CBA Copenhagen Business School
MSc in EBA Finance & Investment
Master Thesis 2017

CONFRONTING THE VOLATILITY RISK PREMIUM ON THE S&P500 INDEX

- AN EMPIRICAL STUDY

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Supervisor:
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Time of submission:
May 15, 2017
Page numbers and characters:
120 pages, 247,135 characters

Abstract

This thesis examines the effectiveness of different short vega option combinations' ability to capture the volatility risk premium on the S&P500 index. We find evidence that delta neutrality of the option combinations is required to gain factor exposure linked to the volatility risk premium. The short delta-hedged strangle proves to be the most profitable strategy to capture the volatility risk premium. However, neither of the initially tested strategies yields statistically significant returns. Using market timing indicators based on moving averages of the VIX- and CDX index, the returns of the option combinations considered are consistently improved and yield statistically significant returns. When considering transaction costs and margin requirements faced when trying to capture the volatility risk premium, the investment doesn't seem as attractive, but is perusable when using market timing indicators.

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Chapter 1 - Introduction

Recent studies find evidence that trading long at-the-money straddles consistently yield losses. This finding can be interpreted as evidence for non-redundancy of options and the existence of a volatility risk premium. The thesis is an empirical study, which analyses different option combinations designed to capture the volatility risk premium. The return properties of four different option combinations are analysed: Short straddle, short strangle, long iron butterfly and long iron condor. The analysis will clarify the empirical properties of each option combination and determine which appropriate strategy to implement when capturing the volatility risk premium.

This thesis aims at clarifying whether the use of market timing indicators and delta hedging can improve the performance of option strategies, which capture the volatility risk premium. Furthermore, the analysis will provide insight into the profitability of capturing the volatility risk premium when accounting for transaction costs and margin requirements. This is done by applying different frequencies of delta hedging to the strategies and studying the impact on the ability to capture the volatility risk premium. Having analysed the strategies' excess returns we will use regression analysis to examine if exogenous factors can explain the returns of the different strategies.

After analysing the impact of delta hedging, we investigate the use of market timing indicators on the strategies. With different moving averages from the VIX- and CDX index, we examine if they can be used as consistent market timing indicators and thereby enhance the performance of the strategies. We present the results of the best performing strategies for respectively the short straddle, the short strangle, the long iron butterfly, and the long iron condor with the use of indicators. The strategies are evaluated based on the overall performance of returns, Sharpe ratios and risk measures. We only consider weekly and daily delta-hedged strategies, as initial delta neutral strategies that are not delta-hedged in the holding period show dependence on the market, which is undesirable when capturing the volatility risk premium.

We then analyse how the strategies' performance changes when certain variables are altered. This provides a deeper understating of the strategies' empirical properties. The variables considered are the sample period, transaction costs and initial moneyness of the options used.

Our results align with findings from Coval & Shumway, Santa-Clara & Saretto and Goltz & Lai, etc. These papers examine different aspects of the volatility risk premium. We extend their individual analysis to include other option combinations with similar properties as the short straddle, but with different degrees of risk. Furthermore, we investigate the effect of using market timing indicators on the performance of short vega strategies, which captures the volatility risk premium.

The thesis is organized as follows. Chapter 1 includes the motivation for this thesis' subject, the research questions and belonging sub-questions. Also, this chapter describes the delimitations of the research object and a description of the data used throughout the thesis. Chapter 2 presents the theoretical fundament for the thesis. Chapter 3 presents the results of the empirical analysis of the option strategies. Methods and relevant factors affecting the strategies' performance are discussed in chapter 4. In chapter 5, an overview of further relevant research is provided. In chapter 6, we provide the concluding remarks of our findings. The remaining chapters include the bibliography, list of figures and tables and the appendix.

1.1 Motivation

It is a well-known fact that index options on the S&P500 sell at relatively high prices. There are two empirical observations that support this statement. First, the implied volatility extracted from ATM options, produce mostly higher prices compared to measures of volatility based on the variability of the underlying returns (realized volatility). Second, several papers present the conclusion that issuers of options tend to earn very high returns *(Santa-Clara & Saretto, 2004)*, while taking on low risk when comparing to an investment in the underlying asset. Figure 1.1 illustrates how the expected volatility under Q (measured by VIX) and the realized volatility have evolved historically and also the spread between these are presented. This implies a positive implied-realized volatility spread of 3.4% on average. The positive spread is consistent with the findings in related literature such as that of Ilmanen *(2011)*, which report spreads between 2% and 4%. In literature, the spread is referred to as the volatility risk premium, which is compensation to the investor for taking on risk of sudden changes in the market.

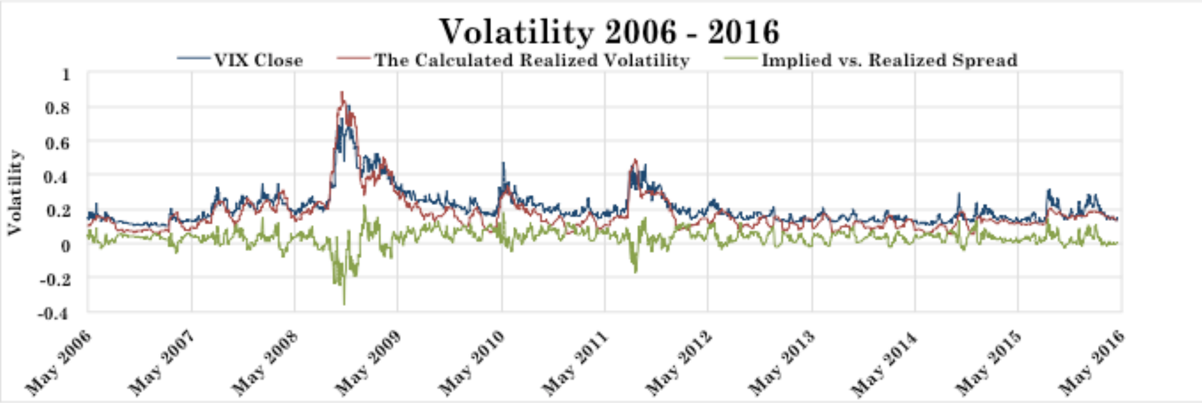

Figure 1.1 – Implied and historical volatility from May 2006 to May 2016

As shown in Figure 1.1 we expect the volatility on average to be lower than what is implied by option prices, and therefore we will use strategies that benefit from this pattern. The option combinations used are all short vega and can potentially profitably capture the volatility risk premium. Further they have various degrees of risk. First, because they are created using varying strike prices, which affect the profit range. Second, two of the option combinations are naked positions while the other two are protected positions. The combinations and their application will be further explained in section 2.4. To capture the volatility risk premium, it is necessary to be delta neutral throughout the holding period, to minimize the exposure to price movements in the underlying asset. We therefore apply delta hedging of the combinations mentioned above with daily and weekly hedging frequencies.

1.2 Research question

Can market timing indicators and delta hedging improve the performance of option strategies, which captures the volatility risk premium?

Is it profitable to capture the volatility risk premium when considering costs and margin requirements of doing so?

Given our research questions, two sub-questions have been formulated to create an overview of the analysis. We present the sub-questions and the relevance of these in the following section.

Sub-question 1: *What is the effect of different delta hedging frequencies on the ability to capture the volatility risk premium?*

We will compare the excess returns of the option strategies while applying daily and weekly delta hedging to the initial delta neutral positions. This will allow us to see the effect of hedging frequencies, while also examining the volatility risk premium. A regression of the results will be used in the analysis to examine which exogenous factors drive the return of each strategy.

Sub-question 2: *By using different moving averages of the VIX- and CDX index as market timing indicators, can the volatility risk premium be captured more efficiently?*

This sub-question analyses whether the VIX- and CDX index can enhance the results from sub-question 1 compared to performance- and risk measures when taking past market trends into account.

1.3 Delimitation

Tax

We delimitate from taxes in both gains and losses, as this is not the focus of the thesis. The taxation is very different depending on the type of entity, which is implementing the strategy. We will however briefly discuss the effect of taxes on the returns in the discussion, but this will not be implemented into the analysis.

Risk free proxy

The risk-free proxy used in this thesis is the OIS rate, which we find to be the closes to the definition of a riskless instrument. We will elaborate on this choice in section 2.7.

Option strategies

The option strategies used in this thesis is a short straddle, short strangle, long iron butterfly and long iron condor. These are initially short vega, and will therefore provide exposure towards the volatility risk premium investigated in this thesis. We will not consider other types of derivatives like variance swaps or additional option combinations.

Market timing indicators

The VIX and CDX indices are chosen as market timing indicators. These measure two different types of risk. The VIX measures the risk in the market and the CDX measures the credit risk within companies. The indices have a correlation of 0.84, hence they do not measure risk equal and can therefore give us two aspects, when trading on signals from these indicators. We will not analyse other market timing indicators but will briefly discuss whether there are other indicators, which could have been used.

Transaction costs

We include transaction costs in the sense that we buy and sell at the available prices in the market at the time the trade is initiated. We use the bid price when selling options and use the ask price when buying options. This is a conservative price compared to other research papers that use the midpoint of the bid-ask spread. Along with the bid and ask prices the real world also demand additional transaction cost per trade entered in the form of brokerage fees. This cost varies among traders and companies, and therefore we do not take this cost into account.

When delta hedging with futures we use the closing price whether we long or short the futures contract. In the real world, there are transaction costs for each trade in futures contract and this is also omitted in this thesis. The influence of transaction costs will be discussed in section 4.3.

1.4 Data & methodology

This section will outline the various data sources that have been used to gather relevant information for the thesis. Further, we will describe in detail how we have cleaned the data using various filters to ensure that only realistic traded options are included in the final sample.

1.4.1 Option & index data

Our primary source of option data for the thesis has been collected from Wharton Research Data Services *(WRDS Option Prices)*. The dataset spans from May 2006 to May 2016, where May 2016 represents the latest available data. The options data include European index options on the S&P500 index (SPX) drawn from the Option Metrics Ivy DB database *(OptionMetrics, 2011)*. The database records information on exchange listed options on the U.S. exchange equity market and include daily closing bid-ask quotes, strike prices, trading volumes, open interests, implied volatilities, option Greeks etc.

The options data have been filtered using similar parameters as Goyal & Saretto *(2008)* and Franzzini & Pedersen *(2012)*. This is done to minimize the impact of recording errors. All options with non-standard settlement or non-standard expiration dates are discarded. Further we remove all observations for which the bid price exceeds the ask price, the bid price is equals to zero or the bid-ask spread is lower than the minimum tick size, which is equal to $0.05 for options trading below $3 and $0.10 in any other case.

Additionally, we are aware of the risk of having look-ahead bias, which is created by using information or data that was not available at the time the trades would have been entered. To ensure this is avoided we include additional filters on the data to certify the results are not inaccurate. We require that all options in the dataset have a positive open interest and non-missing information such as Greeks, implied volatility etc. Further we discard options violating the basic arbitrage bound of a non-negative "time value" which is calculated as $F - V$, where F is the option price and V is the intrinsic value equal to $Max(S - K; 0)$ for calls and $Max(K - S; 0)$ for puts. S is the price of the underlying and K is the strike price of the option.

The option strategies are all constructed to be initially delta neutral and with a holding period of approximately one month. Thus, we only include options with maturity between 25 and 35 days. We only include options ranging from slightly ITM to DOTM (Deep OTM). This is achieved by: $\Delta < |0.5| + 5\%$. This enables us to create the mentioned option combinations, as they are all constructed using options ranging ATM to DOTM.

In addition to the information obtained through the Option Metrics database we use Bloomberg to gather the opening spreads of the credit default swap index CDX.NA.IG. We use Yahoo Finance to get the daily historical opening prices of VIX and the daily adjusted closing prices of the S&P500 index.

The adjusted closing price of the S&P500 index is linked to the expiration date of each option to calculate the individual payoffs. The opening values of VIX, CDX and their respective moving averages of varying length are linked to the options pricing date. This is done because these values are used as trading signals and is used on the day of the trade to assess whether the trade should be entered or not.

The final sample after the cleaning and filtering process include 138,780 index options on the S&P500 index.

1.4.2 Risk free proxy, factor data & further research

The data for the risk-free proxy is gathered from Thomson Reuters Datastream extracted using Excel datastream tools and is the monthly dollar OIS rate.

The inputs used in the regression analysis consist of the trading volume in the underlying asset, the VIX index and a credit spread. We obtain the trading volume and VIX data from Yahoo Finance and the credit spread is collected from the Federal Reserve Economic Data. The credit spread is the spread between a monthly Treasury rate and a monthly Moody's seasoned Aaa corporate bond yield (not seasoned adjusted).

The data used for further research includes historic data from three indices; TED spread, CISS and CFSI. The data representing the TED spread is collected from Federal Reserve Economic Data *(Federal Reserve Bank of Cleveland)*. The CISS and CFSI data is collected from the European Central Bank (European Central Bank Data).

1.4.3 Methodology of option combinations

In the following we will describe how we construct the different option combinations used throughout the thesis. The option combinations are as follows:

- Short straddle
- Short strangle
- Long iron butterfly
- Long iron condor

The short straddle is constructed by shorting a call and a put option that are both trading ATM, meaning that they have moneyness of 1. The options that are used for each short straddle is chosen so they fulfill the condition: $Min(0.5 - |\Delta_{option}|)$. Additionally, the options are traded on the same day, have the same expiration date and have the same strike price. The initial delta of the short straddles ranges from [-0.0173 – 0.0184] with an average of 0.00079.

The short strangle is constructed by shorting a call and a put option that are both trading OTM. When options are OTM the moneyness is less than 1. The options that are used for each short strangle is chosen so they fulfill the condition: $Min(0.4 - |\Delta_{option}|)$. We set the delta of the options used equal to 0.4 as a starting point and we will in the discussion vary the delta to see how this affects the results. Additionally, the options are traded on the same day and have the same expiration date. The initial delta of the short strangles ranges from [-0.0332 – 0.0455] with an average of 0.00056.

Adding a long strangle to the short straddle mentioned above creates the iron butterfly. The options used to construct the long strangle is chosen so they fulfill the condition:

$Min(0.4 - |\Delta_{option}|)$. Again, we set the delta of the options used to form the strangle to be the same as we used above, and will in the discussion change the delta to see how it affects the results. Additionally, all options are traded on the same day and have the same expiration date. The initial delta of the long iron butterflies ranges from [-0.0987 – 0.0549] with an average of 0.00179.

By adding a long strangle constructed with deeper OTM options to the short strangle described above, the long iron condor is created. The options used to construct the long strangle is chosen so they fulfill the condition: $Min\,(0.3 - |\Delta_{option}|)$. For the long iron condor, we will use 0.3 as the starting point for the deltas of the options used for the long strangle and later in the discussion change the delta to see how it affects the results. Additionally, all options are traded on the same day and have the same expiration date. The initial delta of the long iron condor ranges from [-0.0432 – 0.0401] with an average of -0.0001.

These strategies will be used as the benchmark when considering the strategies that use a market timing indicators.

We will allow for delta to have slight differences from zero and we will still refer to the combinations as being initially delta neutral. This is permitted to make our empirical tests closer to an implementable strategy.

Exchange-listed index options expire on the Saturday immediately following the third Friday of the expiration month. As we only do one option combination trade (consisting of up to four individual options) per month, we will compute the return on the first trading day following the expiration of the option contracts. This accumulates to 120 returns for our benchmark strategies during our ten-year estimation period.

1.4.4 Data for delta hedging

In this section, we want to outline the inputs that are used to calculate the delta of the individual option strategies. The actual process of delta hedging will be discussed in section 2.3.

We chose to delta hedge our strategies with S&P500 E-Mini futures contracts. The reason for the use of E-mini futures is that the multiplier is half the size of the regular futures contracts, which means that there is a higher probability that the number of contracts is closer to a whole number. The data of the S&P500 E-Mini futures are collected from Investing.com *(Investing.com, 2007)*. We use similar filtering methods for the futures data as with the options data to ensure that we do not have any look-ahead biases with this data either.

We assume that it is possible to trade partial futures contracts e.g. 0.43. This is not possible in practice, but we will allow for this regardless. The reason for this decision is that we use the smallest number of contracts possible to form the option combinations, e.g. for the short straddle we short one put and one call option. This makes hedging difficult if we only allow for whole futures contracts. The application of using partial futures does not compromise the validity of this thesis as investors in practice trade several contracts at a time, making hedging with whole contracts easier by rounding to the nearest whole number of contracts.

We calculate the new deltas using the option data collected from WRDS i.e. spot price of underlying, strike price, implied volatility, dividend yield of the S&P500 and the monthly OIS rate from Thomson Reuters Datastream. The delta calculation is based on the Black-Scholes-Merton framework (BSM).

Chapter 2 - Theory

This section will begin with a description of the characteristics of call and put options. The Greek letters defines the risks associated with trading options. Further the development of risk over the lifetime of the option and with respect to changes in the value of the underlying are presented. When the reader has been familiarized with option characteristics, the four option combinations used throughout this thesis will be described in depth.

Furthermore, the volatility and the risk free proxy are presented. Each investor has different opinions of which risk free proxy and what exact value of volatility to use. Our choice of volatility and risk free proxy will affect the delta calculation, which will have an effect on the final result. We will also present the VIX- and CDX index, which are used as market timing indicators.

Finally, the performance measures used to evaluate the returns of each strategy is presented followed by the model that is used to regress the returns of the strategies against. The regressions are used to understand the source of the returns and thereby understand which factors influence the returns positively and negatively.

2.1 Options

In this thesis, we use both long and short European options. When going long, the option is bought at a premium and conversely we receive a premium when selling the contract. The premium can be calculated using different option pricing models of which the most common benchmark is the BSM framework.

The concept of moneyness describes the value of the option. An option can either be in-the-money (ITM), at-the-money (ATM) or out-of-the-money (OTM). An ATM option has a strike price equal to the price of the underlying asset and moneyness equal to 1. An ITM option has moneyness higher than 1, whereas OTM option has moneyness lower than 1. The focus in this thesis will be on options with moneyness ranging from ATM to OTM.

How much profit the individual options yield is determined by the intrinsic value and the time value. The intrinsic value of the relevant options is illustrated in Table 2.1, where the stock price with maturity T is referred to as S_T and K is the strike price. The time value is the difference between the intrinsic value and the premium from the option. European options do not have any exercisable time value, as these are only possible to exercise at maturity opposite American options *(Hull, 2012, p. 201)*.

Contract	Payoff - long	Payoff - short
Call	$Max(S_T - K; 0)$	$-Max(S_T - K; 0)$
Put	$Max(K - S_T; 0)$	$-Max(K - S_T; 0)$

Table 2.1 - Payoff from call and put options

Figure 2.1 and Figure 2.2 illustrates the payoff described above, where the strike prices of the options are 50 and the premiums are 20 in both illustrations.

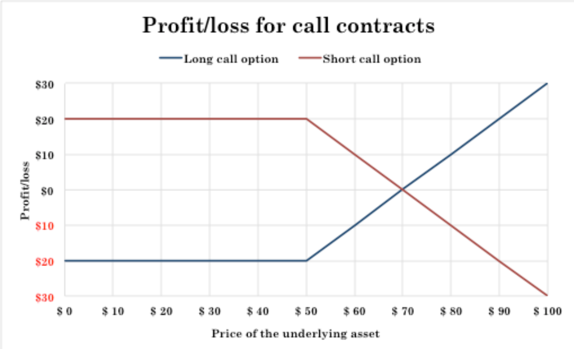

Figure 2.1 – Illustration of call option

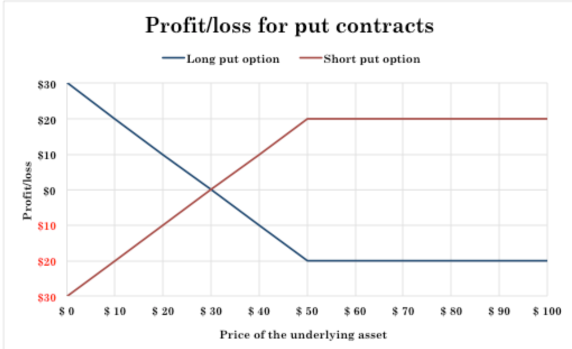

Figure 2.2 – Illustration of put option

2.2 Greeks

When options are traded, it entails exposure to different risk factors, which we will quantify by calculating the Greeks. Knowing the risks faced as an investor enables a hedging possibility. Each Greek letter measures a certain dimension of risk. Illustrations of the Greeks for three levels of moneyness can be seen in appendix 9.1.

2.2.1 Delta

The delta of an option (Δ) is defined as the rate of change in the option price with respect to the price of the underlying asset, thus the delta expresses the sensitivity in the price of the option with respect to the asset price. If a position has a delta of zero it is referred to as being delta neutral and should therefore have an expected return equal to the risk-free rate *(Hull, 2012, pp. 380-82)*. As the factors determining the delta change over time, one must hedge the position continuously to remain delta neutral. Delta will change because of price movements in the underlying and passage of time. We illustrate these findings in Appendix Figure 9.1 to Appendix Figure 9.4. It is important for this thesis to stay delta neutral to ensure that price movements in the underlying asset do not affect the return but rather is effected by the exposure to vega risk (explained in section 2.2.4) to capture the volatility risk premium.

Delta is more sensitive when time to expiration decreases for ITM and OTM options because a change in the underlying price is more significant for the options probability to end either ITM or OTM.

The delta for short options compared to that of long options is inverse. The delta is additive meaning when options are combined, the delta for the combination is the sum of the delta for each option. This is true for all Greeks.

2.2.2 Gamma

The Gamma of an option (Γ) is defined as the rate of change of the option's delta with respect to the price of the underlying asset. An option is not linearly dependent on its underlying asset, and therefore a delta neutral hedging strategy is only effective when the price movements in the underlying asset are small. Therefore, being short gamma is a bet on small price movements in the underlying asset. A gamma neutral hedging strategy is necessary if the underlying asset experience large price movements, as gamma measures the curvature on the nonlinearity dependence. This is illustrated in Appendix Figure 9.9.

Gamma will change over time and with respect to the value of the underlying. This is illustrated in Appendix Figure 9.5 to Appendix Figure 9.8. When an option is shorted, the investor is exposed to $-\Gamma_{C,P}$ *(Hull, 2012, p. 398)*. Gamma exposure is important for our strategies since the naked combinations are affected by gamma over the lifetime of the option.

2.2.3 Theta

The theta of options measures the rate of change of the value of the portfolio with respect to the passage of time. This is also referred to as the time decay of the options. Illustrations of theta with respect to price changes in the underlying asset and time to maturity is shown in Appendix Figure 9.10 to Appendix Figure 9.13. The theta of an option with different moneyness is also illustrated. Strictly looking at changes in time a long option loses value when time passes, while a short position will retain its value. Theta is an important measure as time decay has a positive effect for an investor with a short position. The positive time effect is a consequence of when time passes without a move in the price of the underlying asset, the probability of a movement in the price of the underlying gets smaller. When the price of the underlying does not move, the option combinations have higher returns. We construct the option combinations to be initially ATM or close to ATM since the exposure to theta is highest at this point.

2.2.4 Vega

The vega of an option is the rate of change of the value of the option with respect to the volatility of the underlying asset *(Hull, 2012, p. 393 & 398)*. Volatility measures the speed at which prices move up and down. Illustrations of vega with respect to price movements in the underlying asset and time to maturity can be seen in Appendix Figure

9.14 to Appendix Figure 9.17. When the option price is ATM it has the highest vega exposure. When time to maturity decreases the vega also decreases, as the time value is more sensitive to changes in volatility. Our option combinations are all exposed to short vega, which is a bet on a decrease in implied volatility. This is important as vega measures the exposure to implied volatility, which together with realized volatility determines the magnitude of the volatility risk premium.

2.3 Delta hedging

Delta hedging is performed when an investor wants to eliminate the risk of changes in the value of the underlying asset. In this thesis, we investigate volatility trades and use the S&P500 index as the underlying asset for the options. As mentioned, the delta of an option changes over time, or when other factors affecting the option price change. Therefore, it is necessary to hedge continuously to stay delta neutral. This can be very costly, as investors must pay brokerage fees and face large bid ask spread, which is why investors often choose to hedge less frequent *(Hull, 2012, p. 387)*. In this thesis, we test weekly and daily hedging to investigate the effectiveness of hedging frequency, and we discuss how costs effect hedged returns.

We chose to delta hedge using futures contracts, because it is cheaper and more convenient than to use the underlying asset *(Hull, 2012, p. 401)*. To calculate the amount that must be bought or sold we need to calculate the delta of the option combinations. The delta for a combination is equal to the sum of the individual option's deltas. The inputs used in the formulas are the implied volatilities of the options, the monthly USD OIS rate, the time to maturity and the dividend yield on the S&P500 index. When we know the option delta we can calculate the delta of the option combination at the time we wish to hedge the position. With this information, we can then proceed to calculate the position in the futures contracts we need to purchase or sell to ensure delta neutrality. First we use the following formula to calculate the required position in the asset for delta hedging *(Hull, 2012, p. 62)*.

$$H_A = \frac{Q_A}{Q_F} \tag{2.1}$$

Q_A is the size of the position being hedged (units), while Q_F is the size of one futures contract (units). We can rewrite this formula to incorporate the multiplier of the contracts with regards to the underlying asset (see formula (2.2)). When buying options on the S&P500 the investor is exposed to 100 times the market price of the index. This is referred to as the multiplier. The multiplier for E-Mini futures contracts is 50 times the index value.

$$H_A = \frac{M_A S_A \Delta_S}{M_F S_F} \tag{2.2}$$

M_A and M_F are the multipliers that affect options and futures contracts. S_A and S_F are the spot price of the underlying asset, which in our case are the S&P500 index and the spot price of the S&P500 E-Mini futures contracts respectively. Finally, Δ_S is the delta of the option combination, i.e. the sum of the individual deltas used to create the option combination. Since we are using futures contracts we can use the following formula to delta hedge the position *(Hull, 2012, p. 399)*.

$$H_F = e^{-(r-q)T} H_A \tag{2.3}$$

In this formula r is the risk-free rate, q is the dividend yield and T is the time to maturity of the futures contract. H_A is the required position in the asset for delta hedging, which we calculate with formula (2.2). H_F is the position in the futures contract that ensures the option combination is delta neutral.

2.4 Option combinations

It is possible to create several option combinations with the four options mentioned in section 2.1, which allow an investor to make very specific bets. This thesis will focus on the following option strategies, which aim to capture the volatility risk premium: Short straddle, short strangle, long iron butterfly and long iron condor. These combinations are all mainly short vega and long theta as we construct them to be initially delta and gamma neutral.

The reason we chose these strategies is that existing literature such as Coval and Shumway *(2001)* find that long straddles produce significantly negative returns. This implies the existence of a volatility risk premium or a premium arising because of hedging demand. Since long straddles produce consistent losses, a logical conclusion is that by shorting a straddle an investor can generate profits. However, short straddles are yet to be examined in depth. Additionally, we wish to add to the limited existing literature by including other option combinations with similar properties as the short straddle, but with different degrees of risk. In the following we will briefly explain the characteristics of each option combination and show illustrations based on fictive prices.

2.4.1 Short straddle

A short straddle is a combination of a short ATM call and a short ATM put option with the same maturity date *(Hull, 2012, p. 246)*.

The maximum possible profit from a short straddle is the sum of the premiums received from selling the call and put options, while the maximum downside is that of the individual options as described in section 2.1. The payoff structure of the short straddle is illustrated below in Figure 2.3 as the solid green line. It is constructed by adding the payoff from a short call and a short put, which are shown by the dotted red and blue lines. In this example the prices used are:

Option type	Option price	Strike price
Short call	10	50
Short put	15	50

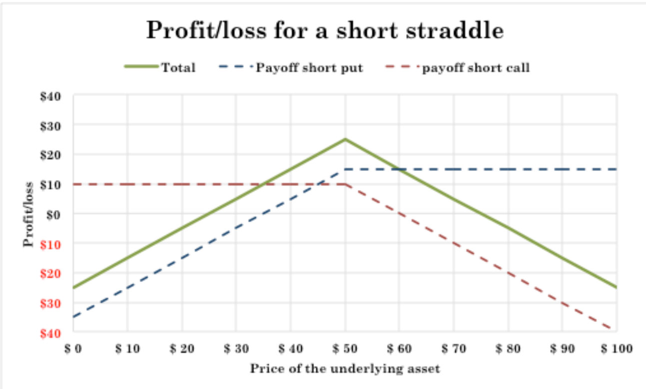

Figure 2.3 – Illustration of short straddle

When entering a short straddle the investor is exposed to short vega, positive theta and short gamma *(RiskReversal.com)*. We create the short straddle to be initial delta and gamma neutral, but since the exposure changes over time the option combination will become exposed to delta and gamma risk as it is not hedged. Large price movements will inherently have a great effect on the profit of the straddle.

As we saw in Appendix Figure 9.11, theta is at its highest when the short options are ATM and vega in Appendix Figure 9.15 is lowest when short options are ATM. Therefore, it is preferable to use ATM options to construct the short straddle. This increases the maximum possible return, as options are more expensive when they are traded ATM relative to OTM options. Further we wish to maximize the exposure to volatility, as this is what the four option combinations are designed to capture.

Additionally, the literature examining the long straddle is extensive and we wish to test the feasibility of a short straddle.

