GK*	*F*	*Signifkans-F*
Regresjon	1	0,20312309	0,20312309	12631,9506	0
Residualer	7043	0,11325218	1,608E-05		
Totalt	7044	0,31637527			

	Koeffisienter	*Standardfeil*	*t-Stat*	*P-verdi*	*Nederste 95%*	*Øverste 95%*	*Nedre 95,0%*	*Øverste 95,0%*
Skjæringspu	2,2489E-05	4,7779E-05	0,47068495	0,63788031	-7,1172E-05	0,00011615	-7,1172E-05	0,00011615
X-variabel 1	0,42071277	0,00374326	112,391951	0	0,41337485	0,4280507	0,41337485	0,4280507

VIX/HVOL >1.3 (1):

SAMMENDRAG (UTDATA)

Regresjonsstatistikk	
Multippel R	0,727653518
R-kvadrat	0,529479642
Justert R-kva	0,529412835
Standardfeil	0,004062355
Observasjon	7045

Variansanalyse

	fg	*SK*	*GK*	*F*	*Signifkans-F*
Regresjon	1	0,13079296	0,13079296	7925,53406	0
Residualer	7043	0,11622874	1,6503E-05		
Totalt	7044	0,2470217			

	Koeffisienter	*Standardfeil*	*t-Stat*	*P-verdi*	*Nederste 95%*	*Øverste 95%*	*Nedre 95,0%*	*Øverste 95,0%*
Skjæringspu	4,34227E-05	4,8403E-05	0,89711628	0,36968754	-5,1461E-05	0,00013831	-5,1461E-05	0,00013831
X-variabel 1	0,337596736	0,00379214	89,0254686	0	0,33016301	0,34503046	0,33016301	0,34503046

VIX/HVOL >1.3 (2):

SAMMENDRAG (UTDATA)

Regresjonsstatistikk	
Multippel R	0,72982051
R-kvadrat	0,53263797
Justert R-kva	0,53257161
Standardfeil	0,00636667
Observasjon	7045

Variansanalyse

	fg	*SK*	*GK*	*F*	*Signifkans-F*
Regresjon	1	0,3253578	0,3253578	8026,68805	0
Residualer	7043	0,2854845	4,0535E-05		
Totalt	7044	0,6108423			

	Koeffisienter	*Standardfeil*	*t-Stat*	*P-verdi*	*Nederste 95%*	*Øverste 95%*	*Nedre 95,0%*	*Øverste 95,0%*
Skjæringspu	4,7203E-05	7,5858E-05	0,62225826	0,53379221	-0,0001015	0,00019591	-0,0001015	0,00019591
X-variabel 1	0,5324596	0,00594317	89,5917856	0	0,52080919	0,54411001	0,52080919	0,54411001

VIX/HVOL >1.3 (3):

SAMMENDRAG (UTDATA)

Regresjonsstatistikk	
Multippel R	0,96127685
R-kvadrat	0,92405318
Justert R-kva	0,92404239
Standardfeil	0,00185208
Observasjon	7045

Variansanalyse

	fg	*SK*	*GK*	*F*	*Signifkans-F*
Regresjon	1	0,29394252	0,29394252	85692,9402	0
Residualer	7043	0,02415878	3,4302E-06		
Totalt	7044	0,31810131			

	Koeffisienter	*Standardfeil*	*t-Stat*	*P-verdi*	*Nederste 95%*	*Øverste 95%*	*Nedre 95,0%*	*Øverste 95,0%*
Skjæringspu	3,3265E-05	2,2067E-05	1,5074503	0,13174012	-9,9932E-06	7,6524E-05	-9,9932E-06	7,6524E-05
X-variabel 1	0,50610107	0,00172888	292,733565	0	0,50271195	0,5094902	0,50271195	0,5094902