2.4.2 Short strangle

A short strangle is, similar to the short straddle, a combination of a short call and a short put option with the same maturity date but with different strike prices. The strike price for the call option is higher compared to the put option and both options are OTM *(Hull, 2012, p. 247)*. The short strangle has the same overall exposure as the short straddle, short vega, long theta and short gamma *(RiskReversal.com)*.

The strangle allows for larger moves in the underlying asset since the strike prices of the options are chosen to be OTM. The maximum profit of the strangle is slightly lower than that of the straddle. This is caused by the lower premiums collected from selling OTM options compared to ATM options. The lower premium is the cost of larger margin for errors. In Figure 2.4 the profit of a short strangle is illustrated. The prices used in this example are:

Option type	Option price	Strike price
Short call	7	60
Short put	12	40

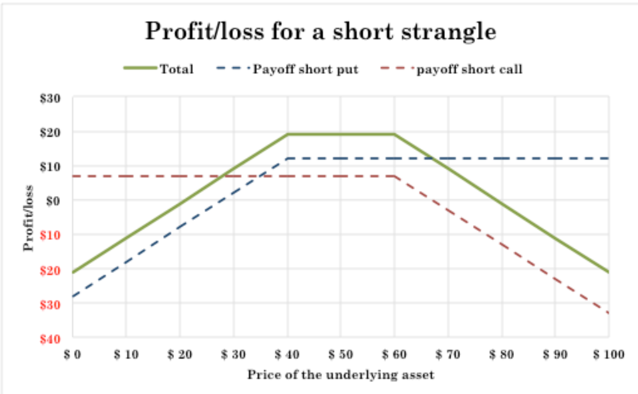

Figure 2.4 – Illustration of short strangle

The vega and theta exposure of the short strangle is only slightly lower than that of the short straddle making it a favorable candidate to compare to the short straddle as it has slightly lower maximum return and risk. Another argument for testing the short strangle is that lower risk can make it more appealing to investors.

2.4.3 Long iron butterfly

The long iron butterfly is a variation of the short straddle, where the downside risk is limited. While the short straddle is made of selling a call and a put option with ATM strikes, the long iron butterfly is set up by buying a lower strike OTM put, selling the call and the put option with ATM strikes and buying an OTM call *(The Options Guide)*. This combination therefore consists of four options. This is shown in Figure 2.5, where the solid green line shows the long iron butterfly. For this example, the prices used are:

Option type	Option price	Strike price
Short call	10	50
Short put	15	50
Long call	22	30
Long put	30	70

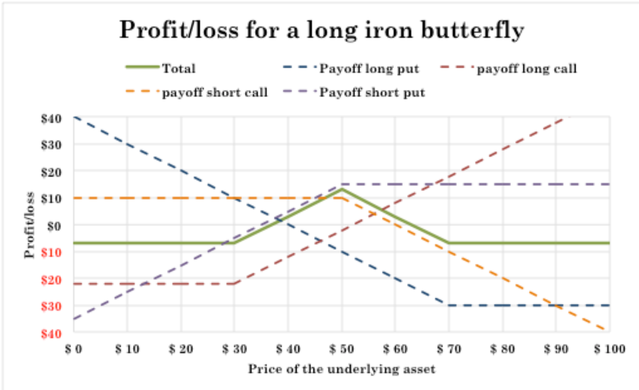

Figure 2.5 – Illustration of long iron butterfly

Similar to the short straddle and short strangle, when entering this combination, it creates a net credit meaning if all the options expire worthless the buyer receives this credit. As Figure 2.5 shows, both the potential profits and the potential losses are limited. The maximum profit is equal to the net premium received upfront. The maximum loss is the difference between the OTM strikes minus the premium. The long iron butterfly is exposed to short vega, long theta and short gamma. It is interesting to consider this protective position as it allows the investor to trade the volatility risk premium while not being exposed to considerable downside risk.

2.4.4 Long iron condor

The long iron condor combination is shown in Figure 2.6, and consists of four options as the iron butterfly. Contrary to the long iron butterfly the strike prices for the shorted options are not identical. This makes the profit range larger, as were the case with the short strangle strategy. The prices used in this example are:

Option type	Option price	Strike price
Short call	10	60
Short put	15	40
Long call	8	80
Long put	12	20

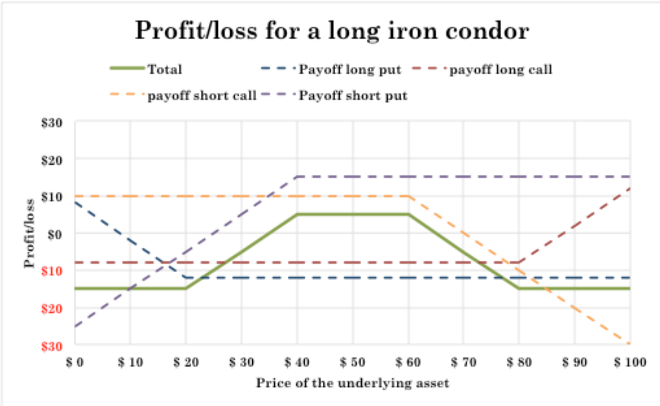

Figure 2.6 – Illustration of long iron condor

The maximum premium of the long iron condor is lower compared to the long iron butterfly since the options that are shorted are slightly OTM and therefore cheaper than the ATM options making the premium received lower. Though the premium is lower, this combination allows for the price of the underlying to move more at the cost of a lower maximum profit. As for the other strategies, the long iron condor is exposed to short vega, long theta and short gamma. The long iron condor is interesting to analyse as this too enables the investor to trade the volatility risk premium with limited downside.

2.5 Volatility

Volatility is not a constant factor but rather varies over time, which makes it nondeterministic. The volatility measure is used when pricing derivatives such as options. This means that the investor's estimate of volatility has impact on the price of options. The historical realized volatility used in this thesis is from WRDS and is illustrated in Figure 1.1 as the red line.

The forward-looking volatility is usually deducted from observed option prices by solving the BSM formula using the Newton Raphson method. This volatility measure is often referred to as implied volatility and is also illustrated in Figure 1.1. An investor can use the implied volatility to see the market's expectation of the volatility on certain assets. By comparing the market's expectation to your own it is possible to make option strategies that captures mispricing of volatility, similar to a delta neutral short straddle, that in theory profits when realized volatility is lower than implied volatility.

The difference between realized and implied volatility is referred to as a volatility risk premium. Risk averse investors who are willing to pay a premium for insurance offered by put options can cause implied volatility of the options to rise and therefore increase the volatility risk premium.

Further, empirical findings show that the implied volatility is lowest when the strike price is ATM and greater when the strike price is either ITM or OTM, which is referred to as a "volatility smile/smirk".

2.6 Indices used as market timing indicators

We wish to investigate whether it is attractive for investors to capture the volatility risk premium with the chosen option combinations. We further want to investigate if it is possible to increase the effectiveness of these strategies to capture the volatility risk premium by using market timing indicators signaling whether to trade or not. The market timing indicators used on the option strategies are based on the VIX and CDX, and will be traded if the current level of a given index is above/below a historic- or moving average of this index. Using this approach, we investigate if there is a trend in the expected movement of the volatility that can enhance the results of the option strategies that is traded each month in the sample period. This should further prove the existence of a momentum/reversal of volatility.

2.6.1 VIX index

A popular measure of the expected near term volatility of the S&P500 is the VIX (CBOE Volatility Index). This index estimates expected volatility by averaging the weighted prices of SPX (S&P500 index) puts and calls over a wide range of strike prices. The VIX has a correlation of -0.58 towards the S&P500 index.

This negative correlation can to some extend be explained by the fact that investors use options as insurance toward the underlying asset. When the S&P500 decreases, investors increase their position in SPX options to insure their position in the S&P500 and when the demand for options increase the prices also increase. Therefore, the VIX increases. The correlation can also be seen with respect to the "leverage effect", where a decrease in S&P500 means an increase in the debt of the respective companies. An increase in debt over equity results in more volatility, hence an increase in VIX.

The chosen option strategies bet on the volatility of the S&P500. We use the VIX index as an indicator for momentum strategies. It is interesting to investigate whether we can use the current level of VIX and compare this to both the historic- and different moving averages and trade on these indicators to examine if this can improve the results compared to the benchmark strategies. The VIX is used as an indicator to see if there is a trend in the expected market risk at time *t-1* that can indicate what the realized volatility will be at time *t*.

2.6.2 Credit default swap indices

Another index we use as a market timing indicator is the index based on credit default swaps (CDX). This is explained below and reflects the individual company's default risk. The CDX is plotted against the VIX and the S&P500 in Figure 2.7, and it shows that the two indices move in tandem over the sample period, where some lags and divergences occurs. The lags can be seen in the figure indicated by the vertical dotted lines, where CDX moves prior to the VIX, but also the CDX shows movements the VIX does not show. The correlation between the indices is 0.82. The S&P500 is also plotted to illustrate the negative relation. Therefore, it is interesting to investigate the CDX index as an indicator in the same way as the VIX index. Also, the differences between these indices will be used as trading indicators to see if the lags can be exploited in the option strategies.

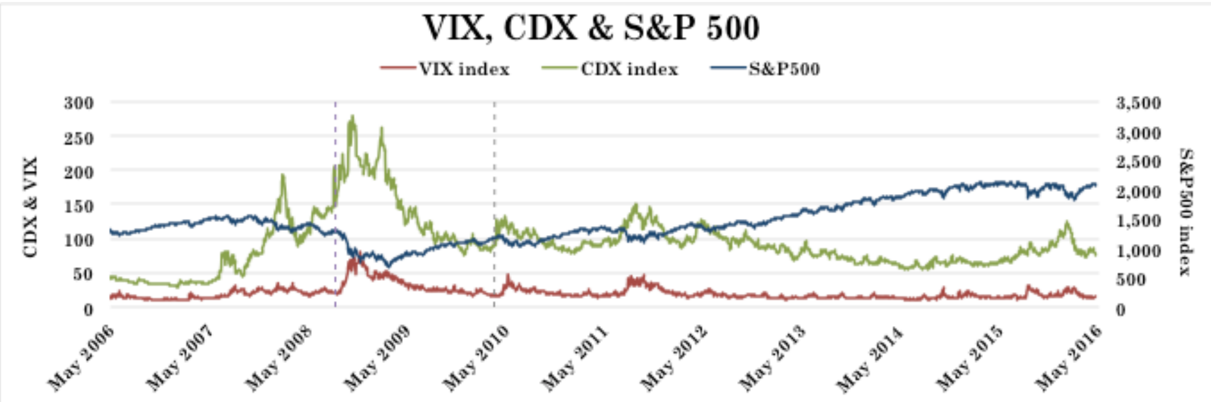

Figure 2.7 – VIX, CDX and S&P500 indices compared

Credit Default Swap

A credit default swap (CDS) is a credit derivative, which provides insurance against the risk of a company's default. When a company defaults, it is known as a credit event. The swap is sold by a third part to the owner of a company's bonds, so the company is not a part of the swap. The buyer of the swap periodically pays the seller until the swap matures. In return the seller agrees that in a credit event the seller will pay the buyer the premium and the interest payments the buyer should have received in case of no credit event *(Hull, 2012, pp. 547-48).*

Credit default swap index

Indices have been developed to track credit default swap spreads, where the CDX NA IG (CDX) will be used in this thesis. The index consists of a portfolio of 125 investment grade companies in North America and is updated every six months. An investment grade company has a rating of BBB or higher rated by firms such as Standard & Poor's or Moody's *(Hull, 2012, p. 555).*

The risk in the market is measured by the spread in the CDX. An increase in the spread implies a weakened quality of the loan/bonds of the underlying company, which again implies an increased risk of default. Opposite, the creditworthiness of the underlying companies improves when the spread of the CDX decreases, as it suggests a lower probability of default. This means that the CDX is, as well as the VIX, inversely correlated to the S&P500 (-0.54). An improvement in the economic conditions will lead to an increase in the S&P500 and a decrease in the CDX and vice versa *(CBOE optionsHub, 2013).*

The CDX is used as a market timing indicator to identify if there are any trends in volatility captured in the CDX that can improve the returns of the option strategies.

2.7 Risk free proxy

When valuing derivatives, a proxy for the risk-free rate is used. A risk-free rate is the rate of return on an asset with no risk. No such thing exists in the real world and therefore a proxy is used instead. Both Treasury securities, LIBOR and OIS are considered as such proxies, as they are close to being risk free.

The OIS rate is the rate on an overnight index swap that pays a predetermined fixed rate in exchange for receiving the realized geometric mean on the federal funds rate over the period of the contract. The OIS rate can be thought of as the market's expectation for the average federal funds rate that will occur over the upcoming period. Assuming that the federal fund transactions are close to riskless, the OIS rate is a reasonable proxy for a riskless rate *(Duffie & Stein, 2015, p. 205)*. Therefore, the OIS rate is chosen as the risk-free proxy in this thesis.

2.8 Return calculation

As mentioned previously, when entering a short position one gains the premium in the beginning and depending on whether the option ends ATM, ITM or OTM the seller should pay the buyer what he owes. Because we do not pay an initial premium we cannot use the normal calculation for percentage returns:

$$R_t = \frac{V_{t-1} - V_t}{V_{t-1}}$$

where R_t is the percentage return at time t, and V is the value in period t and t-*1*.

This thesis defines the percentage return on each option combination as the net profit in relation to a predefined level of funding of $100,000. This level is chosen to accommodate large deviations in the variable margin requirements that may occur in the sample period. We find this to be a reasonable way to calculate the returns, as this makes the returns possible to interpret relative to each other as they are calculated against a common funding level. If we were to use a variable funding level the scale of returns would be affected, which would lead to inconsistent returns and variances.

Therefore, the formula for calculating the percentage return is as follows:

$$R_t = \frac{Profit\backslash Loss_t}{\$100{,}000}$$

$Profit\backslash Loss_t$ is the net profit/loss at the end of the holding period.

2.9 Margin requirements

This thesis back tests option combinations, which involve taking short positions in option contracts on the S&P500 index. When an investor writes an option, the broker requests a cash deposit in a margin account, or an asset with low risk such as specific investment grade bonds. At the end of the trading day, the positions are marked to market and the net change is credited to the margin account. If the account ends up with a lower value than a predetermined minimum, the investor will face a margin call and is required to make the given deposit. If the margin call is not met, the broker liquidates the position. Margin requirements depend on the type of investor and type of option trade. For a naked position, the initial margin requirement at time t can be found by applying the following equation *(Santa-Clara & Saretto, 2004)*:

$$Call: M_t = Max(C_t + \alpha S_t - (K - S_t | K > S_t); C_t + \beta S_t)$$
$$Put: M_t = Max(P_t + \alpha S_t - (S_t - K | S_t > K); P_t + \beta K)$$

where C_t and P_t are the settlement prices announced by the exchange for the current day, α and β are predetermined parameters between 0 and 1, S_t is the underlying price at the end of the day, and K is the strike price of the option.

To calculate the daily margin requirement, a calculation similar to the initial margin calculation is repeated every day but with current market price replacing the proceeds of sale *(Hull, 2012, p. 206)*. For a protected position, the margin requirement can be found using the net premium, and for the daily margin requirements the current market price is still applied *(TradeStation, 2006)*. For this thesis, we use a conservative approach for calculating the total margin requirements for the hedged positions. We assume that there is a margin requirement for $5,000 per E-mini S&P500 futures contract, which is the standard amount used by CME *(CME Group, 1972)*.

The specific values of α and β are dependent on both the type of underlying asset and on the investor trading the option. Usually the parameters are smaller for broad based indexes and for professional investors. The CBOE Margin Manual and Hull specifies α = 15% and β = 10% for broad indexes similar to the S&P500 *(Hull, 2012, p. 205)*. These parameters determine the margin requirements imposed by the exchange to all investors including the brokers. This means that they represent the minimum margin requirements faced by any investor but does not take account for the additional margin requirements imposed by brokers to individual investors.

2.10 Performance- & risk measurements

Performance measures are used to evaluate the option combinations in several ways. In this thesis, we will evaluate the performance of the individual option combinations by considering three risk-reward/performance ratios. These are the Sharpe ratio (SR), the information ratio (IR) and the Sortino ratio (SoR), which is further explained below *(Pedersen, 2015, pp. 29-32)*.

Sharpe ratio (SR) measures the "reward" per unit of risk. It is the expected excess return compared to the risk.

$$SR = \frac{E\left(R - R^f\right)}{\sigma\left(R - R^f\right)} \tag{2.4}$$

Here R is the return on the investment, R^f is the risk-free rate and σ is the volatility. A portfolio with a Sharpe ratio of zero should yield the risk-free rate. A ratio above zero should yield in excess of the risk-free rate and a ratio lower than zero should yield lower than the risk-free rate.

The information ratio (IR) measures the extent to which the strategy outperforms a predefined benchmark per unit of tracking error risk. In this thesis, the S&P500 is chosen as the benchmark for the market performance.

$$IR = \frac{E\left(R - R^b\right)}{\sigma\left(R - R^b\right)} \tag{2.5}$$

Here R^b is the return of the given benchmark (S&P500).

The Sortino ratio (SoR) measures the excess return over the downside risk.

$$SoR = \frac{E\left(R - R^f\right)}{\sigma^{downside}} \tag{2.6}$$

where

$$\sigma^{downside} = \sigma\left(R\ 1_{\{R<MAR\}}\right)$$

$R\ 1_{\{R<MAR\}}$ is the return times either 1 or 0 depending whether the return is above or below a minimum acceptable return (MAR). This MAR could be the risk-free rate or zero. For this thesis, the MAR is set to zero.

The difference between SR and SoR is that SoR only considers downside risk.

Other relevant measures when evaluating an investment are risk measures such as high watermark (HWM), drawdown (DD), Value at Risk (VaR) and expected shortfall (ES), which will be addressed next *(Pedersen, 2015, pp. 35,58-59)*.

The **high watermark (HWM)** is, at time t, the highest cumulative return the strategy has achieved in the past, time s.

$$HWM_t = max_{s \leq t} R_s \tag{2.7}$$

Drawdown (DD) is opposite HWM the cumulative loss since losses started. The DD is the amount that has been lost since the HWM.

$$DD_t = \frac{HWM_t - R_t}{HWM_t} \tag{2.8}$$

When evaluating strategies, the **maximum drawdown (MDD)** should also be considered, as large DD's can lead do redemption from investors who don't have the required capital to suffer a large DD. Therefore, it is relevant to know the maximum of all drawdowns in the lifetime of the strategy.

$$MDD_t = max_{t \leq T} DD_t \tag{2.9}$$

For measures of downside risk, we use **Value at Risk (VaR)**. VaR measures the maximum loss at a given confident level usual set at a 95% level. The VaR is the most extreme one can lose with a 95% confidence. To calculate the VaR the specific loss distribution is needed, but using the return data the value can be found numerically. In practice this is done by sorting the returns and finding the 95% largest negative return.

As VaR does not captures all loses the **expected shortfall (ES)** can be used, which calculates the size of the loss if the loss exceeds VaR at a given confidence level.

$$ES_\alpha = E(loss|loss \geq VaR_\alpha) \tag{2.10}$$

This thesis investigates strategies with theoretical unlimited losses; straddles and strangles. Therefore, theoretically the MDD of these strategies can be endlessly high and the SoR can be very small as the downside risk is high. When R<MAR approach negative infinity, the volatility also approach infinity meaning that the denominator of the SoR calculation becomes infinite $\sigma^{downside} = \sigma\left(R\ 1_{\{R<MAR\}}\right) \rightarrow \infty$

2.11 Regression variables

The explanatory variables used to regress the returns are:

1) The VIX index, which is the best estimate we have of the future market volatility
   - VIX_{t-1}
2) The credit spread between a 10-year treasury bond and Moodys Aaa rated corporate bonds.
   - $C_t = C_{Treasury_{et}} - C_{Moody_{et}}$
3) The trading volume of the S&P500
   - $V_t = \sum_{a=et}^{st} V_a$
4) The market excess return
   - $R_t^m = R_t - R_t^f$

Where *t* denotes the current time, *et* is the day the option combination expires and *st* is the day the option is sold. The correlations between the explanatory variables are displayed in Table 2.2.

Correlations				
	Volatility Measured by VIX	Credit spread	Trading volume	S&P500
Volatility Measured by VIX	1			
Credit spread	0.15	1		
Trading volume	0.71	0.05	1	
S&P500	-0.58	0	-0.47	1

Table 2.2 – Correlation between explanatory variables

Previous studies including Massa & Simonov *(2005)* conclude that there is convincing evidence of correlation between trading volume and returns on stocks. Further, they find no evidence supporting the trading volume is a priced factor. As the option used in our thesis are options of the S&P500 index, this is not entirely in relation to those findings, but if the trading volume in the S&P500 changes this means that there is a disagreement between investors, and this can have an effect on the price of the options used. Therefore, we find it relevant to regress the returns from the option strategies against the trading volume of the S&P500 as an explanatory variable.

The credit spread is calculated using the monthly 10-year Treasury rate and the monthly Moody's seasoned Aaa corporate bond yield (not seasoned adjusted). The credit spread varies based on the credit rating of the issuer. As the default risk of the issuer increases, the credit spread widens. Therefore, if the credit spread increases or decreases it is a result of more or less risk and therefore more or less volatility in the market.

The VIX index is a closely related factor to capture the stock market volatility. By including this variable, we ensure that volatility is not priced in the other factors. As this thesis focus on capturing the volatility risk premium, it is important to know that the volatility factor and not the movements in the market drive the returns. Therefore, we include the excess return on the market to see whether this exogenous variable is significant in explaining the returns of the option strategies or not.

The regression factors are illustrated in Appendix Figure 9.40 and shows how they evolve compared to each other in the sample period. Vertical lines are added to enhance the difference in up an down movements across the factors.

Chapter 3 - Analysis

In the following section, we will present the results from the analysis of the sub-questions. We will start by examining the volatility risk premium in the sample period, as this is a central factor for the option positions that are entered. We will then analyse the returns of the four initial delta neutral option strategies by looking at the performance- and risk measures of each strategy. This will allow us to compare them and thereby understand their differences. Having analysed these results, we will examine the effect of using different delta hedging frequencies on the initial delta neutral positions.

After having analysed sub-question one, we will move on to investigate the results of sub-question two. We will examine if the VIX and CDX indicators can be used as consistent market timing indicators and thereby potentially enhance the performance of the initial strategies with delta hedging of the different frequencies. This is done by first examining the indicators during the sample period, which will enable us to understand their impact on the returns of the strategies. We will then use the chosen indicators as trading signals on our option strategies to see if there is a clear pattern of which indicators work best, i.e. average, moving average (MA) and spread between VIX and CDX. We will present the results of the four best performing strategies for the short straddle and short strangle and four best performing strategies for the long iron butterfly and long iron condor with the use of indicators. We will evaluate the strategies based on the overall performance of returns, Sharpe ratios and risk measures. We will only consider weekly and daily delta-hedged strategies as we find that the initial delta neutral strategy does not remain delta neutral during the holding period.

Further, we use regression analysis to examine whether exogenous factors related to hedging demand can explain the returns of the different strategies. The exogenous factors used are volatility, credit spread between a T-bill rate and an Aaa rated corporate bond and the trading volume in the underlying asset.

In the analysis below we find that applying delta hedging eliminates the dependency of the returns on the market, to some extent. When market movements are eliminated the exposure to changing volatility is more effectively captured. However, delta hedging does not eliminate gamma risk, which means that large movements in the market still affect the returns of the delta-hedged strategies. Using VIX and CDX as market timing indicators makes the returns of the short strategies statistically significant. This is however not the case for the long strategies. The returns from the daily delta-hedged strategies can to some extend be explained by the VIX index, the credit spread and the trading volume. The excess return on the market is only significant for the initial delta-hedged strategies.

3.1 Volatility spread in sample period

As mentioned previously the spread between the implied- and realized volatility is called the volatility risk premium. This spread is visually presented in Figure 1.1 and the descriptive statistics are shown in Table 3.1. The average historical spread is 3.42%, indicating that the implied volatility on average is above the realized volatility. If we assume that investors use the BSM framework to price options it appears that these options on average are overpriced, as higher variance equals higher option prices. However, the specific model, investors use, is not necessarily the BSM as it has some strong assumptions that are not realistic in practice. During the sample period the spread is positive 85% of the time. The spread ranges from 23% to -36% indicating a relatively high uncertainty, though it should be noted that the negative spread of 36% occurs during the peak of the financial crisis in November 2008 *(Kingsley, 2012)*.

Spreads	Date	Result
Largest positive spread	16/01/09	22.58%
Largest negative spread	05/11/08	-35.63%
Mean		3.42%
Total nr. positive spreads		2,105
Total nr. negative spreads		382
Total nr. of observations		2,487
% Positive spread		84.64%

Table 3.1 – Data of historical volatility spread

To potentially gain from this spread in volatility, one could enter a short option strategy as the straddle, as this would give the investor a negative exposure to vega and thereby yield a positive return all else equal. To ensure that the trade primarily benefits from developments in volatility, the investor should delta hedge the position to limit the exposure to the price movements in the underlying asset. When the implied volatility is estimated to be lower than the realized volatility a position with negative exposure to vega would yield a negative return. A negative volatility risk premium occurred during the financial crisis.

3.1.1 Empirical evidence of volatility spread vs. short straddle return

The option combinations used in this thesis are initial short vega, and should in theory yield a positive return on average given the historic data all else equal. The return from the initial delta neutral short straddle is shown in Figure 3.1 together with the implied-realized volatility spread. The illustrations for the other initial delta neutral strategies plotted against the volatility spread can be seen in Appendix Figure 9.21 to Appendix Figure 9.23.

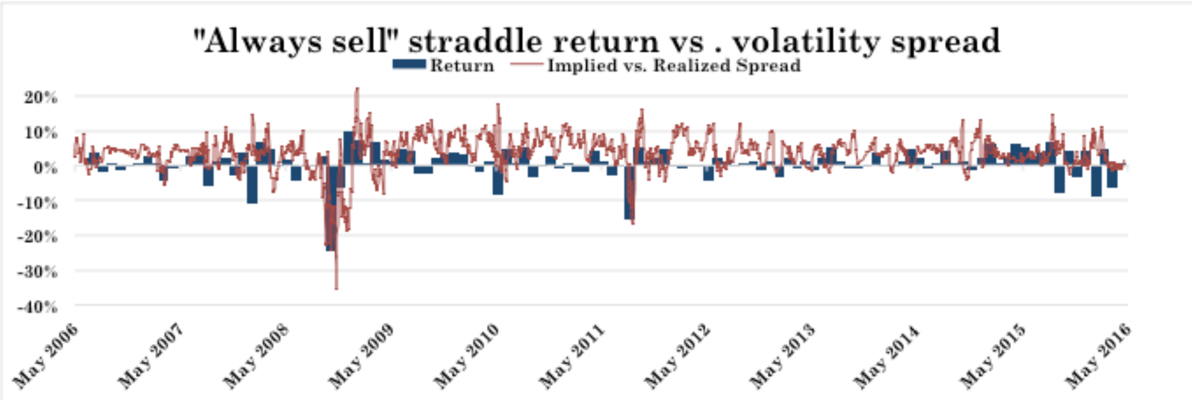

Figure 3.1 – Initial delta neutral short straddle return vs. volatility spread

The figure illustrates that the spread is more or less consistent with the direction of return. In the financial crisis in 2008, the implied volatility was, as mentioned, underestimated and can to some extend explain why the return on the short straddle was negative. An important factor to consider when entering positions that are not continuously delta-hedged is exposure to large price movements in the underlying asset (gamma risk). This is also seen in August 2011 as an effect of the European sovereign debt crisis. When the volatility experiences a spike the market is slow to adjust its estimate in the following period. This leads to an overestimation of volatility, which results in high positive returns, as was the case in April 2009 and the period following the European sovereign debt crisis. This is also illustrated in Figure 3.2, where the premium from the initial delta neutral short straddle tends to be high post an increase in the VIX.

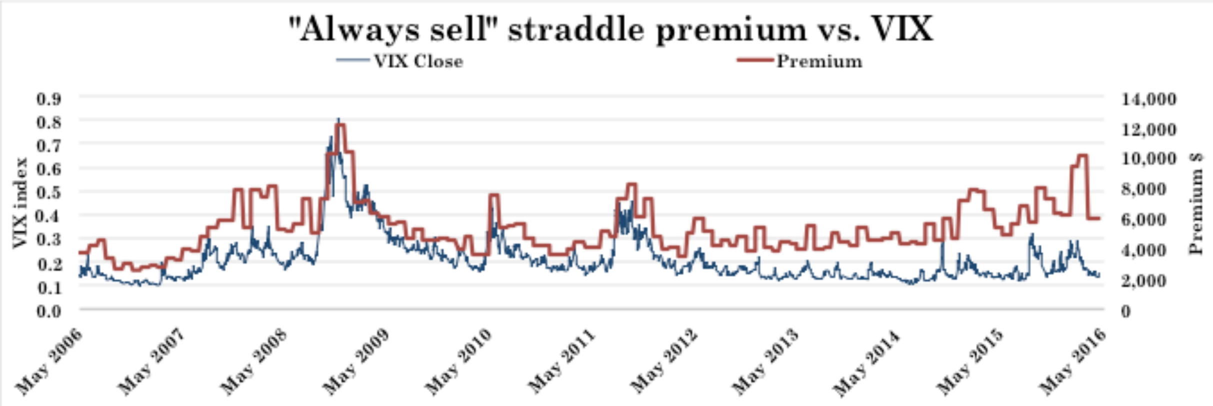

Figure 3.2 – Initial delta neutral short straddle premium vs. VIX index

When the VIX is high, the short straddle has a higher premium in the following period, and if the VIX subsequently drops the short straddle yields a high return if the options are not exercised in this period. This shows a positive correlation between implied volatility and option prices. However, when the volatility is high, the chance the option will end OTM is high as well.

3.2 Initial delta neutral strategies

In the following section, we will present the descriptive statistics for the four initial delta neutral strategies described earlier.

3.2.1 Descriptive statistics

The four strategies consist of 120 trades, one each month for 10 years with an initial delta of zero. All figures in the table below are monthly.

Initial delta neutral strategies				
	Short straddle	**Short strangle**	**Long iron butterfly**	**Long iron condor**
		Descriptive statistics		
Mean	0.51%	0.58%	0.02%	0.06%
Standard deviation	4.44%	3.78%	0.52%	0.82%
Kurtosis	9.08	5.66	2.64	-0.03
Skewness	-2.12	-1.74	1.81	0.76
Minimum	-24.63%	-17.48%	-0.59%	-1.31%
Maximum	9.88%	7.63%	1.73%	2.49%
Spread	34.51%	25.11%	2.32%	3.80%
Number of profitable trades	71	75	37	44
Number of loss trades	49	45	83	76
Mean absolute return (in $)	168	39	25	-112
Cumulative absolute return (in $)	61,345	69,782	2,999	7,543
Cumulative return	62.80%	83.62%	2.88%	7.40%
		Performance measurements		
Risk return measures				
Sharpe ratio	9.34%	12.80%	-12.79%	-3.78%
Information ratio	0.04%	1.25%	-10.22%	-9.35%
Sortino ratio	9.28%	13.59%	-34.28%	-9.00%
Risk measures				
High watermark	180.33%	183.62%	104.47%	107.40%
Maximum drawdown	33%	25%	4%	6%
Date for maximum drawdown	15/10/08	15/10/08	15/04/13	15/01/14
VaR (in $)	-6,317	-5,727	-490	-1,160
ES (in $)	-17,883	-11,893	-533	-1,200
		Average initial Greeks		
Delta	-0.00079	0.00056	-0.00179	-0.00010
Gamma	-0.01266	-0.01209	-0.00041	-0.00125
Vega	-325.90	-314.50	-10.55	-31.55
Theta	350.47	346.59	9.79	30.13

Table 3.2 – Descriptive statistics of initial delta neutral strategies

It is important to notice in Table 3.2 that the initial delta and gamma for each strategy is very close to 0, which is expected as we create each option strategy to be initially delta neutral. However, the vega and theta for each strategy are respectively negative and positive. This is expected as these strategies are created using mainly short positions. This is described in section 2.2.3 and 2.2.4, which states that these strategies are short vega and long theta, due to the short positions used in the option combinations. The sizes of the initial Greeks are not surprising as the riskiest position, the short straddle, has the highest exposure to vega and theta. The short strangle which is relatively less risky compared to the short straddle also has high exposure to vega and theta but slightly less than the short straddle. The high exposure is caused by the fact that both strategies are naked positions. This makes them riskier and doesn't limit the exposure to vega and theta, as protective positions do as a result of the additive nature of Greeks. This is exemplified with the long iron butterfly and long iron condor, which both have far less exposure to vega and theta.

3.2.2 Short straddle

The short straddle has one of the highest cumulative absolute returns of $61,345 (62.80%). As expected, this strategy has the highest spread and standard deviation of 34.51% and 4.44% respectively. The short straddle is expected to produce a high variance in returns as it is a naked spread, which means that the negative returns have no theoretical limit, while the positive returns are capped. This also causes the short straddle to have the biggest maximum drawdown of 32.70% (-$26,532).

The return distribution does not follow a standard normal distribution. The return distribution has a skewness of -2.12, which is caused by the few large negative outliers and a majority of profitable trades. The excess kurtosis is 9.08 for the return distribution, and is therefore leptokurtic, indicating a large mass in the tails, which is a consequence of outliers. The return distribution including a normal curve (blue line) constructed using the sample average and standard deviation from the sample returns are illustrated in Figure 3.3. If the returns are normally distributed the red bars will match the blue curve. An Outlier Box Plot is shown above each histogram to detect the quartiles and possible outliers.

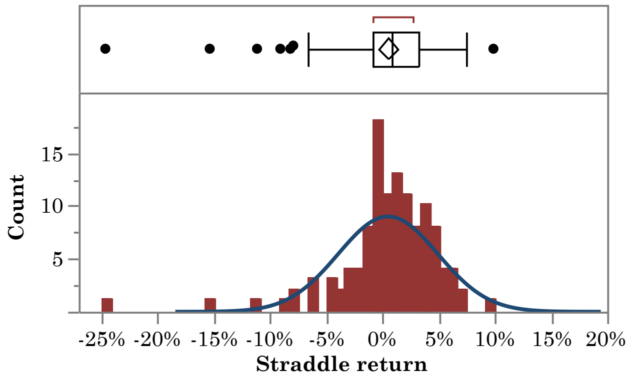

Figure 3.3 – Distribution of initial delta neutral short straddle returns

3.2.3 Short strangle

The short strangle has the highest cumulative absolute return of $69,782 (83.62%). As expected, this strategy has the second highest spread and standard deviation of 25.11% and 3.78% respectively. The short strangle is expected to produce a lower variance in returns compared to the short straddle as the profit range is wider, meaning losses and profits will be lower compared to the short straddle. The reason for the lower losses and profits is that the premiums received from selling OTM options are lower than selling ATM options. This is highlighted by comparing the maximum and the minimum of the returns from the short straddle and short strangle. The minimum return of the short straddle is -24.63%, whereas the minimum for the short strangle is -17.48%. The maximum for the short straddle is 9.88%, while it is 7.63% for the short strangle. Similar to the short straddle the short strangle is also a naked spread, but with lower variance in returns, which causes the short strangle to have the second biggest maximum drawdown of 24.83% (-$21,475).

The return distribution does not follow a standard normal distribution. The return distribution has a skewness of -1.74, which is caused by the few large negative outliers and a majority of profitable trades. The excess kurtosis is 5.66 for the return distribution, which means that it is leptokurtic indicating a large mass in the tails, which is a consequence of outliers. The skewness is very close to that of the short straddle, while the kurtosis is slightly lower. This is expected as the maximum negative returns are lower for the short strangle. The return distribution is illustrated in Figure 3.4.

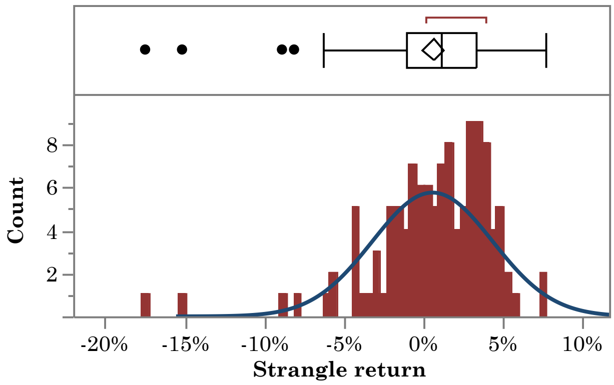

Figure 3.4 – Distribution of initial delta neutral short strangle returns

3.2.4 Long iron butterfly

The long iron butterfly is the first of the two protective combinations we will address. As expected this strategy has a much lower return and standard deviation of returns because the returns are bound in a more confined interval compared to the previously mentioned strategies. The long iron butterfly has the lowest cumulative absolute return of $2,999 (2.88%). This strategy has the lowest spread and standard deviation of 2.32% and 0.52% respectively. The long iron butterfly is expected to produce a low variance in returns, as it is a protective spread, which means that both the positive and negative returns are capped. This also causes the long iron butterfly to have the lowest maximum drawdown of 3.57% (-$2,359). The number of profitable trades is much lower than the number of negative trades. Given the positive absolute return, the positive returns generated by the few outliers in addition to the capped positive returns outweigh the cost of the added security of buying the OTM call and put options.

The return distribution has a skewness of 1.81, which is caused by the few negative outliers of these returns. The excess kurtosis can be calculated to 2.64 for the return distribution, which means that it is leptokurtic indicating a large mass in the tails, which is a consequence of outliers. The return distribution is illustrated in Figure 3.5.

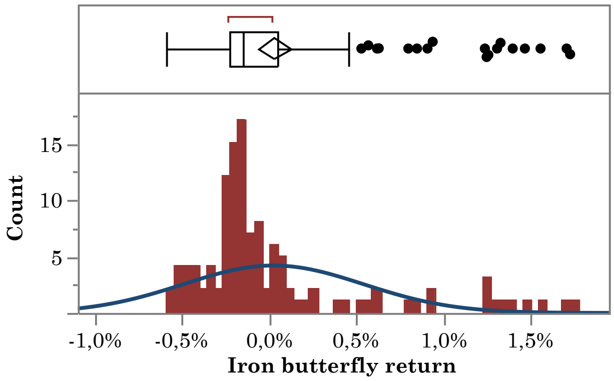

Figure 3.5 – Distribution of initial delta neutral long iron butterfly returns

3.2.5 Long iron condor

The long iron condor is the second of the two protective strategies. As expected this strategy also has a much lower return and standard deviation of returns compared to the short strategies. The long iron condor has the second lowest cumulative absolute return of $7,543 (7.4%). This strategy has the second lowest spread and standard deviation of 3.8% and 0.82% respectively. The long iron condor is also expected to produce a low variance in returns as it is a protective spread. This also causes the long iron condor to have the second lowest maximum drawdown of 6.4% (-$5,983). In this sample period, we see that the capped positive returns outweigh the cost of the added security of the bought DOTM call and put options.

The return distribution has a skewness of 0.76, which is caused by the few positive outliers of this return distribution. The excess kurtosis can be calculated to be -0.03 for the return distribution, which is very close to that of the standard normal distribution. The return distribution is illustrated in Figure 3.6 below.

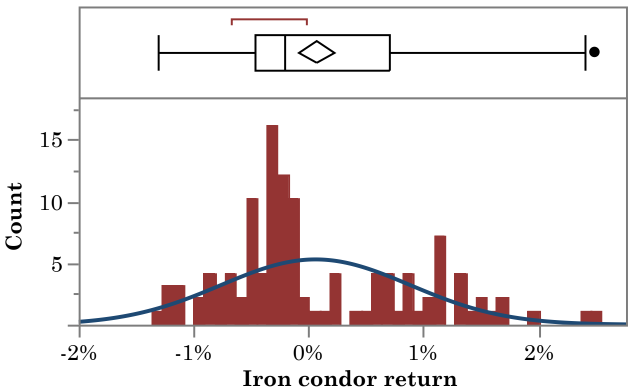

Figure 3.6 – Distribution of initial delta neutral long iron condor returns

3.2.6 General comparison of the strategies' performance measures

In the following section, we will compare the four strategies with respect to their performance- and risk measures. This will provide a deeper understanding of the empirical properties of implementing the different strategies. As shown in the return distribution figures the empirical distributions do not follow a normal distribution. This causes the assumptions underlying the confidence intervals around the mean to be violated. However, we will present the confidence interval regardless as it still has some explanatory value. We will further assume that the empirical return distribution achieved by the individual strategies in the sample period is a true representation of the actual distribution. This will allow us to conclude that the obtained standard deviations are finite, which in assumption of the Sharpe ratio.

We will start by comparing the cumulative returns of the individual strategies and the return on the S&P500 index in the same period.

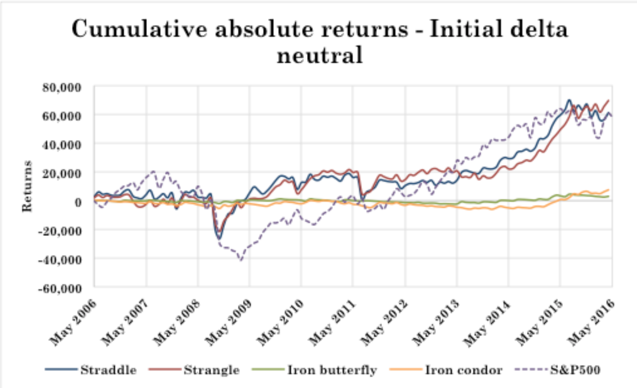

Figure 3.7 – Cumulative absolute returns of initial delta neutral strategies & S&P500

In Figure 3.7 we can see the best performing strategies are the short straddle and the short strangle, which both outperform the S&P500 index over the sample period. The strategies also perform better during the crisis, which is where the strategies are having the highest drawdowns. We see that both the long iron butterfly and the long iron condor are just breaking even and don't move much from the basis point.

Initial delta neutral strategies				
	Straddle	**Strangle**	**Iron Butterfly**	**Iron Condor**
Excess mean	0.0042	0.0049	-0.0007	-0.0003
Confidence Level (95%)	0.0080	0.0069	0.0010	0.0016
Upper limit	0.0122	0.0117	0.0003	0.0012
Lower limit	-0.0039	-0.0020	-0.0017	-0.0019
Statistically significant	**No**	**No**	**No**	**No**

Table 3.3 – Initial delta neutral strategies - statistically significant

We find that the mean returns from each initial delta neutral strategy are non-significant on a 5% level. This indicates a possibility for our positive cumulative returns to be caused by chance. However, this might be a consequence of the small sample size as this is a very important component in statistical significance.

Performance measures

The performance measures of the initial delta neutral strategies are illustrated in Figure 3.8, and can be seen in Table 3.2. The benchmark used in the information ratio is the excess return of the S&P500 index. The S&P500 does not capture the volatility risk premium and is not an equivalent measure for this, but as an alternative investment in the sense of the market movements, this is appropriate. The Sortino ratio has a minimum acceptable threshold of zero, hence when the returns are positive they are not included in this performance measure.

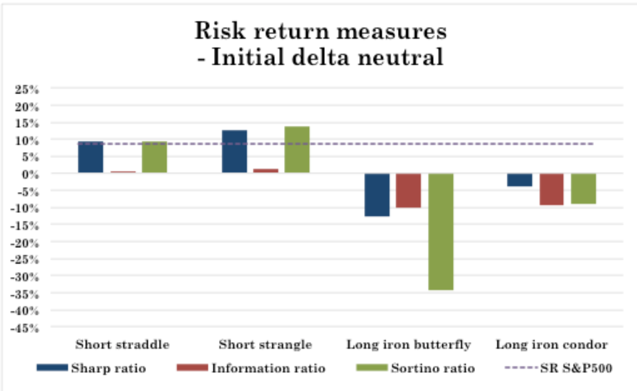

Figure 3.8 – Sharpe ratio, information ratio and Sortino ratio for initial delta neutral strategies

The historically attainable monthly Sharpe ratio from a buy-and-hold position in the underlying S&P500 in the sample period is 8.6% and is illustrated in Figure 3.8 as the dotted line. Comparing the performance measures of the strategies to the S&P500, the short strangle outperforms the market by approximately 4% while the short straddle outperforms the market by 1%. This is consistent with the findings of Coval & Shumway and B. Eraker, who conclude that writing options outperforms the Sharpe ratio received by implementing a buy-and-hold strategy in the S&P500. Coval & Shumway has a sample period from 1986 to 1995 and includes the 1987 crash[1] *(Coval & Shumway, 2001)*. They report that writing options produce a Sharpe ratio of twice that of the S&P500 Sharpe ratio. We find that the short straddle and short strangle produce a

[1] Black Monday

Sharpe ratio that are barely above what is achieved by an investment in the S&P500. This can be caused by the chosen sample period, the return calculation used, transaction costs and the risk-free rate. B. Eraker also reports achievable Sharpe ratios in the magnitude of double the historical S&P500 Sharpe ratio. He considers the period from 1996-2003 *(Eraker, 2013)*, including the IT-bubble in 2002. Other research papers have not tested the short straddle during the financial crisis in 2007.

The protective strategies perform poorly compared to the S&P500. The Long iron butterfly underperforms the S&P500 by 21%, while the long iron condor underperforms with 12%. This is to be expected, as when eliminating downside risk the returns become lower.

The initial delta neutral strangle is the best performing strategy in relation to the information ratio and outperforms the S&P500 in the sample period with an information ratio of 1.25%. The initial delta neutral straddle yields an information ratio of 0.04%, and therefore performs only slightly better compared to a buy-and-hold strategy in the S&P500. The remaining strategies do not perform better than an investment in the S&P500 when looking at this ratio.

The Sortino ratio of a buy-and-hold strategy in the S&P500 in the sample period is 10%. Again, the short strangle is the better performing strategy and outperforms the S&P500 in all scenarios. The short straddle underperforms by approximately 1%, while the long iron butterfly and long iron condor are significantly underperforming the market in this statistic. They both achieve negative Sortino ratios, as they cannot produce positive excess returns.

In conclusion of the performance measurements, the initial delta neutral short straddle and short strangle are more lucrative than a long investment in the S&P500 in the similar sample period. The protective strategies do not perform better than the S&P500 and do not yield Sharpe ratios, information ratios or Sortino ratios above zero. The performance measures of these strategies are discussed again in section 4.1, where the sample period is divided into five sub-periods showing the results for these periods.

Risk measures

The risk measures that will be examined in the following section are the maximum drawdown, Value at Risk and expected shortfall. These measure the downsides of the strategies. It is important to consider these figures, as they are crucial when implementing these strategies, since the investors could face liquidation of the positions if they are not able to withstand the downside risk of the strategy. The risk measures are illustrated in Figure 3.9 and Figure 3.10 below for the initial delta neutral strategies.

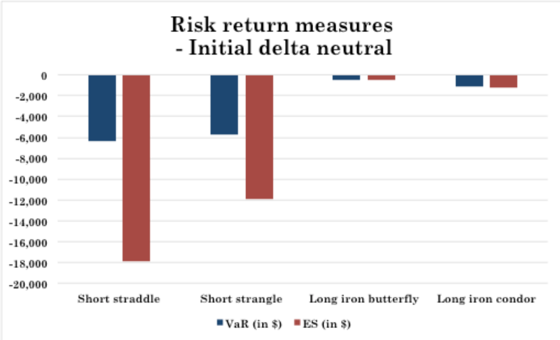

Figure 3.9 – Value at Risk and expected shortfall for initial delta neutral strategies

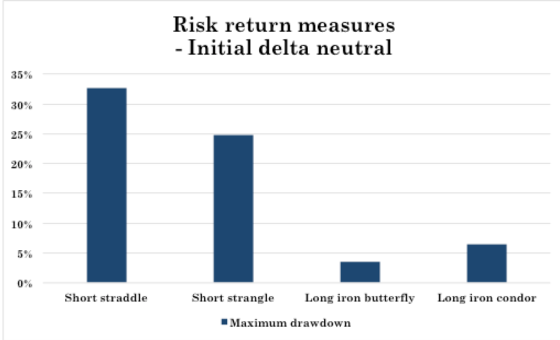

Figure 3.10 – Maximum drawdown for initial delta neutral strategies

The Value at Risk measure (denoted VaR in the following) is an indicator of how much an investor can expect to lose 95% of the time. As expected the VaR measure is significantly higher for the naked spreads. For the short straddle the VaR is -$6,317 while for the short strangle the measure is -$5,727. It is expected that the short strangle performs slightly better as it is a less risky spread that allows for more market movements. As mentioned, the long iron butterfly and long iron condor performs significantly better than the two other strategies since the negative returns are capped for these strategies. The VaR is -$490 for the iron butterfly while it is -$1,160 for the iron condor. This is a surprising result, as one would expect that the long iron condor would perform better than the long iron butterfly when it comes to the risk measures, as this is more likely to end ITM. The ITM area for a long iron condor is wider as seen in Figure 2.6.

The reason why the iron condor performs worse than the iron butterfly is that the premiums collected from selling OTM options is lower than selling ATM options and the larger profit margin from selling OTM options is not compensating for the lower premium collected.

The expected shortfall (denoted ES in the following) shows the same pattern as with the VaR. The short straddle and short strangle has more risk compared to the long iron butterfly and long iron condor. The ES for the short straddle is -$17,883 while for the short strangle it is -$11,893. The long iron butterfly has an ES of -$533 while the long iron condor has an ES of -$1,200. Again, it is expected that the naked strategies have much higher risk than the protective strategies since they don't have capped negative returns as the protective strategies have. It is important to realize that each trade has a potential loss that is quite large, and if this continues for multiple periods in a row, this can be very harmful for the investor. Therefore, it is critical that an investor has capital that can withstand potential losses to avoid liquidation of the positions.

As expected the maximum drawdown from the high watermark (denoted MDD and HWM in the following) for the two naked positions are much bigger compared to the protective positions, given the unlimited downside risk. The MDD for the short straddle and short strangle is 32.7% and 24.83% respectively. For the long iron butterfly and long iron condor the MDD is 3.57% and 6.4% respectively. When choosing to implement an investment strategy the MDD is an important factor to consider, as the investor should be able to lose at least this amount of the invested capital and still be able to continue trading. If we consider a fund implementing one of the naked strategies, a long run of negative returns can cause its investors to withdraw their money, which can be even more problematic when experiencing a negative run. In Figure 3.11 and Figure 3.12 are illustrated the returns, the HWM and the MDD for the short straddle and short strangle. The measures for the short straddle and the short strangle have the same trends, but the short straddle has higher MDD and declines in returns in some spikes compared to the short strangle. This agrees with the short strangle having a larger interval of being ITM and therefore a smaller interval of being OTM than the short straddle. If the same options are entered at the same time with the same strike, the loss for the short strangle is lower compared to the straddle.

The HWM and MDD for the two protective strategies (long iron butterfly and long iron condor) are illustrated in Figure 3.13 and Figure 3.14 and these have considerably smaller MDD's and HWM's compared to the naked strategies. When comparing the long iron butterfly to the long iron condor we see that the long iron condor has considerable higher MDD's than the long iron butterfly. This is caused by the premiums received and paid when entering the position. The further OTM the option is, the less expensive the option is. When considering the volatility smile, the option bought in the long iron condor to insure a decrease in the underlying price is relatively more expensive than the option bought in the long iron butterfly also to insure a decrease in the underlying price. The premium received when entering the short options in the long iron butterfly is also higher than the one received from the long iron condor. This causes the higher MDD in the long iron condor.

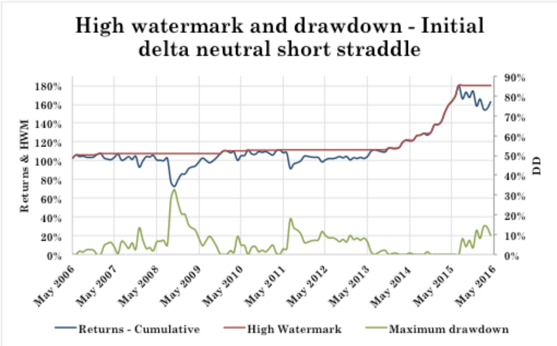

Figure 3.11 – High watermark and Drawdown for initial delta neutral short straddle

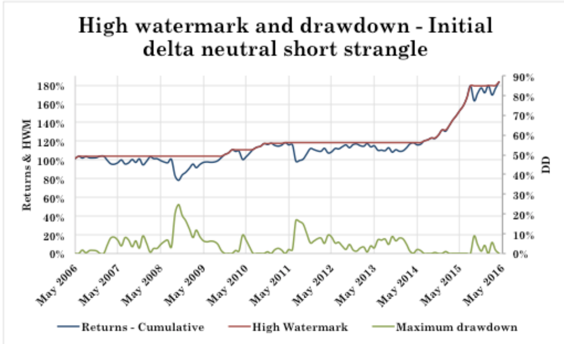

Figure 3.12 – High watermark and Drawdown for initial delta neutral short strangle

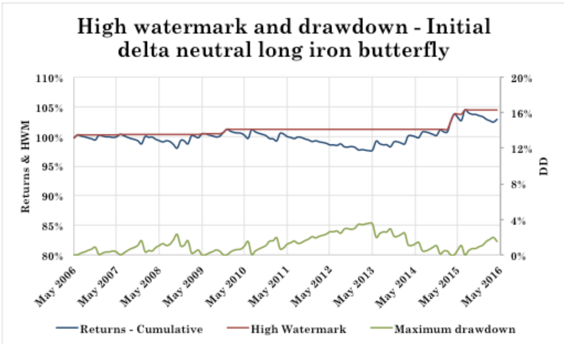

Figure 3.13 – High watermark and Drawdown for initial delta neutral long iron butterfly

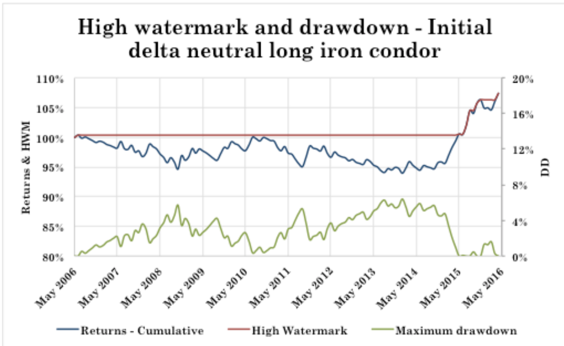

Figure 3.14 – High watermark and Drawdown for initial delta neutral long iron condor

3.2.7 Development of delta during trading period

The option strategies described in the section above are initial delta neutral and are not delta-hedged at any point during the holding period. As shown in Appendix Figure 1.3 and Appendix figure 1.4 delta changes over time and this is also the case for our initial delta neutral strategies. Figure 3.15 illustrates the daily development of delta of each strategy's first trade. The short straddle has the highest variation of delta during the first trade followed by the short strangle, which also experience a high degree of variation in delta. The long strategies do not have as high a variation as the short strategies, which is due to the limited downside risk they face. When the options are close to expiration the delta increases further and at one point both the straddle and strangle have a delta of one. This is representative for each trade made in the sample period for the short strategies. It is very common for the delta to reach one (negative one) at some point during the holding period of the options. When the delta is one it means that the value of the options follows the value of the underlying completely. This is not desirable when we are trying to capitalize on change in volatility and not the price of the underlying.

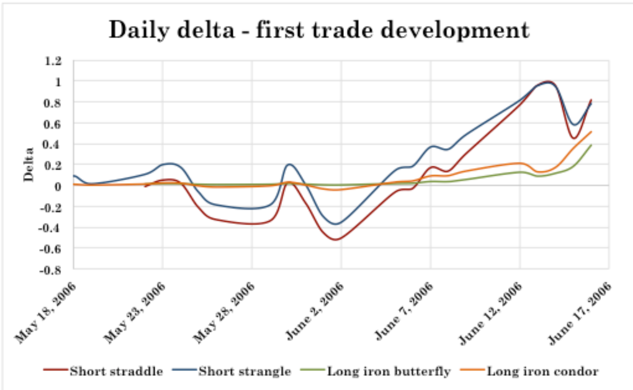

Figure 3.15 – The development of delta in first trade of each strategy

The average delta during the holding period for all initial delta neutral trades are illustrated in Figure 3.16, and is consistent with both Figure 3.15, Appendix Figure 1.3 and Appendix figure 1.4, which shows that the delta of short options increases as time to expiration decreases.

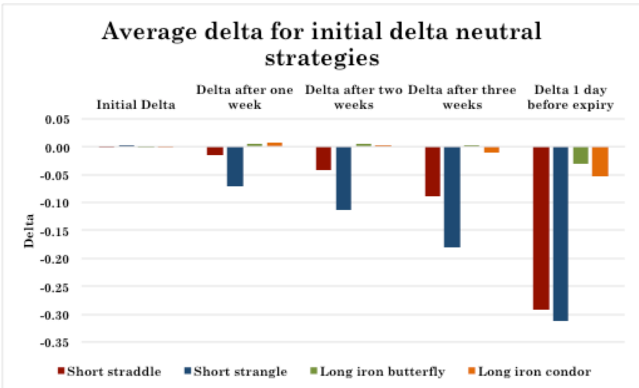

Figure 3.16 – Average delta during the holding period for initial delta neutral strategies

The figure above shows that the delta of the option strategies increases significantly each week, especially the short straddle and the short strangle. The results for the short straddle and short strangle is as expected. The delta of each option is expected to change as time to maturity gets closer to expiration and the price of the underlying moves. The delta of the individual option will develop as with the short straddle and short strangle but due to the additive nature of the delta, the effects cancel out. Therefore, only some deviations from delta neutrality should occur during the life of the option, and larger deviations should occur when the options are very close to maturity. To mitigate the problem of delta neutrality we will in section 3.3 use different frequencies of delta hedging to analyse the impact it has on the returns and the ability to capture the volatility risk premium more efficiently.

To sum up, we can group the four strategies into two categories, one is "*naked strategies*" and the other is "*protective strategies*". The naked strategies are the short straddle and short strangle, while the protective strategies are the two remaining, the long iron butterfly and the long iron condor. The naked strategies perform much better with regards to cumulative returns and general performance measures, but have much higher risk. The protected strategies don't perform well when considering the performance measures. Nevertheless, they produce excellent risk measures. However, since the strategies produce cumulative returns over a 10-year sample period that does not move much from zero they must be considered to be unattractive investments. The short straddle and strangle produce very good results when looking at returns and certainly when considering performance measures. When looking at the risk measures they perform reasonably well and could therefore be considered to be attractive strategies.

When considering the strategies ability to capture the volatility risk premium we find that the deltas of the strategies are far from zero over the life of the options. This causes the strategies to be affected by other factors than just changes in volatility, which is not desirable. A solution to this problem is to consider a delta hedging strategy of the initial delta neutral strategies to capture the volatility risk premium more efficiently.

3.3 Delta-hedged strategies

The short vega option strategies considered in this thesis are not a pure bet on volatility when they are sold and held to maturity without being hedged. Even when the underlying has a high interim volatility and if the price ends near its starting level the strategy makes money. Purer volatility or variance exposure (exposure to vega risk) can for example be achieved by trading delta-hedged short strategies. By delta hedging, the investor captures the difference between implied volatility and realized volatility over the life of the contract *(Ilmanen, 2011, p. 309)*. In the following section, we will present the descriptive statistics for the four different strategies described earlier, while applying delta hedging at two different frequencies, weekly and daily. This is done to illustrate the effect of delta hedging and create strategies that are more directly exposed to vega rather than delta and gamma. When the strategies are delta-hedged with futures on the S&P500 the strategies are no longer naked. In the following we will refer to the short straddle and short strangle as the "*short strategies*" and the long iron butterfly and long iron condor as the "*long strategies*". Again, the four delta-hedged strategies consist of 120 trades, one each month for 10 years with additional trades for the delta hedging. All figures in the table below are monthly.

3.3.1 Descriptive statistics and comparison

Weekly delta-hedged strategies				
	Short straddle	**Short strangle**	**Long iron butterfly**	**Long iron condor**
		Descriptive statistics		
Mean	0.47%	0.49%	-0.01%	-0.03%
Standard deviation	2.93%	2.31%	0.53%	0.72%
Kurtosis	9.85	2.70	1.81	1.20
Skewness	-2.02	-0.98	1.20	0.50
Minimum	-16.55%	-9.02%	-1.11%	-2.03%
Maximum	7.27%	7.36%	1.75%	2.43%
Spread	23.81%	16.38%	2.86%	4.45%
Number of profitable trades	78	79	39	45
Number of loss trades	42	41	81	75
Mean absolute return (in $)	468	492	-12	-31
Cumulative absolute return (in $)	56,157	59,009	-1,460	-3,729
Cumulative return	66.08%	74.50%	-1.61%	-3.96%
		Performance measurements		
Risk return measures				
Sharpe ratio	12.68%	16.98%	-19.31%	-16.87%
Information ratio	-0.74%	-0.31%	-11.00%	-11.17%
Sortino ratio	12.22%	19.82%	-40.77%	-31.34%
Risk measures				
High watermark	201.21%	176.40%	101.59%	99.96%
Maximum drawdown	22%	19%	5%	12%
Date for maximum drawdown	15/02/16	15/12/14	15/10/13	15/12/14
VaR (in $)	-4,540	-4,223	-683	-996
ES (in $)	-8,361	-5,768	-895	-1,466

Table 3.4 – Descriptive statistics - Weekly delta-hedged strategies

Daily delta-hedged strategies				
	Short straddle	**Short strangle**	**Long iron butterfly**	**Long iron condor**
		Descriptive statistics		
Mean	0.19%	0.30%	0.02%	0.02%
Standard deviation	2.04%	1.90%	0.42%	0.53%
Kurtosis	2.02	4.09	4.06	1.89
Skewness	-0.80	-1.35	1.51	0.48
Minimum	-6.69%	-8.44%	-0.94%	-1.81%
Maximum	5.00%	4.59%	1.81%	1.59%
Spread	11.69%	13.03%	2.74%	3.40%
Number of profitable trades	76	82	44	57
Number of loss trades	44	38	76	63
Mean absolute return (in $)	193	304	20	21
Cumulative absolute return (in $)	23,127	36,453	2,414	2,573
Cumulative return	22.89%	40.80%	2.34%	2.43%
		Performance measurements		
Risk return measures				
Sharpe ratio	4.73%	10.77%	-16.62%	-13.07%
Information ratio	-6.80%	-4.37%	-10.30%	-10.12%
Sortino ratio	5.65%	11.37%	-30.19%	-22.59%
Risk measures				
High watermark	126.69%	140.80%	104.10%	102.43%
Maximum drawdown	18%	22%	3%	6%
Date for maximum drawdown	15/10/08	15/10/08	15/05/13	15/01/15
VaR (in $)	-3,667	-2,795	-527	-714
ES (in $)	-5,343	-5,042	-714	-1,065

Table 3.5 – Descriptive statistics - Daily delta-hedged strategies

Short positions in detail

The short strangle, which had the highest cumulative return among the unhedged strategies also remains the most profitable strategy when delta hedging is applied. The hedging frequency has a significant effect on the return, which decreases as the hedging frequency increases. This could indicate that the returns of the unhedged strategies benefit from other sources than just the volatility. However, as the cost of hedging increases when investors trade more frequently this could explain the lower returns. The cost of trading will be further discussed in section 4.3.

Hedging lowers the variance of returns significantly. Again, the hedging frequencies influence the result, as there is an inverse relationship between hedging frequency and variance. This is to be expected as the returns are less affected by changes in the value of the underlying when the hedging frequency increases.

The short delta-hedged strategies still have a larger spread compared to the long delta-hedged strategies when looking at both hedging frequencies. However, applying delta hedging significantly lowers the spread compared to the unhedged strategies. This development is facilitated by the significantly improved minimum returns, and the fact that there are more profitable trades than unprofitable ones. The performance measures are negatively affected by the delta hedging since the decline in returns is relatively higher than the decline in variance. This is discussed further in section 3.3.2 when all risk- and performance measures are compared.

The risk measures are, as expected, greatly improved by applying delta hedging. The maximum drawdown is much smaller for all the hedged strategies compared to the initial delta neutral strategies. The weekly delta-hedged strategies perform better in this statistic. This is counterintuitive but is caused by the higher returns that the weekly delta-hedged strategies produce. This can be seen in the high watermark, which is significantly higher for the weekly delta-hedged strategies, while the VaR and ES are both better for the daily delta-hedged strategies, which is expected. The higher return compensates for the worsened risk factors. However, as less frequently hedged returns are affected by more than vega, we cannot say that it is a more attractive strategy to capturing the volatility risk premium.

The delta-hedged returns are closer to a standard normal distribution compared to the initial delta neutral strategies, which is caused by the fact that the most extreme outliers are avoided. The return distributions are still leptokurtic indicating large masses in the tails, which is a consequence of the remaining outliers. The return distribution for the short and long delta-hedged strategies can be seen in Figure 3.17 to Figure 3.20.

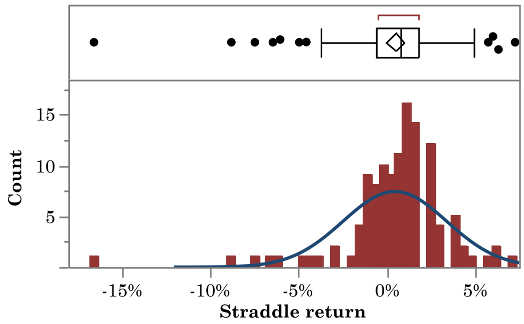

Figure 3.17 – Weekly delta-hedged short straddle returns

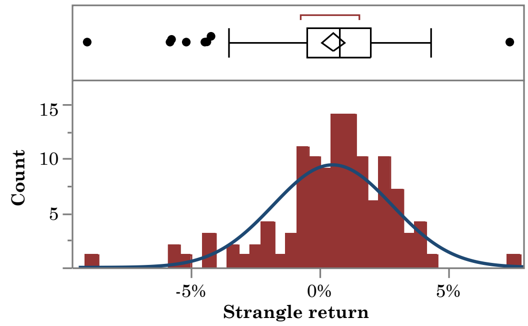

Figure 3.18 – Weekly delta-hedged short strangle returns

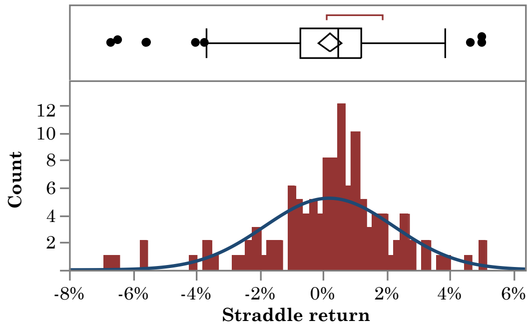

Figure 3.19 – Daily delta-hedged short straddle returns

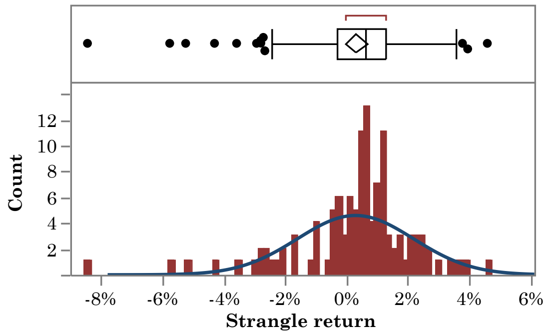

Figure 3.20 – Daily delta-hedged short strangle returns

In Figure 3.21 and Figure 3.22, we see that the cumulative returns are much smoother compared to the unhedged positions. For the short straddle the weekly delta hedge has a positive effect on the cumulative return. This is caused by a few hedges that add to the profitability of the strategy. The hedge should not have a positive return that exceeds the negative return of the security being hedged. Since the delta hedge is designed to mitigate small price movements, bigger price movements (gamma) can still cause the hedge to be profitable (or unprofitable) beyond what was intended. This effect is similar for the short strangle, which has a very large negative return during the financial crisis in 2008 and in the period from August to December 2014, where a series of adverse price movements in the underlying asset causes the weekly hedge to produce large negative returns. These price movements also affect the daily delta-hedged strategies but here the effect is not as significant. The weekly delta-hedged short straddle is not affected as much as the short strangle, which is peculiar. The reason is that the trade dates in this period are not the same. This causes the hedge to be made at a different time and therefore some of the price movements are avoided.

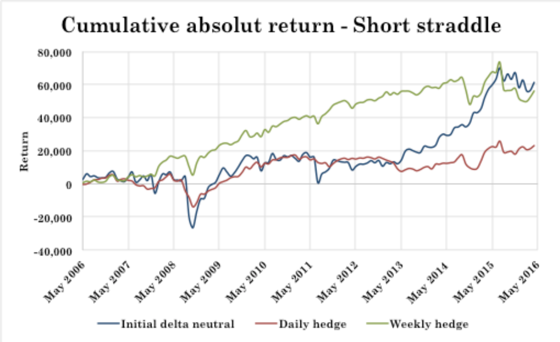

Figure 3.21 – Cumulative returns for short straddle

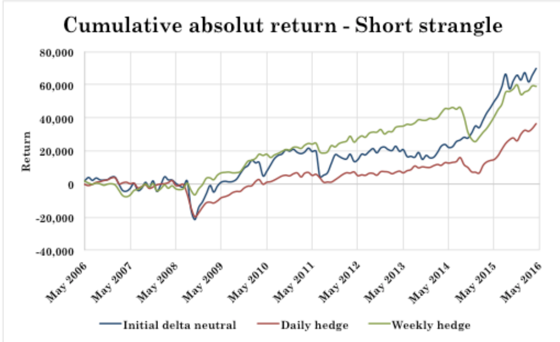

Figure 3.22 – Cumulative returns for short strangle

Long positions in detail

The long positions have the two lowest cumulative returns of the unhedged strategies. As expected, this is still the case when they are delta-hedged. The hedging frequency has no significant effect on the return, apart for the weekly delta-hedged long iron butterfly. This could indicate that the return of the unhedged strategies doesn't benefit from other sources than just the volatility risk premium. The delta hedging lowers the variance of returns slightly. The hedging frequency has no notable influences on the returns, but decrease slightly as hedging frequency increases. This is to be expected as the returns are less affected by changes in the value of the underlying as the hedging frequency increases. Since the development in delta for the long strategies do not move much until they are close to expiration, the hedge will not have any significant effect on the returns in the first period besides the costs incurred when doing so.

The long delta-hedged strategies still have a lower spread than the short delta-hedged positions but have surprisingly increased compared to the unhedged strategies. This development is most likely caused by the cost of the hedge, which lower the returns. The performance measures are negatively affected by the delta hedging since the decline in returns is bigger than the decline in variance. This is discussed further in section 3.3.2 when all risk- and performance measures are compared.

The risk measures are not significantly improved by applying delta hedging. The maximum drawdown is not much smaller for the hedged strategies, and neither are the VaR or the ES. This is because the long positions are not as affected by price movements as the short positions are.

The return distributions for the long delta-hedged returns are shown in Figure 3.23 to Figure 3.26 and do not follow a standard normal distribution. The return distribution is leptokurtic indicating large masses in the tails, which is a consequence of the outliers.

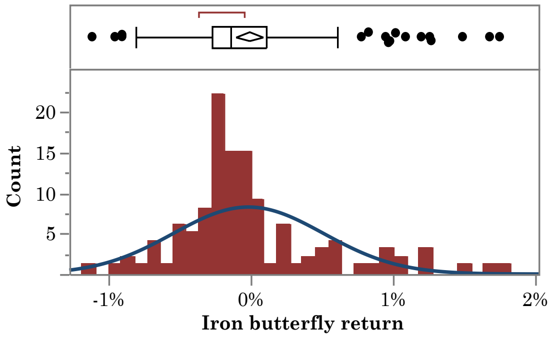

Figure 3.23– Weekly delta-hedged long iron butterfly returns

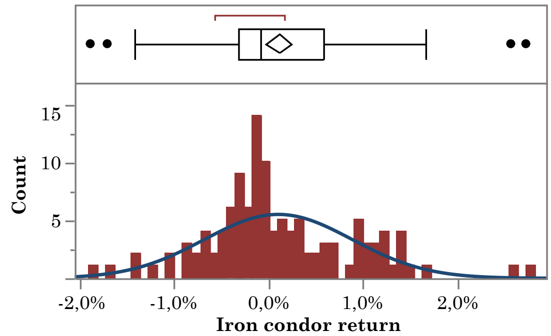

Figure 3.24 – Weekly delta-hedged long iron condor returns

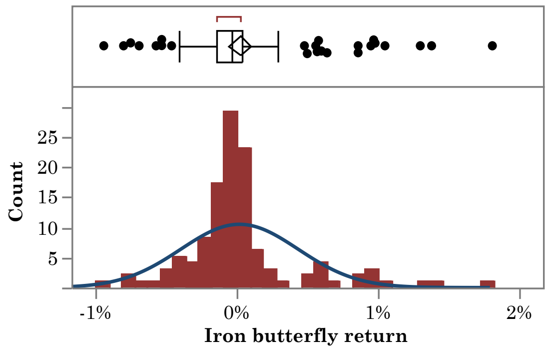

Figure 3.25 – Daily delta-hedged long iron butterfly returns

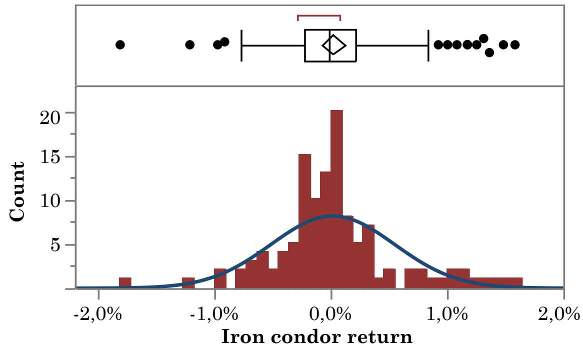

Figure 3.26 – Daily delta-hedged long iron condor returns

As illustrated by Figure 3.27 and Figure 3.28 we see that the returns are still very close to zero. The long iron butterfly with weekly delta hedging is the only strategy that produces a negative cumulative return. This development can be produced by chance as the return is always very close to zero. This means that the chosen sample period will have a great effect on whether the cumulative return is positive or negative. Unlike the short positions, the long positions are not as affected by the adverse price movements in the end of 2008 and 2014. This is expected as the long positions have limited downside and will not experience large negative returns. The long iron condor experiences large positive returns from the end of 2014 till the end of the sample period in mid-2016. The reason is that in this period the payout of the options is either zero or very small causing the profitability of the strategy to increase a lot in this period.

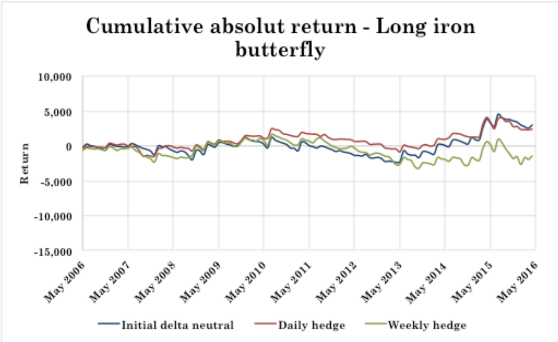

Figure 3.27 – Cumulative returns for long iron butterfly

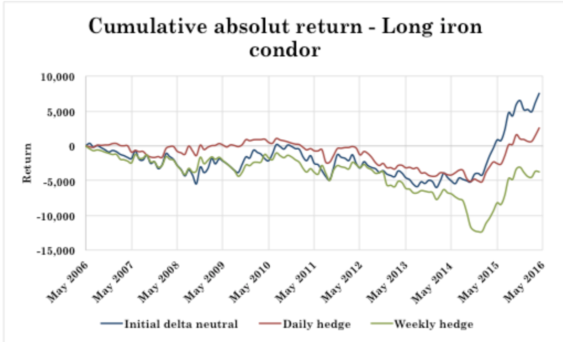

Figure 3.28 – Cumulative returns for long iron condor

3.3.2 General comparison of the hedged strategies' performance measures

In the following section, we will compare the four strategies with respect to their performance- and risk measures. This will provide a deeper understanding of empirical properties of implementing the different delta-hedged strategies. As seen in Table 3.4, Table 3.5, Figure 3.19 to Figure 3.20 and Figure 3.23 to Figure 3.26 the returns for the delta-hedged strategies closer resembles a normal distribution, but cannot be considered normally distributed. Therefore, as discussed in section 3.2.6 the problems of non-normal returns still apply when considering the performance measures that rely on this assumption.

First, we will address the performance of the returns. Only the weekly delta-hedged short strategies outperform a buy-and-hold strategy of the S&P500. The daily delta-hedged short positions perform well, but don't produce returns as high as the returns of the weekly delta-hedged short strategies. This pattern is shown in the previous section in Figure 3.21 and Figure 3.22. We find that the returns for both the long iron butterfly and the long iron condor do not move much from the basis point, and delta hedging doesn't have much effect on the returns.

Weekly delta-hedged strategies				
	Straddle	**Strangle**	**Iron Butterfly**	**Iron Condor**
Excess mean	0.0037	0.0040	-0.0011	-0.0013
Confidence Level (95%)	0.0053	0.0042	0.0010	0.0014
Upper limit	0.0090	0.0082	-0.0001	0.0001
Lower limit	-0.0016	-0.0003	-0.0021	-0.0026
Statistically significant	**No**	**No**	**Yes**	**No**

Table 3.6 – Weekly delta-hedged strategies – statistically significant

Daily delta-hedged strategies				
	Straddle	**Strangle**	**Iron Butterfly**	**Iron Condor**
Excess mean	0.0010	0.0021	-0.0008	-0.0007
Confidence Level (95%)	0.0037	0.0035	0.0008	0.0010
Upper limit	0.0047	0.0056	0.0001	0.0003
Lower limit	-0.0027	-0.0014	-0.0016	-0.0018
Statistically significant	**No**	**No**	**No**	**No**

Table 3.7 – Daily delta-hedged strategies – statistically significant

From Table 3.6 and Table 3.7 we find that the mean returns from each initial delta neutral strategy are non-significant on a 5% level. This indicates there is a possibility that our positive cumulative returns are due to chance. However, this might be a consequence of the small sample size, as this is a very important component in statistical significance analysis, or the fact that the assumption regarding normally distributed returns are violated.

Performance measures

The performance measures of the delta-hedged strategies are illustrated in Figure 3.29 and Figure 3.30, and can be seen in Table 3.4 and Table 3.5. The benchmark used in the information ratio is still the excess return of the S&P500. The Sortino ratio still uses a minimum acceptable threshold of zero.

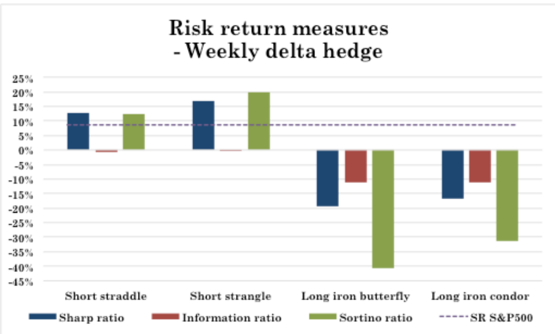

Figure 3.29 – Sharpe ratio, information ratio and Sortino ratio for weekly delta-hedged strategies

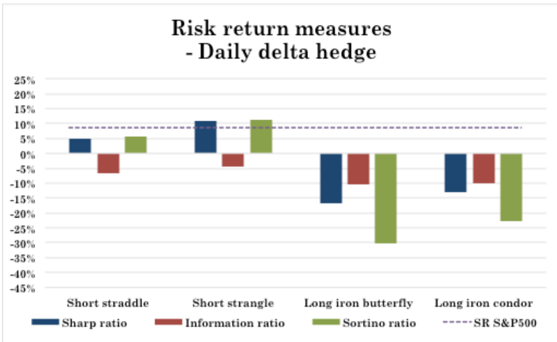

Figure 3.30 – Sharpe ratio, information ratio and Sortino ratio for daily delta-hedged strategies

As mentioned the historically attainable monthly Sharpe ratio from a buy-and-hold position in the S&P500 in the sample period is 8.6% and is illustrated in the figures above as the dotted line. Comparing the Sharpe ratios from the delta-hedged strategies to this, the short strangle consistently outperforms the market and the short straddle outperforms the market when the strategy is delta-hedged weekly.

When the strategy is delta-hedged daily, the monthly Sharpe ratio decreases, because the returns for the daily delta-hedged strategies decrease as discussed in section 3.3.1. This is true for all daily delta-hedged strategies. The long strategies perform poorly compared to the S&P500 in all scenarios and when implementing delta hedging the results worsen. This is caused by the lower returns in the strategies when eliminating the exposure to the market. Also, the long strategies in general have low performance measures, as they are more expensive to trade.

When comparing the Sharpe ratios attained from the delta-hedged strategies to the Sharpe ratios attained from the initial delta neutral strategies, we see the weekly delta-hedged strategies perform better. This is again a consequence of the few delta hedges that add to the profitability of the strategy due to large movements in the underlying. The daily delta-hedged strategies perform slightly worse than the initial delta neural strategies. This is to be expected as we have found that an increase in hedging frequency decrease the returns and lower the variance, but not enough to increase the Sharpe ratio.

Neither of the delta-hedged strategies perform well when looking at the information ratio and do not outperform the S&P500 in the sample period. As expected the short strategies perform better than the long strategies and the weekly delta-hedged strategies perform better than the daily delta-hedged strategies. It is important to remember that an investment in the S&P500 does not capture the volatility risk premium and is not an equivalent measure for this, but as an alternative investment it is appropriate.

The Sortino ratio of a buy-and-hold strategy in the S&P500 in the sample period is 10%. The short delta-hedged strategies perform best when looking at this statistic, as they all produce positive Sortino ratios. Further, only the daily delta-hedged short straddle underperforms the S&P500, where all other short strategies outperform the S&P500. The long strategies yield negative Sortino ratios. One would expect that the long strategies would produce good results in this performance measure, but neither are able to do so because they are unable to generate positive excess returns. One would expect that the short delta-hedged strategies would perform better than the initial delta neutral strategies, as they eliminate the variance caused by market movements. However, the reduced variance is especially lowered for the negative returns, but not enough to compensate for the lower excess returns produced by the short delta-hedged strategies.

In conclusion of the performance measurements, the short strategies perform better than the long strategies, and with regards to Sharpe ratio they also outperform the S&P500. The weekly delta-hedged strategies outperform the daily delta-hedged strategies in every statistic. This is due to the higher cost of more frequent delta hedging, and for the short weekly delta-hedged strategies they also produce higher returns due to some profitable hedges. The information ratio is not positive for any strategy. The weekly delta-hedged short strategies perform better than the S&P500 when considering the Sortino ratio. The daily delta-hedged short strangle also perform better than the S&P500 when looking at the Sortino ratio. We conclude that neither strategy can outperform an investment in the S&P500 in the sample period when delta-hedged. The performance measures of these strategies are discussed again in section 4.1, where the sample period is divided into five sub-periods showing the results for these periods.

Risk measures

The risk measures examined in the following section are the maximum drawdown, Value at Risk and expected shortfall. The risk measures are illustrated in Figure 3.31 to Figure 3.34 below:

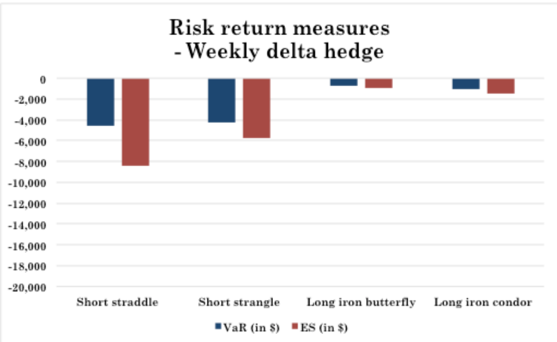

Figure 3.31 – Value at Risk and expected shortfall for weekly delta-hedged strategies

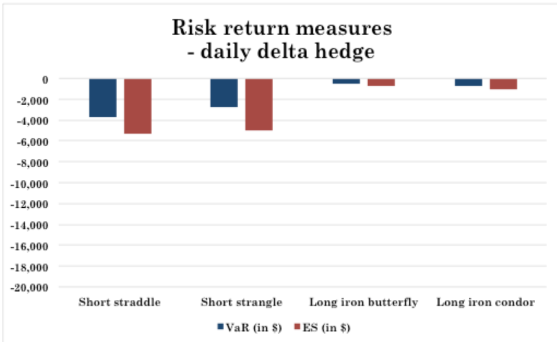

Figure 3.32 – Value at Risk and expected shortfall for daily delta-hedged strategies

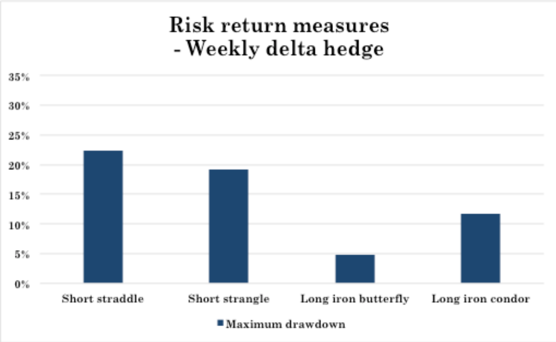

Figure 3.33 – Maximum drawdown for weekly delta-hedged strategies

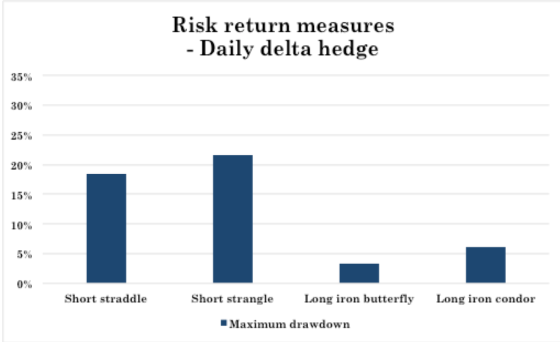

Figure 3.34 – Maximum drawdown for daily delta-hedged strategies

The VaR measure is significantly higher for the short strategies compared to the long strategies. Further, there is an inverse relationship between hedging frequency and VaR, as higher hedging frequency equals lower VaR. The short strangle still perform slightly better than the short straddle as it is a less risky spread. However, the difference is not as significant when applying daily delta hedging. As expected, the long iron butterfly and long iron condor perform significantly better than the two short strategies, since the negative returns are capped for these strategies. The long iron condor still underperforms the long iron butterfly when it comes to the risk measures, and here the difference is not significantly affected by hedging frequency.

The expected shortfall (ES) shows the same pattern as the VaR. The short strategies have more risk compared to the long strategies. Further, the daily delta hedging is more effective at limiting the ES than weekly delta hedging for both the short- and long strategies. As with the VaR there is an inverse relationship between hedging frequency and ES, as higher hedging frequency equals lower ES.

In Appendix Figure 9.24 to Appendix Figure 9.31 the high watermark and the drawdown for the short- and long strategies are illustrated. When considering the maximum drawdown of the strategies this statistic is not significantly improved by applying delta hedging. However, it is important to notice that the high watermark is significantly lower when applying delta hedging. Further, as expected the maximum drawdown from the high watermark for the two short strategies is much bigger compared to the long strategies, given the unlimited downside risk.

In conclusion, the short strategies perform much better with regards to cumulative returns and general performance measures, but have much higher risk compared to the long strategies. In the next section, we will further discuss the implication of delta hedging frequency.

Effect of delta hedging frequency

The point of delta hedging a strategy is to neutralize the effect of price movements in the underlying asset and focus the payoff of the strategy to be caused by changes in volatility. The strategies that are not delta-hedged are exposed to delta and gamma as price movements of the underlying affect the payoff. By delta hedging we can isolate the volatility risk premium more effectively. In Figure 3.15 and Figure 3.16 we can see that the average delta over the lifetime of the options is not close to zero for the initial delta neutral strategies. It is important to stay delta neutral to efficiently capture the volatility risk premium, which is why it is necessary to apply weekly or daily delta hedging.

The effect of hedging is more significant for the short strategies (short straddle and short strangle) compared to the long strategies (long iron butterfly and long iron condor). The reason for this difference in effectiveness is because the short strategies are more exposed to delta and gamma risk compared to the long strategies. The average initial gamma exposure for the short strategies is -0.0124 while for the long strategies the average gamma exposure is -0.00083. The exposure is more extreme during the life of the options as seen in Appendix Figure 9.7 and Appendix Figure 9.8. The gamma exposures are also greater for the weekly delta-hedged strategies compared to the daily hedged. This is to be expected as the gamma risk is neutralized more effectively as the hedging frequency increases.

We find that there is an inverse relationship between delta hedging frequency and return and variance. This means that the overall effect of more frequent delta hedging is lower average and cumulative returns, and lower variance of these returns. The larger negative outliers are avoided causing the return distributions to closer resemble a standard normal distribution, as skewness and excess kurtosis is closer to 0. The lower variance does not compensate for the lower returns as the Sharpe ratio of the strategies are also reduced. However, the investments become less risky as noted by the maximum drawdown, which is significantly lower for the naked positions and slightly lower for the long strategies, as is the VaR and ES. We also find that there is an inverse relationship between delta hedging frequency and VaR and ES. This safety is however achieved at the cost of a lower high watermark, which again is more significantly affected for the short strategies compared to the long strategies. We further find that neither of the delta-hedged strategies can produce excess returns that are significant. This means that we cannot reject the hypothesis that the excess return is 0. The daily delta-hedged short straddle and short strangle yields Sharpe ratios of 5% and 11% respectively. For the weekly delta-hedged short straddle the Sharpe ratio is 13%, while for the weekly delta-hedged short strangle the Sharpe ratio is 17%.

3.4 Regressions

In this section, we examine the link between the different strategies returns and exogenous factors. The regression is done to further understand the properties of the short vega strategies analysed above. We run a linear regression on each strategy's return on the chosen exogenous variables using OLS estimation. As mentioned in section 2.11 we will use the following regression variables, recorded at the entry of the option strategy (t-1).

1) The trading volume of the S&P500
2) The credit spread between a 10-year treasury bond and Moodys Aaa rated corporate bonds
3) The VIX index
4) The market excess return

When the credit spread between the Treasury bond and the corporate bonds increases, it implies an increase in market risk and thus our returns are likely to be affected negatively as described in section 2.11. The riskiness increases as a response to a perceived higher uncertainty of the underlying corporate bonds and therefore the underlying corporations. If the credit spread increases after a trade, a short vega strategy is likely to lose money, as this is an indicator of increased volatility in the market. Short vega strategies are negatively affected when volatility increases. This is only true when the increased volatility in the market is not priced in the options, i.e. only when the volatility spike comes as a surprise to the market. Conversely if the credit spread decreases as a consequence of lower rates on corporate bonds, it is likely a response to more credit worthy corporate bonds. A decrease in the credit spread is an indicator of less volatility, as the corporations are now less risky, given the risk/return argument used in economics. When there are larger changes in the Treasury bond rate it is likely a result of macro-economic factors that will also affect the corporate bond rate.

Therefore, it is less likely that larger changes in the Treasury bond rate will affect the credit spread as the economic environment affects both rates. The economic argument for a change in the VIX index or the trading volume on the S&P500 index is the same. An increase (decrease) in either factor is an indicator of more (less) risk in the market. Further, for all factors we would expect the strategy to perform better in periods where it is decreasing as short vega strategies tend to perform best in these periods.

We will test if the exogenous explanatory variables are statistically significant on a 5% level. First, in the "full model", we will regress against all the variables mentioned, and then exclude insignificant variables one by one until only significant variables remain, which we will refer to as the "final model". In the section below we will only consider the final regression, as several explanatory variables are insignificant, and therefore irrelevant for further analysis. As we are dealing with multiple explanatory variables in our regression we will consider the adjusted R^2 as an indicator of goodness of fit, because it adjusts for the number of explanatory variables in the model.

The linear regression model used assumes that the residuals have the same variance throughout the period. This is referred to as homoscedasticity. If the assumption about homoscedasticity is violated the validity of the tests and confidence intervals are doubtful. We find that the residuals from the regressions are homoscedastic on a 5% level for each strategy. In Appendix Figure 9.32 to Appendix Figure 9.35 the residuals for the final initial delta neutral short straddle are plotted against the explanatory variables. Also, the credit spread plotted against the residuals for the daily delta-hedged short straddle is plotted. The plots of the residuals for the remaining strategies are not included in appendix, as they show somewhat the same results.

Normality in the residuals are an important assumption when testing the significance of the returns. In Figure 3.35 normal probability plots are shown for the short straddle when initial delta neutral, weekly delta-hedged and daily delta-hedged. For the residuals to follow a normal distribution, the observations should not deviate from the trend line. This is not the case in our residuals as the tails deviate from the line. The assumption is not seriously violated, and we therefore conclude the regression results can still be considered valid *(Makridakis, Wheelwright, & Hyndman, 1998).* The normal probability plots from the final regressions of the short straddle are representative for the final regressions of the short strangle and the long iron condor.

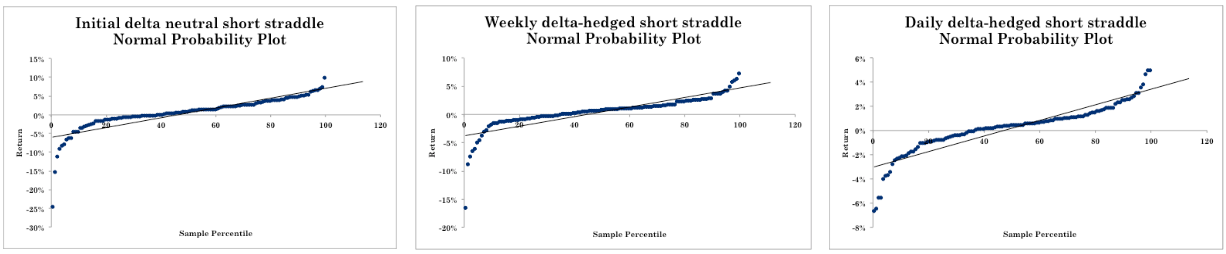

Figure 3.35 – Normal probability plots for residuals in short straddle regression

It is important to consider multicollinearity when using multiple regressions. Therefore, we examine the correlation between the exogenous factors. The critical value for strong multicollinearity is a correlation of maximum 90% and week multicollinearity of maximum 80% *(Bowerman, O'Connell, Murphree, Orris, 2012)*. We have presented the correlation matrices in Appendix Table 9.1 to Appendix Table 9.4. Here it is stated that the correlation between the factors varies between -14% and 71%. We can therefore conclude that multicollinearity is not an issue in either the full model or the final model, even when considering the relatively high correlation between trading volume and VIX.

3.4.1 Regression results

Short straddle

Table 3.8 shows the regression results for the different delta hedging frequencies for the short straddle. The variables we include have a positive coefficient for the volatility (VIX), while for the trading volume, the credit spread and the market excess return they are negative for all hedging frequencies.

We find that market excess return becomes insignificant on a 5% level when delta hedging is applied. This is desired, as we don't want our returns to be affected by the performance of the underlying asset, but just the volatility.

Short straddle						
	Initial delta neutral		Weekly delta-hedged		Daily delta-hedged	
	Full model	Final regression	Full model	Final regression	Full model	Final regression
Intercept	3.11%	4.38%	1.95%	2.01%	1.07%	0.98%
t-statistic	1.78	2.86	1.65	1.96	1.34	1.23
P-value	7.84%	0.50%	10.23%	5.20%	18.23%	22.28%
Vol. measured by VIX	0.21%	0.20%	0.14%	0.14%	0.11%	0.12%
t-statistic	3.82	3.60	3.78	3.94	4.41	4.55
P-value	0.02%	0.05%	0.03%	0.01%	0.00%	0.00%
Trading volume	-0.09%	-0.09%	-0.05%	-0.05%	-0.05%	-0.05%
t-statistic	-3.96	-3.82	-3.29	-3.28	-4.25	-4.24
P-value	0.01%	0.02%	0.13%	0.14%	0.00%	0.00%
Credit spread	-0.36%	N/A	-0.06%	N/A	-0.25%	-0.25%
t-statistic	-1.47	N/A	-0.37	N/A	-2.24	-2.19
P-value	0.01%	N/A	71.18%	N/A	2.73%	3.06%
Market excess return	-18.86%	-18.53%	-8.53%	N/A	-5.83%	N/A
t-statistic	-2.17	-2.13	-1.46	N/A	-1.48	N/A
P-value	3.17%	3.56%	14.80%	N/A	14.27%	N/A
R^2 adjusted	14.49%	13.64%	10.72%	10.54%	16.17%	15.32%

Table 3.8 – Regression of short straddle returns on independent variables

In the final regression, the volatility measured by VIX has a positive coefficient between 0.11% and 0.21% depending on the delta hedging frequency. All the coefficients for VIX are statistically significant as indicated by the t-statistics, and this factor contributes most to the change in our returns. The positive correlation suggests that an increase in VIX by 1% will result in an increase in our returns between 0.11% and 0.21% for the short straddle depending on the delta hedging frequency. This is a surprising result, as we would expect the VIX factor to be negative. An explanation of the positive coefficient could be that we use VIX at entry of the strategy. A high level of VIX will usually equal a positive return, as volatility tends to decline from a higher level of volatility. Conversely if VIX is low, the volatility will tend to climb resulting in a negative return. This is the effect of the well documented mean reversion of volatility. Using VIX at the entry of the strategy causes a positive coefficient for the VIX factor. The VIX has a positive correlation with the returns between 13.6% and 19.9% depending on the delta hedging frequency. This indicates the relatively small relation of the factor and our returns, which is surprising as volatility should be the main driver of the straddle returns. The adjusted R^2 achieved for the short straddles is between 10.54% and 15.52% for the final regression. This is above what is achieved by Goltz & Ni Lai *(2009)* who use a similar regression model and find adjusted R^2 values of around 9%. The explanatory value is far above that achieved by a Fama-French regression, which yields very little explanatory power as found by Goyal & Saretto *(2008)*.

The trading volume has coefficients ranging from -0.09% to -0.05% depending on the delta hedging frequency. All the coefficients for trading volume is statistically significant as indicated by the t-statistics. This implies a negative correlation between the level of trading volume and our returns, which implies that if the trading volume increase by 1% our returns will decrease depending on the strategy between -0.09% to -0.05% for the short straddle. The negative relationship is expected as higher values of trading volume indicates disagreement in the market, and therefore higher volatility. Trading volume has a correlation with the returns between -6% and -13% depending on the delta hedging frequency. The lower correlation is expected, as trading volume is not a direct volatility measure. However, we can see from the correlation matrix in Table 2.2 that the correlation between the VIX and trading volume is quite high, which could lead one to expect more correlation between the trading volume and the returns.

The alpha values for the four strategies can be interpreted as the mispricing of the used model under the interpretation that it is the correct model. However, it could also indicate that the returns are driven by other factors. These could be liquidity in the option market, margin constraints or exposure to other Greeks than delta, which is not hedged. To limit the exposure to other Greeks these can also be hedged, but this is left for further research. Our alphas range between 0.98% and 4.38% for the short straddle. Further the t-statistics confirm that we reject the null hypothesis, that the alpha is zero. Therefore, the intercept is statistically significantly different from zero on a 5% level. This indicates that the explanatory factors used, do not explain the returns fully.

Overall, we can interpret the results as evidence that apart from volatility, the returns are also linked to the exogenous factor that proxy for disagreement in the market (trading volume). However, it is important to realize that even by including every significant factor they only explain a small fraction of the variation in the returns. This is indicated by the adjusted R^2 values, which range from 10.5% and 15.23%. The relatively low value for adjusted R^2 is caused by the fact that there are other factors that explain our returns, which are not included in the regression. We find that the delta-hedged short straddle returns provide factor exposure, which can be interpreted as being related to the volatility risk premium.

Short strangle

Table 3.9 shows the regression results for the different delta hedging frequencies for the short strangle. We find that the results for the short strangle with different hedging frequencies have similar exposure to the different factors as the short straddle and that the same factors are statistically significant. This is not surprising as the short strangle has similar properties as the short straddle. When comparing the short strangle to the short straddle we find that the adjusted R^2 is lower. The reason for the lower adjusted R^2 is that the delta-hedged short strangle is not a pure bet on lower volatility similar to the delta-hedged straddle. Therefore, we expect that the volatility factors should explain more of the short straddle return compared to the short strangle. Further, we find that the excess return on the market is more significant for the initial delta neutral short strangle compared to the short straddle. The explanation is also that the short strangle is not a pure bet on lower volatility as it allows for larger movements in the market. The regression results for the short strangle are shown in Table 3.9 below.

Short strangle						
	Initial delta neutral		Weekly delta-hedged		Daily delta-hedged	
	Full model	Final regression	Full model	Final regression	Full model	Final regression
Intercept	3.14%	4.43%	1.94%	1.78%	0.88%	1.52%
t-statistic	1.99	3.40	1.72	1.94	1.14	2.39
P-value	4.94%	0.09%	8.89%	5.51%	25.70%	1.84%
Vol. measured by VIX	0.22%	0.21%	0.11%	0.11%	0.08%	0.08%
t-statistic	4.85	4.68	3.26	3.43	3.63	3.51
P-value	0.00%	0.00%	0.15%	0.08%	0.04%	0.06%
Trading volume	-0.09%	-0.09%	-0.04%	-0.04%	-0.03%	-0.03%
t-statistic	-5.23	-5.17	-3.26	-3.20	-3.94	-3.78
P-value	0.00%	0.00%	0.14%	0.18%	0.01%	0.02%
Credit spread	-0.33%	N/A	-0.02%	N/A	-0.20%	N/A
t-statistic	-1.42	N/A	-0.11	N/A	-1.80	N/A
P-value	15.82%	N/A	91.31%	N/A	7.46%	N/A
Market excess return	-19.99%	-19.68%	-9.70%	N/A	-6.66%	N/A
t-statistic	-2.42	-2.37	-1.64	N/A	-1.66	N/A
P-value	1.70%	1.92%	10.34%	N/A	9.96%	N/A
R^2 adjusted	22.67%	21.99%	9.43%	8.89%	13.67%	10.84%

Table 3.9 – Regression of short strangle returns on independent variables

The volatility measured by VIX has a positive coefficient between 0.08% and 0.21% depending on the delta hedging frequency. All the coefficients for VIX are statistically significant as indicated by the t-statistics, and it contributes mostly to the change in our returns compared to the other regression factors. The VIX factor still has a relatively low correlation with the returns, which is consistent with the findings for the short straddle. Since volatility should be the main driver of the returns it is still surprising that the correlation is this low.

The trading volume has coefficients ranging from -0.03% to -0.09% depending on the delta hedging frequency. All the coefficients for trading volume is statistically significant as indicated by the t-statistics. The trading volume factor has correlations with the returns between -11.8% and -21.1% depending on the delta hedging frequency. This correlation is higher for the short strangle returns compared to the short straddle returns, which indicates that trading volume has more explanatory power for this strategy.

The alpha values for the short strangle regressions are significant for the initial delta neutral- and daily delta-hedged short strangle. For the weekly delta-hedged short strangle the alpha is only slightly insignificant as shown by the t-statistics. The coefficients are between 1.52% and 4.43%.

Overall, we can interpret the results as evidence that apart from volatility, the returns are also linked to the exogenous factor that proxy for disagreement in the market (trading volume). However, it is important to realize that even by including every significant factor they only explain a small fraction of the variation in the returns. This is indicated by the adjusted R^2 values, which range from 8.9% and 22.0%. The relatively low value for adjusted R^2 is caused by the fact that there are other factors that explain our returns, which are not included in the regression. We find that the delta-hedged short strangle returns provide factor exposure, which can be interpreted as being related to the volatility risk premium.

Long iron butterfly and long iron condor

For the long iron butterfly and long iron condor we find that every exogenous variable is insignificant meaning that the variables do not hold any explanatory power of our returns as stated in Table 3.10 and Table 3.11. This is an interesting result as volatility and market disagreement should be able to explain the returns of an option strategy that is short vega. We therefore conclude that the long strategies' returns do not provide factor exposure, which can be interpreted as being related to the volatility risk premium even when delta-hedged.

Long iron butterfly						
	Initial delta neutral		Weekly delta-hedged		Daily delta-hedged	
	Full model	Final regression	Full model	Final regression	Full model	Final regression
Intercept	-0.06%	N/A	-0.27%	N/A	-0.15%	N/A
t-statistic	-0.25	N/A	-1.19	N/A	-0.84	N/A
P-value	80.60%	N/A	23.64%	N/A	40.41%	N/A
Vol. measured by VIX	0.00%	N/A	0.00%	N/A	0.00%	N/A
t-statistic	0.18	N/A	0.14	N/A	-0.52	N/A
P-value	85.44%	N/A	88.92%	N/A	60.10%	N/A
Trading volume	0.00%	N/A	0.00%	N/A	0.00%	N/A
t-statistic	0.11	N/A	0.95	N/A	1.08	N/A
P-value	91.49%	N/A	34.46%	N/A	28.09%	N/A
Credit spread	-0.01%	N/A	0.01%	N/A	0.00%	N/A
t-statistic	-0.23	N/A	0.18	N/A	-0.01	N/A
P-value	81.74%	N/A	85.65%	N/A	99.52%	N/A
Market excess return	-0.02%	N/A	0.98%	N/A	0.65%	N/A
t-statistic	-0.02	N/A	0.88	N/A	0.73	N/A
P-value	98.66%	N/A	38.28%	N/A	46.66%	N/A
R^2 adjusted	-3.31%	N/A	-1.00%	N/A	-1.89%	N/A

Table 3.10 – Regression of long iron butterfly returns on independent variables

Long iron condor						
	Initial delta neutral		Weekly delta-hedged		Daily delta-hedged	
	Full model	Final regression	Full model	Final regression	Full model	Final regression
Intercept	-0.13%	N/A	-0.18%	-0.22%	-0.10%	N/A
t-statistic	-0.38	N/A	-0.54	-1.39	-0.43	N/A
P-value	70.41%	N/A	59.36%	16.61%	67.06%	N/A
Vol. measured by VIX	0.01%	N/A	0.01%	0.02%	0.00%	N/A
t-statistic	0.77	N/A	1.26	2.27	-0.17	N/A
P-value	44.33%	N/A	21.03%	2.47%	86.82%	N/A
Trading volume	0.00%	N/A	0.00%	N/A	0.00%	N/A
t-statistic	-0.38	N/A	-0.13	N/A	0.61	N/A
P-value	70.58%	N/A	90.01%	N/A	53.99%	N/A
Credit spread	-0.05%	N/A	-0.02%	N/A	0.01%	N/A
t-statistic	-1.08	N/A	-0.35	N/A	0.20	N/A
P-value	28.20%	N/A	72.55%	N/A	84.23%	N/A
Market excess return	-1.62%	N/A	0.09%	N/A	0.31%	N/A
t-statistic	-0.93	N/A	0.05	N/A	0.27	N/A
P-value	35.63%	N/A	95.70%	N/A	78.56%	N/A
R^2 adjusted	-1.24%	0.92%	-1.01%	3.39%	-2.93%	N/A

Table 3.11 – Regression of long iron condor returns on independent variables

In conclusion, we find that the short strategies have very similar properties as measured by the explanatory variables. We further find that only when the strategies are delta-hedged market movements do not explain the returns. This leads us to conclude that both delta-hedged short straddle- and delta-hedged short strangle returns provide factor exposure, which can be interpreted as being related to the volatility risk premium. However, as the adjusted R^2 is relatively low there must be other factors, which are not necessarily related to volatility, that drive the returns. We further find that the long strategies' returns cannot be explained by the exogenous variables tested in this regression and do not provide factor exposure, which can be interpreted as being related to the volatility risk premium. The regression models are tested for multicollinearity and based on the correlation between the variables this is rejected.

3.5 Market timing indicator strategies

The strategies examined in the above sections are traded each month in the sample period. In sub-question two we ask whether the VIX or CDX indices can be used as market timing indicators to enhance the performance of the four strategies. The indices are strongly negative correlated with the S&P500 (-0.59 and -0.54), and we wish to analyse if this negative correlation can be used as a market timing indicator for the option strategies.

In Figure 2.7 this inverse relationship is illustrated. When the S&P500 decreases, both the VIX and the CDX indices increases. As seen in the figure, the VIX and the CDX is not identical and must therefore include different information. That is why we test the four option strategies against both indices. It is also noticeable that the CDX index is slightly faster to indicate abnormal high risk in the market compared to VIX e.g. in the financial crisis in late 2008 and also the European sovereign debt crisis in August 2011. The dotted vertical lines in Figure 2.7 identify this.

3.5.1 Indicators and their statistics

As mentioned in section 2.6 the indicating factors used in this thesis are based on the current level of the VIX- and CDX index. The benchmark we use to measure the results against is the earlier analysed strategies, where we enter the position at all time regardless of the economic environment. The indicators should modify whether to enter the position or not. The chosen indicators are based on dynamic thresholds on both the VIX and the CDX index to exploit most recent data at each trade.

The first dynamic strategy is based on an average on either index. To avoid look-ahead biases the averages starts from January 2nd 2003 and calculates the average used for the first trade until May 1st 2006. Continuously the average will be expanded calculating a new average for each day that passes in our sample period. Therefore, the latest traded combination will be based on an average calculated from January 2nd 2003 to April 30th 2016. This method has been used for both the VIX and the CDX data and the beginning thresholds are 16.36 and 51.57 respectively and the last thresholds for them are 19.46 and 84.44 respectively. For both indices, we see an increase, which primarily is caused by the financial crisis where the volatility was very high and where the risk of credit defaults was high.

To determine if the trade should be made, we compare the current value of the VIX and the CDX to this average. We have a strategy for when the current value is above or below the average. This gives us four indicating strategies for each option strategy.

The other dynamic strategies are calculated using a moving average (MA) of historical data for different frequencies. The frequencies chosen in this thesis are 10, 30 and 50 trading days. A MA is based on past prices and is a trend-following indicator. It can also be thought of as a lagging indicator (lagged 10, 30 or 50 days) *(Newbold, Carlson, & Thorne, 2013, p. 689)*. The MA for both VIX and CDX are shown in Appendix Figure 9.18 and Appendix Figure 9.19 with a smaller sample period, so the differences are more significant. It shows that the longer the moving average, the smoother the moving average is compared to the raw prices. When trading based on the moving average, we again test if the moving average is above and below the current value of the index. This summarize to six indicating strategies for each index.

The relationship between the VIX index and the CDX index is also interesting to evaluate, as they are strong correlated (0.84). Figure 2.7 showed that the VIX index was lagged in the reaction to market risks compared to CDX, and therefore the CDX/VIX relationship can be an indicator on whether to trade or not. This results in two additional indicating strategies.

Including the benchmark of entering the position each month, we have a total of 19 (1+4+6+6+2) indicating strategies we wish to test against the strategies analysed in section 3.3 above. This gives us $19 * (4 + 4) = 152$ tested strategies in total[2].

The chosen MA's are based on short terms as we wish to spot short-term trend changes. This is because the option strategies have a duration of one month, which can be considered short term.

3.5.2 General presentation of strategies

Each market timing indicator strategy is compared to the appropriate "always sell" benchmark strategy. Meaning that when testing a market timing indicator on the daily delta-hedged straddle we compare the result to the "always sell" daily delta-hedged straddle. We will select the best performing strategies by comparing both the risk- and the performance measures. As concluded above the short- and the long strategies perform quite different due to the risks. Therefore, we will analyse the strategies separately, where we compare the short straddle and the short strangle in the first part and afterwards the long iron butterfly and long iron condor. We will select the best short straddle and short strangle when applying weekly- and daily delta hedging, and likewise for the long strategies. We therefore end up with four short- and four long market timing indicator strategies.

In this section, we will present a general overview of the results of the strategies. This is done to clarify which indicators produce consistent results.

We will be evaluating the following key performance indicators, since looking at all the statistics covered in the previous analysis would be too extensive:

- Cumulative absolute return in excess of the initial strategy (% increase)
- Increase in Sharpe ratio compared to the initial strategy
- Maximum drawdown

To evaluate which indicators (VIX, CDX, above, below) that produce the best key performance indicators we find the top ten best performing strategies for each of the three key performance indicators. The analysis will be divided into short- and long strategies in the following section.

[2]Four weekly delta-hedged strategies, four daily delta-hedged strategies

Short straddle and short strangle

Focusing on the top ten best performing strategies, we can now examine how each individual indicator performs. In Table 3.12, we present the directional indicators (above/below) contribution to the top ten best performing strategies when looking at the three key performance indicators. This helps us understand which type of indicator performs best. We find that 80% of the top ten best performing strategies trades when the moving average was above the current level of the index. When considering maximum drawdown, we find that 90% of the top ten involves using an indicator that trades when the moving average is above the current level of the index.

Above/below averages and MAs				
	Short strategies		Long strategies	
	Above	Below	Above	Below
Cumulative absolute return compared to initial strategy (in %)	8	2	3	7
Sharpe ratio	9	1	4	6
Increase in Sharpe Ratio compared to initial strategy	8	2	1	9
Maximum drawdown	9	1	2	8

Table 3.12 – Top ten performing strategies split between above/below on chosen performance- and risk measures

This pattern is not surprising. It is well known, and documented, that volatility is highly mean-reverting *(Coval & Shumway, 2001)*, and tends to revert to its average. Since the option strategies considered in this thesis benefit from volatility being lower than expected, it seems reasonable that we should benefit from mean reversion by trading when volatility is higher than normal. In other words, when the implied volatility in the market is much higher than average historical volatility, it can be indicative of misestimating of mean reversion in volatility. A common conjecture is the notion of overreaction to current information, which can lead to temporary spikes in implied volatility, which can be exploited. However, as seen in Table 4.1 to Table 4.4 the initial strategies perform poorly when implemented in periods of unusually high volatility such as the financial crises. When considering delta-hedged strategies, high volatility can make it difficult to implement an effective delta hedging strategy. In periods with high degree of volatility in the market a gamma hedging strategy might be beneficial. For the short positions one must realize, that given the unlimited theoretical loss, when the volatility suddenly spikes, the strategy performs very poorly. Conversely when the volatility is at its peak the strategy will receive higher premiums compared to periods of lower volatility. However, the higher returns received in these periods when volatility falls, do not outweigh the loss experienced when the market crashes.

When looking at Table 3.13, we see a tendency for VIX to perform best when looking at longer moving averages, but also when applying short term moving average. The 30-day moving average does not perform well at all, having no strategy in the top ten that use this indicator. Interestingly we find that using the average VIX as an indicator proves not to be as effective as using a MA. This might be explained by the fact that our historic average is calculated from 2003 and therefore the crisis will have a notable effect on the level after this date. By excluding the crisis or using a longer period for calculating the historic average might have inferred that the indicator would have been more effective, but this will be left for further research. As we see in Appendix Figure 9.18, when using a 10-day moving average that trades when the MA10 is above the current level results in a lag after a volatility spike. This results in a trading signal that usually doesn't trade before a spike, but rather after a spike has occurred and therefore gains when volatility declines. The longer moving average of 50 days, benefits from not trading during the financial crisis, but rather trades during the recovery period. We know from Table 4.1 to Table 4.4 that the performance of short vega strategies are very strong in the recovery period. The 30-day moving average does not fully capture either of the two trends just described. This means that the 30-day moving average indicator has some adverse trades during the financial crisis and doesn't fully capture the benefits of trading during the recovery period or after a recent lag.

Top ten best performing short strategies based on each indicator			
	Short straddle & short strangle		
	Cumulative absolute return compared to initial strategy (in %)	Increase in Sharpe ratio compared to initial strategy	Maximum drawdown
MA50 VIX	2	2	1
MA30 VIX	0	0	0
MA 10 VIX	1	2	1
Average VIX	0	1	0
MA50 CDX	0	1	1
MA30 CDX	0	0	1
MA10 CDX	3	2	2
Average CDX	1	2	1
Average spread	3	0	3

Table 3.13 – The top ten best performing short strategies spilt into each group of indicators, both above and below

Moving on to the CDX indicator we see that it performs better when looking at the short term moving average of 10 days. When applying longer moving averages the performance is not remarkable. The reason why the CDX indicator performs best when looking at short term MA is most likely due to the fact that it reacts quicker to spikes in volatility as illustrated in Figure 2.7. This is because it benefits from the same trend as the VIX, where the indicator is lagged after a spike causing a buy signal since the MA10 is above the current level. This means that the short vega strategy benefits from a likely decrease in volatility due to the mean reverting nature of volatility.

When considering the indicator that trades according to the historic average of the CDX we find that it is more effective than the equivalent indicator for VIX. This is because the average CDX is below the current level of the CDX during certain periods where volatility experience spikes, contrary to the average VIX as seen in Appendix Figure 9.18 and Appendix Figure 9.19.

When looking at the market timing indicator using the spread between the VIX and the CDX, we find that it performs well when comparing increased cumulative absolute return to the initial strategy and for maximum drawdown. However, it does not perform well when looking at increase in Sharpe ratio compared to the initial strategy. This indicates that the increase in returns does not outweigh the standard deviation of these returns. The reason for this trend is that the average spread captures information from both indices but it is less consistent compared to MA on the individual indices.

Long iron butterfly and long iron condor

In Table 3.12, we present the directional indicators (above/below) contribution to the top ten best performing strategies when looking at the three key performance measures. This helps us understand which type of indicator performs best for the long strategies. We see that for the long strategies it is not clear whether it is best to trade when the indicator is above or below the current index. However, there is a slight overweight of directional indicators trading below the current level. This is contrary to the findings for the short strategies, which could be caused by the fact that the strategies can be used to gamble more profitably during periods of high volatility as the return in these periods can be high and the downside risk is limited.

The indicators are unable to improve the performance of the delta-hedged strategies to the point that they have a positive Sharpe ratio. Only one strategy is improved enough to have a positive monthly Sharpe ratio of 2%. It should however be noted that all these strategies had negative Sharpe ratios before applying the indicators. The economic interpretation of this result is therefore contrary to the one presented above, for the long strategies it is not profitable to trade on mean reversal of volatility.

In Table 3.14 we see for the long iron butterfly and long iron condor, the indicators perform best when looking at short- to mid-term MA for both VIX and CDX. This is an interesting finding and a possible explanation is they benefit from the same trend as the short strategies described above. Further, the mid-term MA is profitable for the long strategies as the strategies can be used to gamble more profitably during periods of high volatility as the return in these periods can be high and the downside risk is limited.

The indicators using the simple average of the index and the spread between the VIX and CDX do not prove effective. Only the indicator for the average CDX yields improvements in maximum drawdown.

Top ten best performing long strategies based on each indicator			
	Long iron butterfly & long iron condor		
	Cumulative absolute return compared to initial strategy (in %)	Increase in Sharpe ratio compared to initial strategy	Maximum drawdown
MA50 VIX	0	0	0
MA30 VIX	2	1	2
MA 10 VIX	1	3	0
Average VIX	0	0	0
MA50 CDX	1	0	1
MA30 CDX	2	3	2
MA10 CDX	3	3	1
Average CDX	1	0	2
Average spread	0	0	0

Table 3.14 – The top ten best performing long strategies spilt into each group of indicators, both above and below

In conclusion, we find that the best indicators for the short strategies most often involve trading when the market timing indicator is above the current level of the index. The success of this strategy can be explained by the highly mean-reverting nature of volatility. Further we find that for the short straddle and short strangle the best indicators involve long- or short term MA of the VIX index or short term MA for the CDX. Additionally, the spread between the VIX and CDX have some success in indicating when to trade. For the long strategies, there is a slight overweight of the directional indicators trading below the current level. This is contrary to the findings for the short strategies, which could be caused by the fact that the strategies can be used to gamble more profitably during periods of high volatility as the return in these periods can be high and the downside risk is limited. Now that we have analysed the best performing indicators on a general level we will continue the analysis in the next section by looking at the individual strategies that have proven most profitable when trying to capture the volatility risk premium.

3.5.3 Descriptive statistics - Best performing strategies

In the following we will divide the analysis in two parts. First we wish to analyse the short straddle and short strangle. Second, we will focus on the long iron butterfly and the long iron condor. The reason why we divide this section is that the short straddle and short strangle performs much better when looking at return while the long iron butterfly and long iron condor perform better when considering the risk parameters. We will finalize this section with a comparison across all strategies.

	Weekly delta-hedged		Daily Delta-hedged	
	Short straddle	Short strangle	Short straddle	Short strangle
	Straddle Average VIX < Current VIX	Strangle MA50 VIX > Current VIX	Straddle MA10 CDX > Current CDX	Strangle MA10 CDX > Current CDX
	Descriptive statistics			
Mean	0.42%	0.48%	0.20%	0.37%
Standard deviation	1.57%	1.37%	1.26%	1.14%
Kurtosis	7.17	1.50	4.55	3.70
Skewness	0.62	0.25	0.21	0.58
Minimum	-6.43%	-4.38%	-4.02%	-3.58%
Maximum	7.27%	3.87%	5.00%	4.59%
Spread	13.69%	8.25%	9.02%	8.17%
Number of profitable trades	33	47	40	48
Number of loss trades	15	23	19	18
No trades	72	50	61	54
Mean absolute return (in $)	423	481	200	369
Cumulative absolute return (in $)	50,803	57,691	23,982	44,258
Cumulative absolute return compared to initial strategy ($)	-5,354	-1,318	856	7,804
Cumulative absolute return compared to initial strategy (%)	-9.53%	-2.23%	3.70%	21.41%
Cumulative return	63.63%	75.85%	25.88%	54.37%

	Performance measurements			
Risk return measures				
Sharpe ratio	24.23%	31.22%	11.99%	28.22%
Increase in Sharpe ratio compared to initial strategy (%)	11.55%	14.24%	7.25%	17.44%
Information ratio	7.07%	6.10%	-8.09%	-14.30%
Sortino ratio	20.93%	38.16%	11.40%	30.54%
Risk measures				
High watermark	167.49%	176.33%	125.88%	154.37%
Maximum drawdown	11.09%	6.93%	8.05%	4.79%
Date for maximum drawdown	15/10/08	15/10/07	15/09/08	15/10/11
VaR (in $)	-819	-868	-2,114	-1,036
ES (in $)	-2,723	-2,524	-3,080	-2,208

Table 3.15 – Descriptive statistics for chosen short market timing indicator strategies

Short market timing indicator strategies				
	Straddle Average VIX < Current VIX	**Strangle MA50 VIX > Current VIX**	**Straddle MA10 CDX > Current CDX**	**Strangle MA10 CDX > Current CDX**
	Weekly hedge	**Weekly hedge**	**Daily hedge**	**Daily hedge**
Excess mean	0.0038	0.0044	0.0015	0.0032
Confidence Level (95%)	0.0028	0.0025	0.0023	0.0021
Upper limit	0.0067	0.0069	0.0038	0.0053
Lower limit	0.0010	0.0018	-0.0008	0.0012
Statistically significant	**Yes**	**Yes**	**No**	**Yes**

Table 3.16 – Short market timing indicator strategies – statistically significant

Weekly delta-hedged straddle and strangle

Weekly delta-hedged short straddle: Trading when Average VIX < Current VIX

The first strategy we will consider is the short straddle that trades when the average VIX is below the current VIX, which is designed to exploit the mean reverting nature of volatility. In the following we will compare this strategy to the initial strategy that trades every month.

We find that the indicator has some interesting attributes as the profitability slightly decreases while the variance is significantly reduced. This means that the Sharpe ratio increases and is now significant on a 5% level, meaning we reject the null hypothesis that the excess return is zero, as stated in Table 3.16. We have plotted the return distribution of the strategy and have not included returns equal to zero (no trade). When doing so it affects the kurtosis and skewness represented in the descriptive statistics, but is a better illustration on how the remaining returns are distributed. The excess kurtosis of the return distribution including zero is reduced slightly compared to the "always sell" weekly delta-hedged straddle but is still leptokurtic indicating a large mass in the tails, which is a consequence of the outliers. Interestingly the skewness is now slightly positive due to a majority of positive returns. The return distribution for the weekly delta-hedged short straddle that trades when the current level of VIX is above the all-time average is illustrated in Figure 3.36. Using the indicator, it significantly reduces the spread of the return distribution, which now has a higher maximum attained return compared to the minimum return in absolute terms. Using the indicator, it removes some of the negative outliers, which is reduced to -6.43% from -16.55%. As mentioned the return is slightly reduced using this market timing indicator as the cumulative absolute return compared to the initial strategy is reduced by 9.53%. The cumulative percentage return is 2.45% lower over the 10-year period, which can be considered to be marginally lower. A possible explanation for the success of the market timing indicator, which signals a trade when the long term average VIX is below the current VIX could be mean reversion of volatility. The short vega strategies benefit from decreasing volatility during the holding period of the options. When volatility is higher than normal it tends to decrease due to the mean reverting nature of volatility. One would expect this to be priced in the options, but it does not seem to be the case as the indicator performs better than the initial strategy. The market timing indicator signals a trade during periods with high degree of volatility in the market. We find in section 4.1 that the options tend to perform worse in these periods. The strategy trades during the financial crisis and the recovery period but avoids the biggest loss of the sample during the post European sovereign debt crisis. The big loss is caused by a large move in the underlying asset, which causes the delta hedge to be very unprofitable. By avoiding this trade the strategy lowers the variance of the returns significantly. Since this is one of the major reasons why this strategy performs well, it is unclear whether the indicator would be effective in a different sample period. For further research, it could be interesting analysing how well the indicating strategies perform with changing variables, i.e. sample period.

Since the variance of the strategy significantly reduces, the performance measures are greatly improved. The strategy realizes a monthly Sharpe ratio of 24.23%, which is an increase compared to the initial strategy of 11.55%. The information ratio is reduced by approximately 6%, which is expected as the profitability of the strategy is reduced.

However, given the fact that the volatility is significantly lower than the market, the market timing indicator signaling a trade when the average VIX is below the current level of VIX, is a clear improvement of the initial strategy. The Sortino ratio is greatly improved by approximately 9%. This is caused by the fact that the largest negative outlier is removed and consequently the standard deviations of these are lowered as the more extreme outliers are eliminated.

The risk measures are greatly improved by using the indicator. The maximum drawdown is only half as big and the VaR and ES are reduced by 82% and 67% respectively. This is the effect of the lower spread and reduced variance, which significantly improves the performance of the strategy.

It is important to notice, when using the indicator, the number of trades is reduced from 120 (one each month for 10 years) to 48 trades over the 10-year period. This have some potential drawbacks for an investor using this strategy, as money allocated for the trade are not used, when the market timing indicator signals no trade. Therefore, the investor might invest in an alternative asset or go long the strategy in these periods, but this is left for further research.

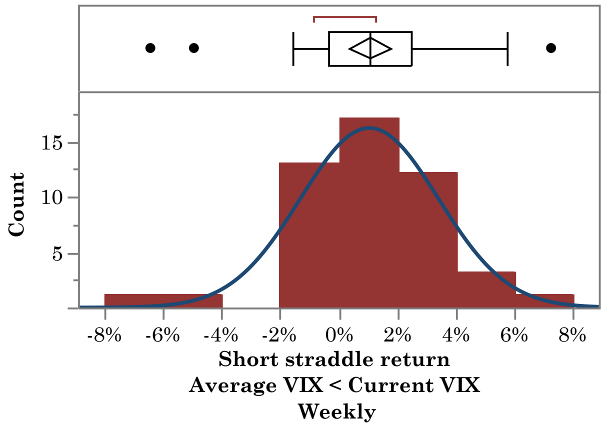

Figure 3.36 – Return distribution for weekly delta-hedged short straddle: Average VIX < Current VIX (zero not included)

Weekly delta-hedged short strangle: Trading when MA50 VIX > Current VIX

Having looked at the straddle we will now focus on the short strangle with weekly delta hedging, which trades when the 50-day moving average of VIX is above the current VIX. As described in section 3.5.2 the market timing indicator trading when the 50-day moving average of VIX is above the current level of VIX exploits a longer lag of the volatility. When the lag is 50 days the indicator doesn't trade during the financial crisis but rather in the recovery period where the short vega strategies benefits from declining volatility in the market. The long lag also benefits the strategy as it doesn't trade in other periods with rising volatility but trades when it is declining afterwards. In the following we will compare this strategy to the initial strategy that trades every month.

This indicator has similar attributes to the one described for the short straddle, as it slightly decreases the profitability but significantly reduces the variance of returns. This again means that the Sharpe ratio increases and is significant to a 5% level, meaning we reject the null hypothesis that the excess return is zero, as stated in Table 3.16. The high watermark of the strategy is however not affected by the lower profitability, which is very attractive as the standard deviation is significantly lower. The excess kurtosis of the return distribution is reduced slightly but is still leptokurtic indicating a large mass in the tails, which is a consequence of the outliers. However, the excess kurtosis is again significantly lower compared to the straddle. Similar to the short straddle described above the skewness is now slightly positive due to an overweight of positive returns. The return distribution is illustrated in Figure 3.37 and do not include returns of 0% (no trade).

When the market timing indicator is used, it significantly reduces the spread of the return distribution, which is almost halved compared to the original strategy. As mentioned the return is slightly reduced when using this indicator as the cumulative absolute return compared to the initial strategy is reduced by 2.23%. The cumulative percentage return is slightly higher compared to the initial strategy, since negative percentage returns has a more significant effect on the cumulative returns than the positive returns. This is opposite to the way absolute returns work where negative and positive returns have equal weight. We find that the strategy, which uses the market timing indicator signaling a trade when the 50-day moving average is above the current level trades during periods with declining volatility. The reason being that the strategy avoids the financial crisis, while it trades during the recovery period, due to the lagged variance indicator. Therefore, it is expected that the strategy performs better with regards to lower volatility of returns as the largest negative outliers is avoided. However, it is surprising that the return is not higher when the strategy trades during the periods with more stable returns. The reason for this is the strategy is slow to indicate a trade after a spike, which significantly lowers the return of the strategy since these periods are the most profitable.

The performance measures are significantly improved when using the market timing indicator signaling a trade when the 50-day moving average of VIX is above the current level of VIX. The strategy realizes a monthly Sharpe ratio of 31.22%, which is an increase compared to the initial strategy of 14.24%. The information ratio is reduced by approximately 3%. This is to be expected as the profitability of the strategy is reduced. However, given the fact that the volatility is lower than the market this is still a lucrative investment. The Sortino ratio is greatly improved by approximately 18%, which is double the improvement realized by the straddle strategy described above. This is caused by the fact that the number of negative outliers is reduced and consequently the standard deviation of these is lowered as the more extreme outliers are eliminated.

The risk measures are likewise improved when using the indicator. The maximum drawdown is improved by approximately 12% and the VaR and ES are reduced by 79% and 56% respectively. This is the effect of the lower spread and reduced variance.

Similar to the straddle the number of trades are reduced from 120 to 70 trades. An investor using this market timing indicator should, as described above, invest in an alternative strategy when the market timing indicator signals no trade.

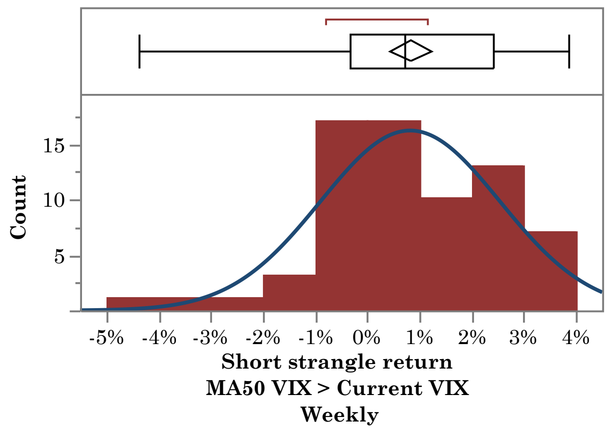

Figure 3.37 – Return distribution for weekly delta-hedged short strangle: MA50 VIX > Current VIX (zero not included)

Daily delta-hedged straddle and strangle

Having analysed the weekly delta-hedged market timing indicator strategies, we now analyse the daily delta-hedged strategies. Here we have chosen a similar indicator for both the straddle and strangle as these produce the best results. The indicator signals a trade when the 10-day moving average of the CDX index is higher than the current level. As described in section 3.5.2 the market timing indicator trading when the 10-day moving average of the CDX is above the current level exploits the short-term lag of volatility. The market timing indicator trades when there has been a spike in volatility, which is when the volatility tends to decline, while it usually doesn't trade before a spike. As in the analysis above we will compare this strategy to the initial strategy that trades every month.

Previously we found that the weekly delta-hedged strategies performed best and this is still the case in terms of return, but in terms of the risk factors the daily delta-hedged strategies are performing better.

Daily delta-hedged short straddle: Trading when MA10 CDX > Current CDX
For the short straddle the effect of using the market timing indicator signaling a trade when the 10-day moving average of the CDX index is above the current level of CDX is a slight increase in the profitability and decrease in variance of returns. The Sharpe ratio increases but is not significant on a 5% level, meaning we fail to reject the null hypothesis that the excess return is zero, as stated in Table 3.16. We include this strategy regardless since it is almost significant (significant on a 10% level), and as the returns are not normally distributed the test is not completely accurate. The high watermark of the strategy is not affected by the lower profitability, which is very attractive as the standard deviation is lower.

We have plotted the return distribution on each indicating strategy and have not included returns equal to 0% (no trade). When doing so it affects the kurtosis and skewness represented in the descriptive statistics, but is a better illustration on how the remaining returns are distributed. The return distribution for the daily delta-hedged short straddle that trades when the current level of VIX is above the all-time average is illustrated in Figure 3.38. From the descriptive statistics, the excess kurtosis of the return distribution is reduced slightly but is still leptokurtic. The skewness is slightly higher compared to the initial strategy and is now positive. As mentioned the return has slightly increased by using this market timing indicator and affects the cumulative return compared to the initial strategy to increase 3.7%, while the cumulative percentage return increases by 2.99%. The market timing indicator signaling a trade when the 10-day moving average of the CDX is above the current level of CDX is expected to perform well as it usually trades after a spike in volatility. By trading after a spike in volatility the strategy benefits from the mean reversal of volatility and should therefore earn money as volatility declines after the trade. Using this market timing indicator proves to eliminate the worst outliers in the sample period making the volatility of returns lower. It is not surprising that the mean return is higher as many of the negative trades are eliminated while the most profitable trades are still included.

The performance measures are significantly improved when using the market timing indicator signaling a trade when the 10-day moving average of CDX is above the current level of CDX. The strategy realizes a monthly Sharpe ratio of 11.99%, which is an increase compared to the initial strategy of 7.25%. The information ratio is reduced by approximately 1%.

This is to be expected as the information ratio is calculated only for the periods where the strategy is executed, which indicates that in less volatile periods the S&P500 index outperforms the daily delta-hedged strategy. The Sortino ratio is greatly improved by approximately 5.4%. This is caused by the fact that the number of negative outliers is reduced and consequently the standard deviation of these is lowered as the more extreme outliers are eliminated.

The risk measures are greatly improved when using the indicator. The maximum drawdown is improved by approximately 10% and the VaR and ES are reduced by 42% and 53% respectively. This is the effect of the lower spread and reduced variance.

Similar to the weekly delta-hedged strategies analysed above the number of trades is reduced from 120 to 59 trades. An investor using this market timing indicator should, as described above, invest in an alternative strategy when the market timing indicator signals no trade.

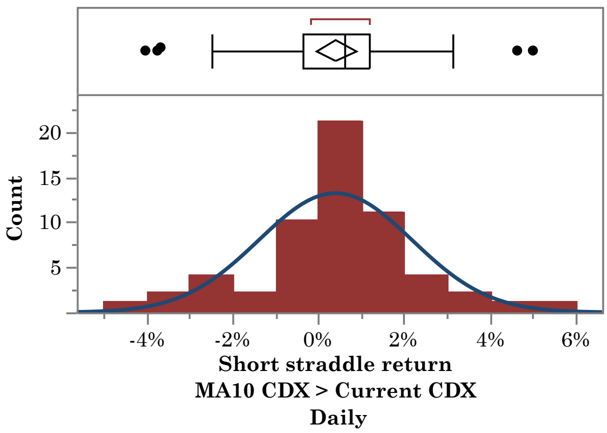

Figure 3.38 – Return distribution for daily delta-hedged short straddle: MA10 CDX > Current CDX (zero not included)

Daily delta-hedged short strangle: Trading when MA10 CDX > Current CDX

Having analysed the daily delta-hedged short straddle we will now focus on the daily delta-hedged short strangle using the same indicator, which again trades when the 10-day moving average of the CDX index is higher than the current level. This indicator also exploits the lagged volatility, which tends to give a trading signal after a spike and not before. As in the analysis above we will compare this strategy to the initial strategy that trades every month.

For the short strangle the effect of using the market timing indicator is a slight increase in the profitability and decrease in variance. This again means that the Sharpe ratio increases and is significant on a 5% level, meaning we reject the null hypothesis that the excess return is zero, as stated in Table 3.16. The high watermark of the strategy is improved by the higher profitability, which is very attractive as the standard deviation is lower.

We have plotted the return distribution on the strategy and have not included returns equal to zero (no trade). When doing so it affects the kurtosis and skewness represented in the descriptive statistics, but is a better illustration on how the remaining returns are distributed. The excess kurtosis of the return distribution from the descriptive statistics is reduced slightly but is still leptokurtic. The skewness is slightly higher compared to the initial strategy and is now positive. The distribution of the returns without returns of 0% is illustrated in Figure 3.39. As mentioned the return has slightly increased when using this market timing indicator and affects the cumulative return compared to the initial strategy with an increase of 21.41%, while the cumulative percentage return increases by 13.57%. As with the short straddle the reason for the slightly higher returns and lower standard deviation of returns is that the market timing indicator signals trades after a spike in volatility, which is when volatility tend to decline. The market timing indicator further eliminates the worst negative returns making the strategy more profitable.

The market timing indicator significantly improves the performance measures of the strategy. The strategy realizes a monthly Sharpe ratio of 28.22%, which is an increase compared to the initial strategy of 17.44%. The information ratio is reduced by approximately 10%, which is surprising, as the profitability of the strategy has improved. The explanation for the reduced information ratio is that the strategy doesn’t trade during the financial crisis where the most negative returns of the S&P500 occur. The initial strategy performs a lot better compared to the S&P500 during the financial crisis. Therefore by not trading during these periods the strategy doesn't benefit from this quality. The information ratio is calculated only for the periods where the strategy is executed, which indicates that in less volatile periods the S&P500 index outperforms the daily delta-hedged strategy. The Sortino ratio is greatly improved by approximately 19.5%. This is caused by the fact that the number of negative outliers is reduced and consequently the standard deviation of these is lowered as the more extreme outliers are eliminated.

The risk measures are greatly improved when using the indicator. The maximum drawdown is improved by approximately 17% and the VaR and ES are reduced by 63% and 69% respectively. This is the effect of the lower spread and reduced variance.

Similar to the weekly delta-hedged strategies analysed above the number of trades are reduced from 120 to 66 trades. An investor using this market timing indicator should, as described above, invest in an alternative strategy when the market timing indicator signals no trade.

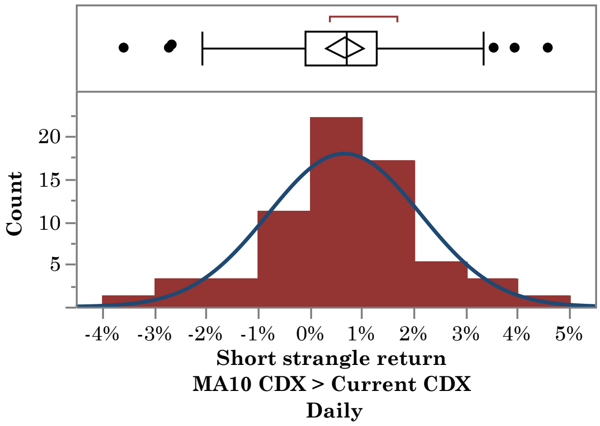

Figure 3.39 – Return distribution for daily delta-hedged short strangle: MA10 CDX > Current CDX (zero not included)

Weekly delta-hedged iron butterfly and iron condor

Weekly delta-hedged long iron butterfly: Trading when MA10 CDX < Current CDX

The first strategy we will look at is for the long strategies the long iron butterfly that trades when the 10-day moving average of the CDX is below the current CDX. This is opposite what we found worked for the short straddle. This indicator trades in more risky periods, which doesn't affect the long iron butterfly as much because of the limited downside. In the following we will compare this strategy to the initial strategy that trades every month.

	Weekly delta-hedged		Daily Delta-hedged	
	Long IB	Long IC	Long IB	Long IC
	Iron Butterfly MA10 CDX < Current CDX	Iron Condor MA50 VIX > Current VIX	Iron Butterfly MA10 CDX < Current CDX	Iron Condor MA30 VIX > Current VIX
	Descriptive statistics			
Mean	0.03%	0.01%	0.06%	0.06%
Standard deviation	0.45%	0.53%	0.35%	0.39%
Kurtosis	4.18	1.84	8.75	3.59
Skewness	1.52	0.32	2.56	1.50
Minimum	-1.11%	-1.90%	-0.75%	-0.77%
Maximum	1.75%	1.48%	1.81%	1.49%
Spread	2.86%	3.39%	2.56%	2.26%
Number of profitable trades	22	28	25	36
Number of loss trades	39	42	36	30
No trades	59	50	59	54
Mean absolute return (in $)	33	11	57	63
Cumulative absolute return (in $)	3,927	1,365	6,787	7,542
Cumulative absolute return compared to initial strategy ($)	5,387	5,094	4,373	4,969
Cumulative absolute return compared to initial strategy (%)	368.92%	-136.60%	181.16%	193.08%
Cumulative return	3.88%	1.21%	6.94%	7.73%
	Performance measurements			
Risk return measures				
Sharpe ratio	-3.43%	-6.01%	2.14%	2.94%
Increase in Sharpe ratio compared to initial strategy (%)	15.88%	10.87%	18.77%	16.01%
Information ratio	-1.66%	-5.57%	-1.06%	2.78%
Sortino ratio	-5.55%	-9.00%	3.86%	4.82%
Risk measures				
High watermark	104.78%	101.28%	108.13%	107.73%
Maximum drawdown	3.61%	5.35%	1.62%	2.95%
Date for maximum drawdown	15/02/2014	15/11/2014	15/04/2013	15/11/2013
VaR (in $)	-518	-822	-334	-535
ES (in $)	-803	-1,093	-463	-670

Table 3.17 – Descriptive statistics for chosen long market timing indicator strategies

Long market timing indicator strategies				
	Iron butterfly MA10 CDX < Current CDX	**Iron butterfly MA50 VIX > Current VIX**	**Iron butterfly MA10 CDX < Current CDX**	**Iron condor MA30 VIX > Current VIX**
	Weekly hedge	**Weekly hedge**	**Daily hedge**	**Daily hedge**
Excess mean	-0.0002	-0.0003	0.0001	0.0001
Confidence Level (95%)	0.0008	0.0010	0.0007	0.0008
Upper limit	0.0007	0.0007	0.0007	0.0009
Lower limit	-0.0010	-0.0013	-0.0006	-0.0006
Statistically significant	**No**	**No**	**No**	**No**

Table 3.18– Long market timing indicator strategies – statistically significant

We find the market timing indicator has some interesting attributes as it increases the profitability while slightly reduces the variance. This means that the Sharpe ratio increases, however the excess returns of this strategy are not significant to a 5% level, meaning we fail to reject the null hypothesis that the excess return is zero, as stated in Table 3.18. In Figure 3.40 we have illustrated the return distribution on the strategy and have not included returns equal to zero (no trade). When doing so it affects the kurtosis and skewness represented in the descriptive statistics, but is a better illustration on how the remaining returns are distributed. The excess kurtosis of the return distribution from the descriptive statistics is increased and is therefore still leptokurtic indicating a larger mass in the tails, which is a consequence of the outliers. The skewness is also increased slightly and is still positive due to a few positive outliers. The market timing indicator strategy doesn't change the spread as the minimum and maximum return attained by the initial strategy is not removed. As mentioned the return is increased by using this indicator, which causes the cumulative absolute return compared to the initial strategy to increase by 368.92%. The cumulative percentage return is 5.49% higher over the 10-year period, which is significantly higher. However, since the cumulative return of the initial strategy is -$1,460 and the cumulative return of the strategy using the market timing indicator is $3,927 the strategy does not seem reasonable to implement as $3,927 collected over 10 years is not an attractive investment since the return isn't statistical significant on 5% level. It is surprising that the weekly delta-hedged long iron butterfly can thrive when the volatility is expected to be increasing. However, it seems that the strategy is performing well. As seen in section 4.1, we find that the weekly delta-hedged long iron butterfly performs well during the financial crisis. The market timing indicator signals to trade when the 10-day moving average of CDX is below the current level CDX, which is the case during the financial crisis.

The market timing indicator strategy significantly increases the performance measures but for this strategy they are all negative. The strategy realizes a monthly Sharpe ratio of -3.45%, which is an increase compared to the initial strategy of 15.88%. The information ratio is -1.66% but is improved by approximately 9.5% from the initial strategy. The Sortino ratio is greatly improved by approximately 35%. This is caused by the fact that the number of negative trades is reduced, causing the standard deviation of these to decrease as well.

The risk measures are slightly improved by using the market timing indicator strategy. The maximum drawdown is lowered by approximately 1%, while the VaR and ES are reduced by 24% and 10% respectively. This is the effect of the higher return and reduced variance. The strategy is not desirable to pursue when trying to capture the volatility risk premium do low insignificant returns, negative performance measures and only slightly improved risk measures.

Further, similar to every other strategy using indicators there are many months where the trade is not implemented, which is another factor to consider.

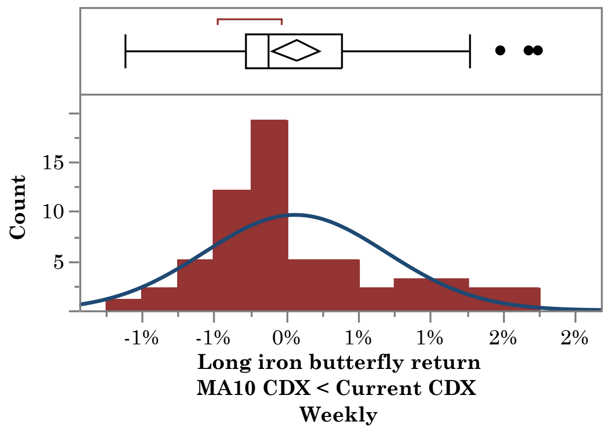

Figure 3.40 – Return distribution for weekly delta-hedged long iron butterfly: MA10 CDX < Current CDX (zero not included)

Weekly delta-hedged long iron condor: Trading when MA50 VIX > Current VIX

Having looked at the long iron butterfly we will now focus on the long iron condor with weekly delta hedging, which trades when the 50-day moving average of VIX is above the current level of VIX. This indicator exploits the same pattern as the short strategies, where the market timing indicator signals a trade after a spike in volatility. In the following we will compare this strategy to the initial strategy that trades every month.

This indicator has similar attributes to the one described above for the long iron butterfly, as it slightly increases the profitability while maintaining the variance. This again means that the Sharpe ratio increases but is not significant on a 5% level, meaning we fail to reject the null hypothesis that the excess return is zero, as stated in Table 3.18. In Figure 3.41 we have plotted the return distribution on the strategy and have not included returns equal to zero (no trade). When doing so it affects the kurtosis and skewness represented in the descriptive statistics, but is a better illustration on how the remaining returns are distributed. The excess kurtosis of the return distribution from the descriptive statistics is increased slightly and is still leptokurtic indicating a large mass in the tails. However, the excess kurtosis is significantly lower compared to the long iron butterfly. The skewness is now only marginally positive due to less positive outliers. Using the market timing indicator, it slightly reduces the spread of the return distribution, which is caused by an absolute decrease in both the minimum and maximum return. As mentioned the return is slightly increased by using this market timing indicator as the cumulative absolute return compared to the initial strategy has increased by 136.6%. The cumulative percentage return is slightly higher compared to the initial strategy, which has increased by approximately 5%. The market timing indicator strategy is expected to have the same effect as it did for the short strategies, as it trades in periods of decreasing volatility.

The market timing indicator strategy significantly increases the performance measures, but not enough to make them positive. The strategy realizes a monthly Sharpe ratio of -6.01%, which is an increase compared to the initial strategy of 10.87%. The information ratio is increased by approximately 5%, which does not make it positive, as the initial strategy yields an information ratio of -5.57%. The Sortino ratio is improved by approximately 22%. This is caused by the number of negative outliers are reduced and consequently the standard deviation of these is lowered as the more extreme outliers are eliminated.

The risk measures are greatly improved when using the market timing indicator. The maximum drawdown is improved by approximately 6% and the VaR and ES are reduced by 17% and 25% respectively. This is the effect of the lower spread and reduced variance. Similar to the long iron butterfly described above, the strategy is not desirable to pursue when trying to capture the volatility risk premium do to low insignificant returns, negative performance measures and only slightly improved risk measures. The number of months where the trade is not performed is to be considered when making the trade and we see that for the iron condor it is 50 months or approximately 41% of the sample period where there is no trade for this strategy. Given the indicators ability to produce a higher mean return and lower variance it is not surprising that the performance- and risk measures are improved.

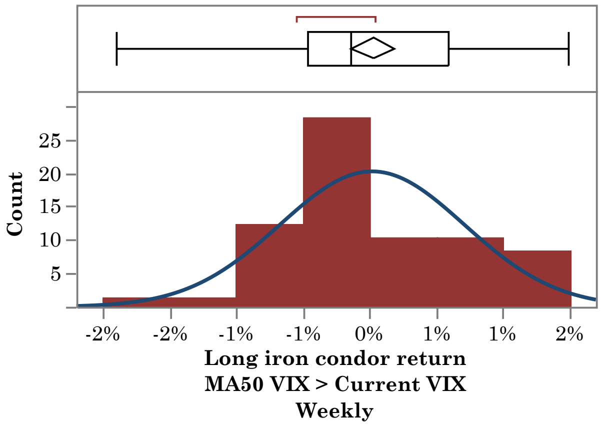

Figure 3.41 – Return distribution for weekly delta-hedged long iron condor: MA50 VIX > Current VIX (zero not included)

Daily delta-hedged long iron butterfly and long iron condor

Having analysed the weekly delta-hedged strategies we will now focus on the daily delta-hedged strategies. Here we have chosen two different indicators for the long iron butterfly and long iron condor that produces the best results. The indicator used for the long iron butterfly trades when the 10-day moving average of the CDX index is below the current level, which is opposite what we found worked for the short strategies. This indicator trades in more risky periods, which doesn't affect the long iron butterfly as much because of the limited downside. The indicator used for the long iron condor trades when the 30-day moving average of the VIX index is above the current level. This indicator exploits the same pattern as the short strategies, where the market timing indicator signals a trade after a spike in volatility. As in the analysis above we will compare these strategies to the initial strategies that trade every month.

Previously we found that the weekly delta-hedged strategies performed best. This is not the case when using the market timing indicators as the daily delta-hedged strategies perform much better with respect to performance- and risk measures.

Daily delta-hedged long iron butterfly: Trading when MA10 CDX < Current CDX

For the long iron butterfly the effect of using the indicator is a slight increase in the profitability and a decrease of variance. This again means that the Sharpe ratio increases and is now positive. However, the excess return of the strategy is not significant to a 5% level, meaning we fail to reject the null hypothesis that the excess return is zero, as stated in Table 3.18. In Figure 3.42 we have plotted the return distribution on strategy and have not included returns equal to zero (no trade). When doing so it affects the kurtosis and skewness represented in the descriptive statistics, but is a better illustration on how the remaining returns are distributed. The excess kurtosis of the return distribution from the descriptive statistics is more than doubled and is still leptokurtic. The skewness is slightly higher compared to the initial strategy. As mentioned the return is slightly increased by using this market timing indicator as the cumulative absolute return compared to the initial strategy is increased by 181.16%, while the cumulative percentage return increases by 4.61%. It is surprising that the daily delta-hedged long iron butterfly can thrive when the volatility is expected to be increasing. However, it seems that the strategy is performing well. As seen in section 4.1, we find that the daily delta-hedged long iron butterfly performs well during the financial crisis. The market timing indicator signals to trade when the 10-day moving average of CDX is below the current level CDX, which is the case during the financial crisis.

The market timing indicator strategy significantly increases the performance measures. The strategy realizes a monthly Sharpe ratio of 2.14%, which is an increase compared to the initial strategy of 18.77%. The information ratio is improved by approximately 9% but is still negative, meaning that the strategy doesn't outperform a buy and hold of the S&P500 index. The Sortino ratio is greatly improved by approximately 34%. This is caused by the fact that the number of negative outliers is reduced and consequently the standard deviation of these is lowered as the more extreme outliers are eliminated.

The risk measures are slightly improved by using the indicator. The maximum drawdown is improved by approximately 2% and the VaR and ES are reduced by 37% and 35% respectively. This is the effect of the lower spread and reduced variance. Given the indicators ability to produce a higher mean return and lower variance it is not surprising that the performance- and risk measures are improved.

Similar to the other strategies using market timing indicators the number of trades is reduced from 120 to 59 trades.

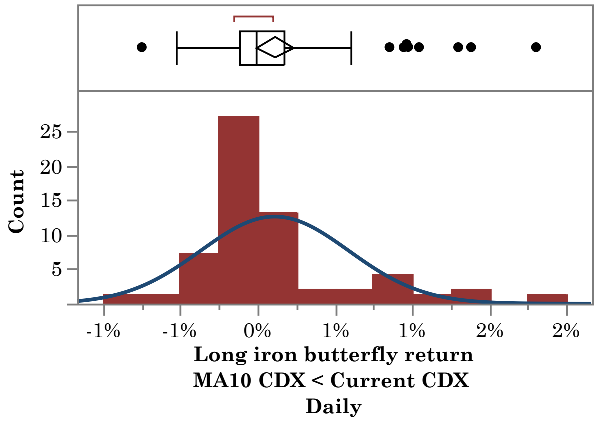

Figure 3.42 – Return distribution for daily delta-hedged long iron butterfly: MA10 CDX < Current CDX (zero not included)

Daily delta-hedged long iron condor: Trading when MA30 VIX > Current VIX

Having analysed the daily delta-hedged long iron butterfly we will now focus on the daily delta-hedged long iron condor. The market timing indicator signals a trade when the 30-day moving average of VIX is above the current level of VIX. This indicator exploits the same pattern as the short strategies, where the market timing indicator signals a trade after a spike in volatility. As in the analysis above we will compare this strategy to the initial strategy that trades every month.

For the long iron condor, the use of the indicator results in a slight increase in profitability and in a decrease of variance. This again means that the Sharpe ratio increases but is not significant to a 5% level, meaning we fail to reject the null hypothesis that the return is 0, as stated in Table 3.18. The high watermark of the strategy is slightly improved by the higher profitability, which is attractive as the standard deviation is lower.

In Figure 3.43 we have plotted the return distribution on the strategy and have not included returns equal to zero (no trade). When doing so it affects the kurtosis and skewness represented in the descriptive statistics, but is a better illustration on how the remaining returns are distributed. The excess kurtosis of the return distribution from the descriptive statistics is slightly increased and is still leptokurtic. The skewness is slightly lower compared to the initial strategy but still positive. As mentioned the return has slightly increased when using this market timing indicator and the cumulative return compared to the initial strategy increases by 193.08% while the cumulative percentage return increases by 5.3%. The market timing indicator is expected to have the same effect as it did for the short strategies, as it trades in periods of decreasing volatility.

The market timing indicator strategy significantly increases the performance measures. The strategy realizes a monthly Sharpe ratio of 2.94%, which is an increase of 16.01% compared to the initial strategy. The information ratio is improved by approximately 9%, and is the only long strategy that produces a positive ratio. This is caused by the fact that this strategy trades in periods where the S&P500 has negative returns, making this strategy more profitable. The Sortino ratio is improved by approximately 27%. This is caused by the fact that the number of negative outliers is reduced and consequently the standard deviation of these is lowered as the more extreme outliers are eliminated.

The risk measures are greatly improved by using the indicator. The maximum drawdown is improved by approximately 3% and the VaR and ES are reduced by 25% and 37% respectively. This is the effect of the lower spread and reduced variance, which significantly improves the performance of the strategy. Given the indicators ability to produce a higher mean return and lower variance it is not surprising that the performance- and risk measures are improved.

Similar to the weekly delta-hedged strategies analysed above the number of trades is reduced from 120 to 54 trades.

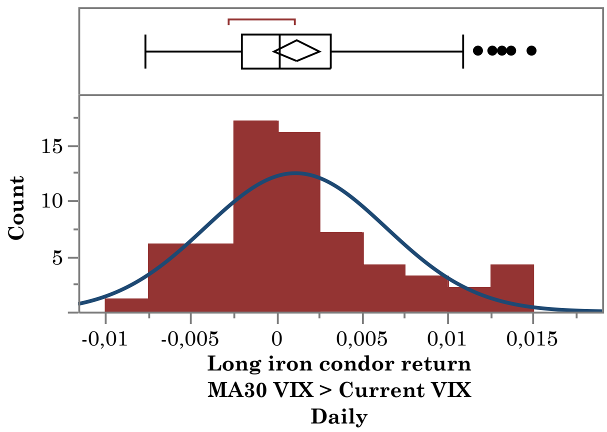

Figure 3.43 – Return distribution for daily delta-hedged long iron condor: MA30 VIX > Current VIX (zero not included)

General comparison of the strategies' performance measures

In the following section, we will compare the short- and long strategies with respect to their performance- and risk measures. This will provide an overview of the empirical properties of each strategy when using the different market timing indicators. The daily delta-hedged straddle trading when the MA10 CDX > Current CDX is the only short strategy with non-significant excess return on a 5% level. All other short strategies have excess return, which are statistically significant on a 5% level, as stated in Table 3.16.

In Figure 3.44 we see the weekly delta-hedged strategies are performing better than the daily delta-hedged strategies. This is not surprising, as they have proven to be more profitable, due to profitable hedges caused by large movements in the underlying asset. This is important to notice since the effect could have produced the opposite outcome. All strategies perform very well during the crisis and other periods with high volatility. This is to be expected as we are considering delta-hedged strategies, which should be unaffected by changes in the underlying index.

The long iron butterfly and the long iron condor are improved, compared to the initial strategies when using the market timing indicators. However, the cumulative returns of the strategies are still close to zero throughout the period as illustrated in Figure 3.45. The excess returns from each strategy are still non-significant on a 5% level as stated in Table 3.18. This indicates the possibility that our positive cumulative returns are due to chance. However, this might be a consequence of the small sample size as this is a very important component in statistical significance.

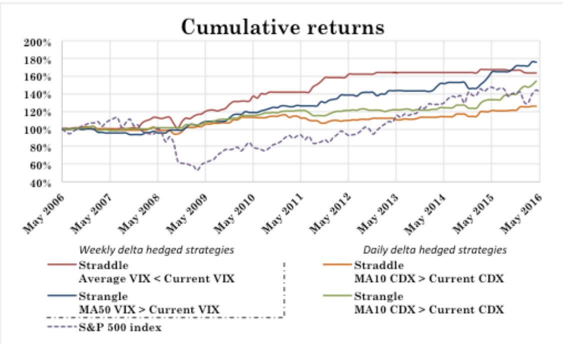

Figure 3.44 – Cumulative returns for short indicating strategies (short straddle and short strangle)

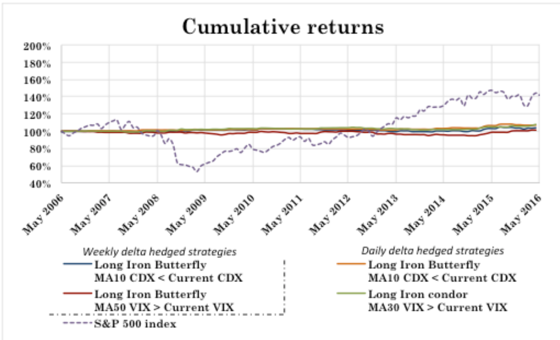

Figure 3.45 – Cumulative returns for long indicating strategies (long iron butterfly and long iron condor)

Performance measures

The performance measures of the four best performing short strategies are illustrated in Figure 3.46 and Table 3.15. The benchmark used in the information ratio is still the excess return of the S&P500. The Sortino ratio still uses a minimum acceptable threshold of zero.

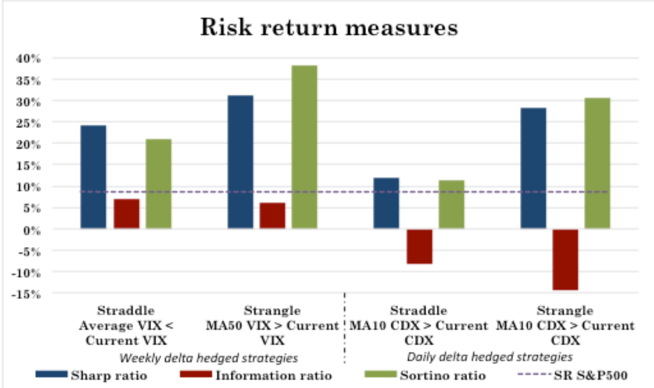

Figure 3.46 – Sharpe ratio, information ratio and Sortino ratio for short indicating strategies (short straddle and short strangle)

The historically attainable monthly Sharpe ratio from a buy-and-hold position in the S&P500 in the sample period is 8.6% and is illustrated in the figure above as the dotted line. Comparing the performance measures to the Sharpe ratio of the S&P500, every strategy outperforms this significantly. The strategies yield Sharpe ratios three to four times that of the buy-and-hold position in the S&P500. The daily delta-hedged straddle trading when the 10-day moving average of the CDX is above the current CDX is however only outperforming the Sharpe ratio of the S&P500 by approximately 3%. As mentioned the Sharpe ratios are improved between 7.25% to 17.44% from the initial strategies, and are now also significantly above the levels reported by Coval & Shumway and B. Eraker. They use a different sample period and other related variables, but conclude that writing options outperform the Sharpe ratios generated from a buy-and-hold strategy in the S&P500.

The short strangle strategies produce the highest Sharpe ratios. This is not surprising, as we have seen they produce higher returns and lower standard deviation compared to the straddles. As with the initial strategies when daily delta hedging is applied the Sharpe ratios are reduced. The monthly Sharpe ratio decreases because the returns in daily delta-hedged strategies decrease as discussed in section 3.3.1.

The weekly delta-hedged strategies have the highest information ratio and outperform the S&P500 in the sample period with an information ratio between 6% and 7%. The daily delta-hedged strategies do not perform better than an investment in the S&P500 when looking at this ratio. The Sortino ratio of a buy-and-hold strategy in the S&P500 in the sample period is 10%. Every strategy outperforms this performance measure. Similar to the Sharpe ratio however, the daily delta-hedged straddle trading when the moving average of the CDX is above the current level of the CDX only slightly outperforms the equivalent measure for the S&P500 index. The strangle strategies have the highest Sortino ratios, and this is because this ratio only considers the standard deviation of the negative returns. As shown previously the short strangle produces less and lower negative returns (in absolute terms). This is also the reason they perform better than the short straddles and the S&P500.

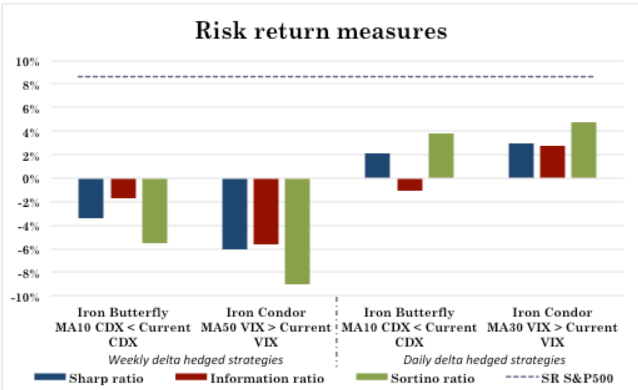

Figure 3.47 – Sharpe ratio, information ratio and Sortino ratio for long indicating strategies (long iron butterfly and long iron condor)

The performance measures of the four best performing long strategies are illustrated in Figure 3.47 and Table 3.17. The long iron butterfly and long iron condor underperform a buy-and-hold strategy of the S&P500 for every market timing indicator strategy when considering the Sharpe ratio. Only the daily delta-hedged long strategies produce positive excess returns and therefore positive Sharpe ratios. However, neither of the strategies' returns is statistically significant on a 5% level, as shown in Table 3.18. The daily delta-hedged long iron condor is the only strategy that has a positive information ratio, meaning that it outperforms an investment in the S&P500. When considering the Sortino ratio only the daily delta-hedged strategies yield positive measures but do not outperform the equivalent measure achieved by an alternative investment in the S&P500. This suggests that the long strategies are not attractive when capturing the volatility risk premium. It is not surprising that the long strategies aren't improved to the point where they can outperform an alternative investment in the S&P500. The returns, produced by the initial delta neutral and delta-hedged long strategies, are very close to zero at all times. Therefore, it is unlikely that a market timing indicator would be able to significantly improve the performance of the strategy to the point where they could compete with other strategies with significantly higher returns.

In conclusion of the performance measures, every short strategy outperforms a long investment in the S&P500 in the similar sample period. The daily delta-hedged straddle trading when the 10-day moving average of the CDX is above the current level of CDX does not outperform the S&P500 in the sample period. However, the strategy yields much lower standard deviation and can be considered the better investment as it takes on less risk. The hedging frequency still influences the return, as the daily delta-hedged strategies yield lower returns compared to the weekly delta-hedged strategies. It is important to notice, that the higher return from the weekly delta-hedged strategies is due to profitable delta hedges, which is not expected to be consistent in the future. The short strategies considered in this chapter are all delta-hedged either weekly or daily. The regression analysis concludes that market movements do not affect the returns of the delta-hedged short strategies. The short delta-hedged strategies do, however, provide factor exposure, which could be linked to variance and the volatility risk premium. We conclude that using the market timing indicators described in this section for the short market timing indicator strategies significantly improves the performance of the strategies and makes them attractive to use when capturing the volatility risk premium.

When considering the long iron condor and long iron butterfly we see that they can't produce statistically significant returns on a 5% level. Furthermore, they don't produce attractive performance measures and therefore the investment is unattractive when trying to capture the volatility risk premium.

Risk measures

The risk measures that will be examined in the following section are the maximum drawdown, Value at Risk and expected shortfall. These measure the downsides of the strategies. It is important to consider these figures, as they are crucial when implementing these strategies, since the investors could face liquidation of the positions if they are not able to withstand the downside risk of the strategy. The risk measures are illustrated in Figure 3.48 to Figure 3.51 below.

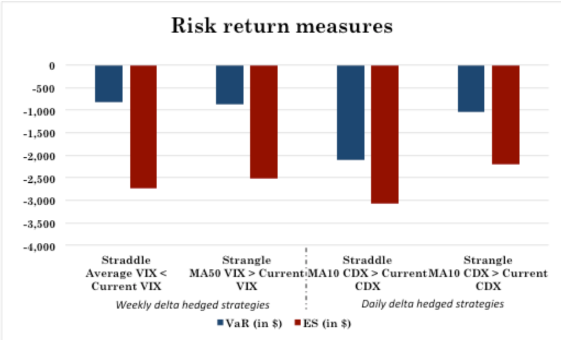

Figure 3.48 – Value at Risk and expected shortfall for short indicating strategies (short straddle and short strangle)

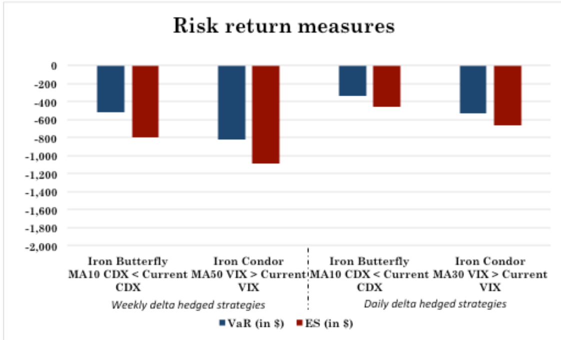

Figure 3.49 – Value at Risk and expected shortfall for long indicating strategies (long iron butterfly and long iron condor)

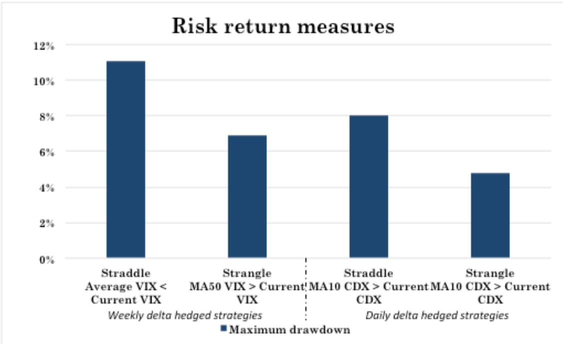

Figure 3.50 – Maximum drawdown for short indicating strategies (short straddle and short strangle)

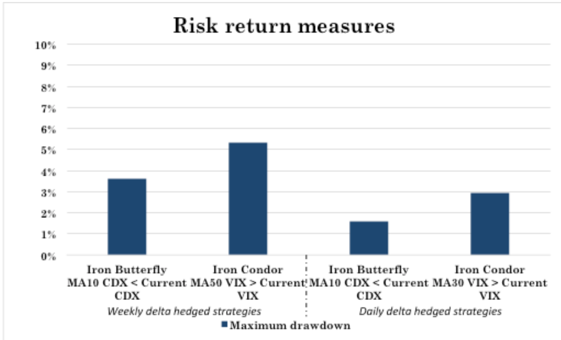

Figure 3.51 – Maximum drawdown for long indicating strategies (long iron butterfly and long iron condor)

When comparing the market timing indicator strategies to the initial strategies the VaR are significantly lower for the short straddle and short strangle strategies. In Table 3.15 we see the VaR for the short straddle and short strangle strategies are between approximately -$800 to -$2,100. The daily delta-hedged strategies perform worse than the weekly delta-hedged strategies. This is surprising, as one would assume that the daily delta hedging would prevent larger negative returns. This could be caused by the market timing indicator signaling a trade in some months that are more volatile, causing the VaR to be higher. Further, the short strangle performs better compared to the short straddle for the daily delta-hedged strategies but not for the weekly delta-hedged strategies. The strategies are based on different market timing indicators and they do not necessarily trade in the same month. Therefore, the strategies cannot be directly compared in their performances and risk measures, however it is still relevant to discuss their differences.

When comparing the market timing indicator strategies to the initial strategies, the VaR are slightly lower for the long iron butterfly and long iron condor. In Table 3.17 we see the VaR for the long iron butterfly and long iron condor are between approximately -$334 to -$882. The daily delta-hedged strategies perform better than the weekly delta-hedged strategies. This is in accordance with the findings in the performance measures, where the daily delta-hedged strategies performed better than the weekly delta-hedged strategies. Further, the long iron butterfly performs better compared to the long iron condor for both delta hedging frequencies. This is the same pattern that was found for the initial delta neutral and delta-hedged long strategies.

The expected shortfall shows the expected pattern. The short straddle has more risk compared to the short strangle, which again has higher risk compared to the long iron butterfly and long iron condor. The ES for the short straddle and short strangle range from approximately -$2,200 to -$3,000, which is significantly lower compared to the initial strategies (in absolute terms). The ES for the long iron butterfly and long iron condor range from approximately -$463 to -$1,093, which is slightly lower compared to the initial strategies (in absolute terms). It is expected that the short strategies have higher risk than the long strategies since they don't have limited downside. When using the market timing indicators, it is very rare that a single trade has a potential loss that is very big, and it is unlikely to continue for multiple periods in a row, which is a very attractive feature.

As expected the maximum drawdowns from the high watermark (denoted MDD and HWM in the following) are greatly improved for the short straddle and short strangle strategies when using the indicators compared to the initial strategies. The MDD ranges from approximately 5% to 11% for the different hedging frequencies and as expected the short straddle performs a worse compared to the short strangle in this measure. For the long iron butterfly and long iron condor the MDD is between 1.62% and 5.35% for the different hedging frequencies.

To summarize, the risk measures are significantly improved for all market timing indicator strategies compared to the initial strategies. The long strategies still perform better compared to the short strategies but now the difference is not as significant compared to not applying the indicators.

In conclusion, the market timing indicators improve the performance of the strategies significantly. The return of the daily delta-hedged short strangle signaling a trade when the 10-day moving average of CDX is above the current level of CDX is the only short strategy that is not statistically significant on a 5% level. The returns of the other short strategies are statistically significant on a 5% level. For the long strategies, the performance is also improved, but the returns are still not statistically significant on a 5% level. This enables us to conclude that the long market timing indicator strategies are not suitable to capture the volatility risk premium. The short market timing indicator strategies are however very effective at capturing the volatility risk premium and the market timing indicators improve the performance- and risk measures significantly.

3.5.4 Regressions of indicating strategies

When using market timing indicators for whether to trade or not, there will inevitably be some months where there is no trade. This results in months where the return is zero. When running a regression where several months have returns of zero, the explanatory factors cannot accurately describe the returns. For example, if in one month the return is 0% and the VIX has increased, the return of 0% cannot be explained by a higher VIX, as this increase has no influence on our return. By excluding all months when there is no trade (0% return), the exogenous factors wouldn't yield an accurate indication of the explanatory power of the factor. The reason for this is that if we remove five consecutive returns of 0%, the explanatory variable for this period could have moved significantly in one direction, and therefore the return in the next period would not reflect this significant change in an explanatory variable. We have done the regression for both scenarios described above and find that the explanatory variables are all insignificant, as expected.

The market timing indicator strategies' returns are based on the returns from the initial strategies. In section 3.4 we performed a regression analysis on these returns and found that they provide factor exposure linked to volatility and the volatility risk premium. Therefore, the returns of the short market timing indicator strategies are linked to the volatility risk premium. The regression of the returns of the long market timing indicator strategies does not provide evidence that they are linked to the volatility risk premium.

Chapter 4 - Discussion

In this chapter, we will address a few key variables, which have not been discussed in the analysis. We will present how changing certain variables will affect the performance of the strategies. This will provide a better understating of the empirical properties of the strategies. We will first present the effect of dividing the entire sample period into sub-periods to investigate how different economic environments affects the performance of the option strategies used in this thesis. We find that the performance between the different option strategies is very similar in each sub-period. However, the performance is significantly improved by trading in the recovery period (after the financial crisis) and post crisis (after the European sovereign debt crisis). Conversely the performance is significantly worse during periods with high volatility. This is expected as short vega strategies should perform better in periods with declining volatility.

We further address how changing the initial moneyness of the options used in the short strangle, in the long options for the long iron butterfly and in the long iron condor affect their performance. This is interesting as the analysis above only uses very specific levels of moneyness when creating the strategies. By changing this variable, we can conclude how the level of moneyness affects the performance measures. This is particularly interesting for the long strategies, as they have proven to be an unattractive investment in the analysis above. We find that the short straddle is most profitable when looking at Sharpe ratio when applying the moneyness used in the analysis above ($|0.4|$). For the long strategies, the performance measures are significantly improved by using DOTM options for the long legs. This is expected as these options are very cheap and makes the payoff resemble that of the short straddle and short strangle, as the tails are bought back very DOTM.

We will further address the impact transaction costs and margin requirements have on the performance of the strategies. We find that transaction costs significantly decrease the performance of the strategies, which is expected. Furthermore, we find that margin requirements are very high for the strategies, which can make them unattractive when trying to capture the volatility risk premium.

We will finalize this chapter by discussing the impact the return calculation has on the results in the analysis. This will provide insight to the chosen method of return calculation and why other viable methods have been discarded.

4.1 Performance across sub-periods

To investigate whether our results are robust to the chosen sample period we divided the sample period into five sub-periods: Pre-crisis, Financial crisis, Recovery period, European sovereign debt crisis and post-crisis. The reason for the division is to see how different economic environments affect the results of the different initial strategies. The pre-crisis spans from May ’06 to June ’07, the financial crisis spans from July ’07 to March ’09, the recovery period spans from April ’09 to March ’10, the European sovereign debt crisis stretches from April ’10 to June ’12 and the post-crisis is from July ’12 to the latest date in the sample period, which is April ’16.

In the tables below we present different descriptive statistics for the sub-periods as well as some performance- and risk measures for each option combination. The intention is to analyse the risk and performances across the sub-periods, to further understand the implication of the strategies. It is noticeable the post-crisis ranges across a longer period compared to the other sub-periods.

The results when dividing the sample period into sub-periods are quite consistent for all option combinations, however we will display a table of each strategy to provide the full overview of the effect of different sample periods.

In Table 4.1 and Table 4.2 we see the result from the short strategies. They perform best in the recovery period, where the Sharpe ratio is 53% and 87% for the short straddle and short strangle respectively. In the financial crisis, the Sharpe ratio is -8% for both short strategies and is the period with worst performance. As expected the standard deviation is lowest in the recovery period and highest during the financial crisis. The spread between the highest and lowest return is largest during the financial crisis followed by the European sovereign debt crisis. This is to be expected as these are the periods with the highest degree of variance.

During the post-crisis period the short strategies perform best in relation to the Sharpe ratio. When comparing the returns to the S&P500 (information ratio), the returns from the short strategies perform better during the financial crisis. This is also true for the other periods and strategies, since this is the period where the S&P500 performs worst. In other periods where the S&P500 is not affected by high volatility (non-crisis periods) the information ratio will be smaller, as the returns on the S&P500 increases.

When the strategies are weekly delta-hedged, the dependence on the underlying asset is reduced compared to the initial delta neutral strategies. The performance in the crisis periods is therefore improved when weekly- and daily delta hedging is applied. The information ratio is therefore significantly improved for both strategies. Increasing the delta hedging frequency has a negative effect on the performance measures of the short strategies. This relationship is consistent with the findings for the entire sample period.

We find that the strategies are performing significantly better in stable economic periods. As expected the short strategies perform best in periods with declining volatility and stable growth, which is the case in the recovery period. The short strategy doesn't perform well in periods with rising volatility like the European sovereign debt crisis. However, the short strategies perform better than the S&P500 during periods with sudden spikes in volatility like the financial crisis. Consistent with the findings for the entire sample period the short strangle perform better in most periods compared to the short straddle.

Short straddle

	Pre-crisis May '06 Jun '07	Financial crisis Jul '07 Mar '09	Recovery Apr '09 Mar '10	Sovereign crisis Apr '10 Jun '12	Post crisis Jul '12 Apr '16
			Initial delta neutral		
Mean	0.52%	-0.36%	1.37%	-0.15%	1.07%
Std. deviation	2.27%	7.52%	2.59%	4.34%	3.43%
Minimum	-4.51%	-24.63%	-2.60%	-15.35%	-9.07%
Maximum	3.72%	9.88%	4.52%	5.32%	6.60%
SR	4.05%	-7.53%	52.57%	-3.80%	30.99%
IR	-22.76%	20.31%	-14.90%	-18.84%	3.23%
SoR	5.77%	-7.36%	123.54%	-3.89%	36.50%
MDD	6.05%	31.43%	4.93%	17.73%	14.14%
			Weekly delta hedge		
Mean	0.40%	0.70%	0.87%	0.69%	0.15%
Std. deviation	1.40%	3.06%	1.90%	2.11%	3.79%
Minimum	-2.75%	-6.43%	-3.71%	-4.54%	-16.55%
Maximum	2.78%	7.27%	3.77%	4.26%	6.33%
SR	-1.97%	15.93%	45.42%	31.93%	3.70%
IR	-33.31%	37.59%	-23.91%	-4.37%	-14.57%
SoR	-2.75%	21.88%	42.97%	50.00%	3.25%
MDD	3.27%	11.09%	3.71%	4.80%	22.42%

Daily delta hedge					
Mean	0.12%	-0.24%	1.37%	0.10%	0.16%
Std. deviation	1.33%	2.91%	1.21%	1.41%	2.18%
Minimum	-3.74%	-6.47%	-1.06%	-2.77%	-6.69%
Maximum	1.61%	5.00%	3.13%	2.35%	5.00%
SR	-22.75%	-15.25%	112.41%	5.95%	6.91%
IR	-59.88%	30.22%	-16.94%	-21.48%	-17.59%
SoR	-22.35%	-19.60%	N/A	8.25%	8.69%
MDD	3.75%	18.37%	1.06%	6.87%	8.51%

Table 4.1 – Descriptive statistics for short straddle in sub-periods

Short strangle					
	Pre-crisis May '06 Jun '07	**Financial crisis** Jul '07 Mar '09	**Recovery** Apr '09 Mar '10	**Sovereign crisis** Apr '10 Jun '12	**Post-crisis** Jul '12 Apr '16
Initial delta neutral					
Mean	0.03%	-0.25%	1.49%	0.18%	1.13%
Std. deviation	2.15%	5.59%	1.69%	4.22%	3.24%
Minimum	-4.38%	-17.48%	-1.55%	-15.16%	-8.88%
Maximum	3.00%	7.29%	3.70%	5.49%	7.63%
SR	-18.50%	-8.12%	87.45%	4.09%	34.40%
IR	-37.06%	22.41%	-15.11%	-12.48%	4.68%
SoR	-23.04%	-9.49%	175.37%	3.67%	47.57%
MDD	8.25%	24.31%	1.55%	16.78%	8.88%
Weekly delta hedge					
Mean	-0.27%	0.31%	1.29%	0.41%	0.65%
Std. deviation	1.66%	2.45%	1.29%	1.87%	2.79%
Minimum	-3.29%	-4.46%	-0.45%	-5.18%	-9.02%
Maximum	2.77%	3.87%	3.18%	3.70%	7.36%
SR	-42.17%	4.08%	98.58%	21.29%	22.91%
IR	-52.71%	30.77%	-17.82%	-10.81%	-5.41%
SoR	-59.75%	6.99%	N/A	23.55%	22.99%
MDD	9.14%	6.95%	0.45%	5.88%	19.24%
Daily delta hedge					
Mean	0.04%	-0.57%	1.18%	0.11%	0.67%
Std. deviation	1.20%	2.98%	0.75%	1.47%	1.76%
Minimum	-3.58%	-8.44%	0.03%	-2.80%	-4.30%
Maximum	1.23%	3.33%	2.63%	2.23%	4.59%
SR	-32.36%	-25.96%	155.66%	6.46%	37.49%
IR	-66.91%	24.25%	-23.39%	-19.93%	-5.55%
SoR	-29.62%	-26.58%	N/A	8.59%	61.43%
MDD	3.58%	20.22%	0.00%	5.78%	9.01%

Table 4.2 – Descriptive statistics for short strangle in sub-periods

In Table 4.3 and Table 4.4 we see the result from the long strategies. The initial delta neutral strategies perform best in the recovery period, where the Sharpe ratio is 4% and 15% for the long iron butterfly and long iron condor respectively. The long strategies have similar qualities as the short strategies. We find that the strategies are also performing significantly better in stable economic periods. As expected the long strategies perform best in periods with declining volatility and stable growth, which is the case in the recovery period. The short strategy doesn't perform well in periods with rising volatility like the European sovereign debt crisis.

As prior analysis showed, the results from the long strategies do not yield a high return, and this is also the case when dividing the sample period into sub-periods. The spread of the results between the sub-periods is not as large as for the short straddle and short strangle proving again that the long strategies are less risky, even when considering a crisis period with high volatility. The strategies are only able to outperform the S&P500 during the financial crisis, which is not surprising as the long strategies have limited downside and therefore do not suffer large losses in this period.

In conclusion, the crisis period causes the returns of the short straddle and short strangle to be very unstable and risky. The strategies perform much better when the market is more stable and less volatile. This is in agreement with our findings in section 3.3.1 and since selling short straddles is a bet on lower volatility, this confirms this theory. The long iron butterfly and long iron condor have a smaller spread compared to the short strategies proving these to be less risky in all states of the economy. When dividing the results into sub-periods the results changes significantly for the short straddle and short strangle, and therefore the selection of the timing for implementing the option strategies have a high impact on the returns and performance- and risk measures.

Long iron butterfly					
	Pre-crisis May '06 Jun '07	**Financial crisis** Jul '07 Mar '09	**Recovery** Apr '09 Mar '10	**Sovereign crisis** Apr '10 Jun '12	**Post-crisis** Jul '12 Apr '16
Initial delta neutral					
Mean	0.02%	-0.01%	0.05%	-0.07%	0.09%
Std. deviation	0.33%	0.59%	0.35%	0.45%	0.60%
Minimum	-0.31%	-0.59%	-0.32%	-0.51%	-0.55%
Maximum	0.80%	1.40%	0.63%	1.47%	1.73%
SR	-122.00%	-34.08%	9.97%	-19.18%	13.86%
IR	-48.39%	30.04%	-47.98%	-26.18%	-22.17%
SoR	-224.84%	-98.85%	46.90%	-62.88%	52.90%
MDD	0.85%	2.12%	0.60%	2.55%	1.96%

Weekly delta hedge					
Mean	-0.01%	0.02%	0.03%	-0.05%	-0.02%
Std. deviation	0.29%	0.55%	0.34%	0.45%	0.66%
Minimum	-0.67%	-0.51%	-0.38%	-0.64%	-1.11%
Maximum	0.47%	1.27%	0.61%	1.49%	1.75%
SR	-151.50%	-29.19%	4.00%	-14.63%	-4.11%
IR	-53.12%	30.41%	-48.87%	-25.56%	-25.20%
SoR	-166.22%	-69.06%	11.08%	-50.70%	-8.64%
MDD	0.50%	1.66%	0.73%	2.36%	3.55%
Daily delta hedge					
Mean	-0.01%	0.02%	0.08%	-0.03%	0.04%
Std. deviation	0.22%	0.46%	0.30%	0.33%	0.51%
Minimum	-0.35%	-0.80%	-0.22%	-0.46%	-0.94%
Maximum	0.60%	1.05%	0.64%	1.30%	1.81%
SR	-191.33%	-35.18%	22.45%	-12.02%	5.34%
IR	-51.40%	30.19%	-47.35%	-25.01%	-23.88%
SoR	-290.77%	-59.73%	80.28%	-29.16%	10.41%
MDD	0.46%	1.37%	0.52%	1.78%	1.79%

Table 4.3 – Descriptive statistics for long iron butterfly in sub-periods

Long iron condor					
	Pre-crisis May '06 Jun '07	**Financial crisis** Jul '07 Mar '09	**Recovery** Apr '09 Mar '10	**Sovereign crisis** Apr '10 Jun '12	**Post-crisis** Jul '12 Apr '16
Initial delta neutral					
Mean	-0.05%	-0.09%	0.12%	-0.04%	0.21%
Std. deviation	0.42%	1.04%	0.68%	0.86%	0.83%
Minimum	-0.52%	-1.22%	-0.50%	-1.27%	-1.31%
Maximum	1.12%	2.41%	1.14%	1.93%	2.49%
SR	-113.19%	-27.34%	14.99%	-6.08%	24.50%
IR	-50.61%	28.75%	-48.33%	-24.04%	-18.84%
SoR	-178.40%	-70.34%	95.05%	-14.66%	75.24%
MDD	2.17%	4.26%	1.93%	4.94%	3.15%
Weekly delta hedge					
Mean	-0.09%	-0.03%	-0.03%	-0.01%	-0.02%
Std. deviation	0.43%	0.77%	0.55%	0.70%	0.84%
Minimum	-0.70%	-1.01%	-0.82%	-1.13%	-2.03%
Maximum	1.23%	1.96%	1.08%	1.45%	2.43%
SR	-121.43%	-29.42%	-8.27%	-3.50%	-4.10%
IR	-55.56%	29.13%	-50.92%	-23.07%	-24.74%
SoR	-251.55%	-63.63%	-19.80%	-8.50%	-6.37%
MDD	2.39%	2.82%	2.70%	3.89%	8.84%

Daily delta hedge					
Mean	-0.05%	0.03%	0.07%	-0.06%	0.07%
Std. deviation	0.29%	0.62%	0.29%	0.54%	0.60%
Minimum	-0.91%	-0.71%	-0.28%	-1.81%	-1.21%
Maximum	0.29%	1.49%	0.74%	1.01%	1.59%
SR	-160.83%	-25.84%	19.23%	-13.90%	10.46%
IR	-53.01%	29.62%	-49.26%	-25.43%	-22.55%
SoR	-160.83%	-68.90%	57.31%	-16.62%	21.60%
MDD	1.24%	1.35%	0.49%	3.37%	4.00%

Table 4.4 – Descriptive statistics for long iron condor in sub-periods

4.2 Initial moneyness

In the following section, we will focus on the initial moneyness used to create the option combinations and the effect it has on the results in the analysis when changing this. It is important to consider the effect of moneyness, as it will allow us to understand how to create the most profitable strategies.

In Table 4.5 to Table 4.7, we display the mean return, standard deviation of returns and the Sharpe ratio for the short strangle, long iron condor and long iron butterfly. The moneyness for the long strategies is for the long legs in the combination. This means that the short options used in the long iron condor does not change moneyness from the initial level of |0.4|. When changing the moneyness the effect has a clear pattern. For the long strategies, the profitability increases as moneyness decreases. This is to be expected as the DOTM options are very cheap and the combination is closer at resembling a short straddle and short strangle. This increases the profitability but will also cause the risk measures to perform worse. The tails are bought back further away from ATM, which increases the downside of the strategy. The level of moneyness provides a tradeoff between performance measures and risk of the strategy.

For the short strangle, we find that it is most profitable when using a moneyness level of |0.4| compared to the other levels of moneyness we test. This is the level used in the analysis of the thesis. By increasing moneyness the maximum profit increases as well as the risk, which maximizes at a moneyness level of |0.5|. When the options have moneyness of |0.5| they are ATM and therefore the combination is called a short straddle. By decreasing the moneyness the strategy widens the margin for profit. This causes the maximum profit and the risk to decrease.

Initial delta neutral short strangle							
	Moneyness ∣0.2∣	**Moneyness ∣0.25∣**	**Moneyness ∣0.3∣**	**Moneyness ∣0.35∣**	**Moneyness ∣0.4∣**	**Moneyness ∣0.45∣**	**Moneyness ∣0.5∣**
Mean	0.12%	0.43%	0.47%	0.45%	0.58%	0.59%	0.51%
Std dev	2.93%	2.94%	3.34%	3.64%	3.78%	4.15%	4.44%
SR	0.73%	11.37%	11.28%	9.60%	12.80%	11.94%	9.34%

Table 4.5 – Changing moneyness for the initial delta neutral short strangle

Initial delta neutral long iron butterfly							
	Moneyness ∣0.05∣	**Moneyness ∣0.1∣**	**Moneyness ∣0.15∣**	**Moneyness ∣0.2∣**	**Moneyness ∣0.25∣**	**Moneyness ∣0.3∣**	**Moneyness ∣0.35∣**
Mean	0.34%	0.23%	0.15%	0.12%	0.09%	0.10%	0.04%
Std dev	3.90%	3.28%	2.74%	2.18%	1.70%	1.24%	0.89%
SR	6.22%	4.01%	1.86%	1.19%	-0.47%	0.21%	-6.38%

Table 4.6 – Changing moneyness for the initial delta neutral long iron butterfly

Initial delta neutral long iron condor							
	Moneyness ∣0.05∣	**Moneyness ∣0.1∣**	**Moneyness ∣0.15∣**	**Moneyness ∣0.2∣**	**Moneyness ∣0.25∣**	**Moneyness ∣0.3∣**	**Moneyness ∣0.35∣**
Mean	0.42%	0.28%	0.16%	0.12%	0.09%	0.06%	0.01%
Std dev	3.33%	2.80%	2.37%	1.82%	1.31%	0.82%	0.44%
SR	9.64%	6.58%	2.64%	1.14%	-0.04%	-3.78%	-18.83%

Table 4.7 – Changing moneyness for the initial delta neutral long iron condor

The moneyness is an important measure to consider when deciding the level of risk that is desired from the option combinations. For the short strangle the moneyness used in the analysis provides the best performance measures, which indicates that it is a viable option when trying to capture the volatility risk premium.

4.3 Transaction costs

In the following section, we will focus on transaction costs and the effect these have on the results presented in the analysis. It is important to consider the effect of transaction costs, as it will allow us to understand the degree to which these frictions prevent an investor from exploiting the profits from the strategies examined in this thesis.

There are two main drivers of transaction costs; brokerage fees and bid-ask spreads. As stated by B. Eraker *(2013)* transaction costs such as brokerage fees, typically only apply at the retail level. Investment firms with reasonably large holdings face negligible additional costs. We therefore choose to ignore the effect of brokerage fees on the performance of the option strategies and will henceforth refer to transaction costs only as bid-ask spreads.

The results so far are based on returns computed using the bid prices for short options and ask price for long options. These prices are chosen to ensure we are able to enter the position, since we know someone is willing to buy and sell at these prices. This enables us to investigate how the option strategies fair in "real life". This is only done at the initiation of option strategies as we let the options expire every month. Other literature use the mid bid-ask spread in their analysis. However, we wish to investigate an implementable strategy and assume that it is not realistic to trade at the mid bid-ask spread. We will instead use the mid bid-ask spread when investigating the transaction costs faced by investor. The disagreement on the fair price between buyer and seller will have a significant effect on the performance of the strategy. By using the mid bid-ask price we would receive higher premiums for the short options and would pay less for the long options used in the protected strategies. This would cause the returns of the strategies to increase significantly. Using the mid bid-ask price will serve as an indicator of how the performance of the strategy would fair in a market with no disagreement between buyer and seller (bid and ask price is equal). We refer to this as a market with no transaction cost.

We indirectly incorporate the effect of liquidity into our previous analysis, by using the mid bid-ask spread this will be somewhat eliminated. However, ATM options are rarely thinly traded and will not produce very large spreads compared to some equity options. By using the mid bid-ask price we exclude most of the performance driven by liquidity in the market.

In the previous analysis, we have incorporated transaction cost, which is done to investigate whether the positive returns presented below are caused by violations of market efficiency. To conclude whether this is true, we need to analyse the economic significance of these positive returns. We analysed whether the positive returns achieved by the short vega strategies outweigh the risk and transaction cost required to exploit them. In Table 4.8 we have presented the average return and Sharpe ratio when loosening the assumption regarding transaction cost from our return calculation and use the mid bid-ask as reference to the returns. The option returns increase substantially, as expected.

Initial delta neutral strategies using the midpoint in bid/ask spread				
	Short straddle	**Short strangle**	**Long iron butterfly**	**Long iron condor**
Cumulative absolute return (in $)	81,720	89,187	5,174	10,293
Cumulative return	99.54%	122.76%	5.14%	10.39%
Mean	0.68%	0.74%	0.04%	0.09%
Standard deviation	4.43%	3.78%	0.52%	0.82%
Sharpe ratio	0.13	0.17	-0.09	-0.01

Table 4.8 – Descriptive statistics for initial delta neutral strategies using midpoint in bid/ask spread as price

We find that neither of the returns, including nor excluding transaction costs, are statistically significant on a 5% level. This is evidence that the positive returns are not caused by violations of market efficiency, as they are not statistically significant. Further, the economic significance is also doubtful, as the transaction costs limits the profitability of the strategy severely. Additionally, the initial delta neutral strategies do not provide direct exposure to the volatility risk premium unless they are delta-hedged.

Considering the added transaction cost incurred when delta hedging, which is required to provide more direct exposure to the volatility risk premium, it is clear that the returns are not statistically significant, as stated in Table 3.6 and Table 3.7. When separating the effect of transaction costs and the effects of delta hedging the conclusion is the same. We find that none of the strategy, neither including transaction costs nor excluding transactions costs, provides returns, which are statistically significant on a 5% level. When looking at delta hedging we find that the cost of delta hedging significantly lowers returns and therefore make the returns less statistically significant. These findings are consistent with the literature on transaction costs in option markets. We can conclude that transaction costs destroy some of the positive return and make the initial option strategies considered in this thesis less desirable to use, when capturing the volatility risk premium.

4.4 Option combinations and their margin requirements

When analysing different option combination through a sample period it is interesting to investigate the maximum margin requirements the combinations take on. This gives an indication of the risk related to the trade and also the size of capital needed, to enter the trade in a period.

The margin requirement is calculated as presented in section 2.9 and includes both margins for the short options and for the futures position in the delta-hedged strategies. The results for the initial delta neutral- and delta-hedged strategies are presented in Table 4.9, and plotted in Appendix Figure 9.36 to Appendix Figure 9.39.

Margin requirements					
Option combinations		**Min**	**Max**	**Spread**	**Average**
Short straddle	*Initial delta neutral*	3,875	40,492	36,617	10,050
	Weekly delta hedge	6,719	61,918	55,199	16,972
	Daily delta hedge	7,240	53,901	46,661	12,945
Short strangle	*Initial delta neutral*	2,245	30,169	27,925	7,512
	Weekly delta hedge	5,112	40,310	35,199	14,838
	Daily delta hedge	6,157	44,901	38,744	11,203
Long iron butterfly	*Initial delta neutral*	1,349	8,067	6,719	2,718
	Weekly delta hedge	1,668	8,245	6,577	3,534
	Daily delta hedge	5,723	25,780	20,057	9,759
Long iron condor	*Initial delta neutral*	687	7,786	7,099	2,671
	Weekly delta hedge	1,246	10,223	8,977	4,024
	Daily delta hedge	5,399	12,088	6,689	7,044

Table 4.9 – Margin requirements for straddle, strangle, iron butterfly and iron condor

The initial delta neutral strategies have the lowest maximum margin requirement compared to the delta-hedged strategies. The reason for these low margin requirements for the non-delta-hedged strategies is that they don't contain the margin requirements on the futures contracts used in the delta-hedged strategies. When delta hedging, the risk of the option combination is reduced, but the margin requirement for each trade (options and futures) are increased.

The maximum margin requirement is higher for the weekly delta-hedged strategies compared to the daily delta-hedged strategies. This is because the exposure of the daily delta-hedged strategy does not increase or decrease as much before it is delta-hedged again. The underlying price will move more when considering a weekly timeframe, making the risk and hereby the margin requirement higher. Though the weekly delta-hedged strategies' margin requirements are higher than the daily delta-hedged strategies', it requires more in relation to transaction costs to delta hedge the position daily compared to weekly or not at all. The analysis delimitates from transaction costs, but has been discussed briefly in section 4.3.

In general, the short straddle requires more margin compared to the same delta strategy for the short strangle. The short strangle requires more than the long iron butterfly and also the long iron butterfly requires more than the long iron condor. This is reflected by the minimum and the maximum margin requirement. The margin requirements are considerably higher during periods with high volatility, as the price of the underlying moves further during the holding period of the options. The margin requirements are especially high during the financial crisis, which is where the maximum is attained for each strategy. It is very important to consider the margin requirements when implementing the strategies as the investor should be able to provide the margin required, otherwise the positions will be liquidated and could cause huge losses for the investor. If an investor were to increase the exposure to the strategies examined in this thesis, the margin requirements would rise accordingly. The high margin requirements during the financial crisis severely limit the attractiveness of the strategies as the maximum margin requirements is several times larger than the premium received. This is further evidence that the positive returns of the initial strategies are not attractive to peruse given the margin requirements and costs associated with doing so. This again adds to the conclusion that the positive returns are not caused by market inefficiencies, as the cost and risk associated with pursuing them is too high. However, as we calculate the returns of the strategies by using a reference amount which is considerably larger than the maximum margin requirement during the sample period. We can conclude that by using market timing indicators it is possible to profitable capture the volatility risk premium using the short strategies analysed in this thesis.

4.5 Calculation of percentage returns

In this section, we will clarify the use of option returns in this thesis, and discuss the implication of the chosen method of calculating returns in relation to other relevant methods.

The analysis in this thesis is based on the percentage return calculated from each option strategy. Therefore, it is relevant to discuss this calculation and the effect it has on the results compared to other return calculations. As written in section 2.8, the percentage return is calculated from a predefined funding level. This is to ensure that the returns of the option strategies can be directly compared to each other. Further, by always using the same reference amount we ensure that the returns have constant relative variance and magnitude to each other and across strategies. This is important to be able to compare the strategies.

The formula used for the return calculation in this thesis is:

$$r_t = \frac{Profit\backslash Loss}{\$100.000} \quad (4.1)$$

where Profit\Loss is calculated as:

$$Profit\backslash Loss = Premium\ recieved - payout$$

The choice of the predefined funding level of $100,000 is discussed in the following. As discussed in section 4.4, an investor is faced with margin requirements when shorting options, which can cover the potential losses of the trade. In Table 4.9 we illustrate the margin requirements for the different strategies, and find that the weekly delta-hedged portfolios face the highest margin requirements. The maximum margin requirement faced in the sample period is for the weekly delta-hedged straddle, which has a maximum margin requirement of approximately $62,000. When choosing the predefined funding level used as a reference for our return calculations, we focus on having a low risk of being liquidated. Therefore, we use the maximum margin requirement and add an additional buffer to ensure that liquidation is a highly unlikely event. We decide to use a constant of $100,000. This is a subjective amount of funding, but we find it to be a reasonable reference point. This funding level has a direct effect on our returns, as a lower level would produce higher and more volatile returns, while a higher level would infer the opposite. For this method, the returns are theoretically bound in an interval spanning from a maximum of the theoretical limit of the premium received over $100,000, to a maximum loss of negative infinity, as we assume the option position would not be liquidated due to margin constraints. From an economical point of view, this return calculation ensures that returns are monotone across different time periods. This means that an absolute return of $1,000 (-$1,000) would produce the same positive (negative) percentage return regardless of the month the trade is implemented or past performance of the strategy. In Table 4.10 we demonstrate examples of a return calculated using the different definitions of return calculation. By using this return calculation, we ensure that the returns are more accurate across option combinations as it produces stable returns and variances. This enable us to analyse the returns and make conclusions based on these that is comparable.

When the $100,000 is set on a margin account, this can be used to trade other predefined instruments with low risk. We will delimitate from this and assume that the margin account is invested at the risk-free rate.

To be clear we are not using the formulas stated below in the analysis of this thesis:

We have an investment horizon of 1 month for each trade and the constant of \$100,000 does not change one month to the next in the sample period. We could choose to analyse longer horizons by keeping the \$100,000 fixed and combining returns over longer periods of time.

$$r_t = \frac{Profit\backslash Loss_t}{\$100{,}000 + \sum Profit\backslash loss_{t-n}} \quad (4.2)$$

where $\sum Profit\backslash loss_{t-n}$ is the cumulative absolute return from all previous trades.

For this method the returns are theoretically bound in an interval spanning from a maximum of infinity to a maximum loss of negative infinity, as the reference point could technically be zero, implying that any gain would be infinitely big. Conversely, since the position would not be liquidated due to margin constraints the theoretical maximum loss is negative infinity.

Another approach for calculating the percentage return is to calculate the maximum margin requirement for each strategy at each month and comparing this to the profit\loss.

$$r_t = \frac{Profit\backslash Loss_t}{\mathrm{Max(margin\ requirement)_t}} \quad (4.3)$$

where $\mathrm{Max(margin\ requirement)_t}$ is the maximum margin requirement in the one-month holding period of the options. The maximum margin requirement can be seen in Appendix Figure 9.36 to Appendix Figure 9.39. By using this as a reference for our return calculation, we would present the returns compared to the amount of capital needed to fund the trade. This would however cause the percentage returns to be higher for the long iron butterfly and long iron condor as they require less margin. This would cause difficulties comparing the returns between the different strategies. Further, the hedged positions would face lower returns as they have higher margin requirements. However, this method would again result in a non-constant returns and volatility in returns as were the case above. For this method, the returns are bound in an interval spanning from a maximum of the premium over the minimum margin requirement to a maximum loss of 100%, as the position would be liquidated, as the margin requirement is not met.

Another way of calculating returns is by looking at the options as unfunded positions.

$$r_t = \frac{Profit\backslash Loss_t}{\mathrm{E}} = \frac{Profit\backslash Loss_t}{\mathrm{M} * \mathrm{S_0}} \quad (4.4)$$

where E is exposure to the underlying, M is the multiplier of the option contract.

Here, the reference price is the exposure to the underlying asset. This would create a synthetic return that would depend on the value of the underlying asset at entry. This method would again result in a non-constant return and volatility in returns as were the case above. When this is the case the economic interpretation of the results is difficult to comprehend. By using this method, the returns would be bound between negative infinity and a positive number corresponding to the premium over exposure to the underlying index.

The final approach for calculating returns is an inversion of the return of a long position.

$$r_t = \frac{Profit\backslash Loss_t}{\text{Premium}} \tag{4.5}$$

We do not use this approach, as long and short options do not have the same characteristics. An investor entering a long position pays a premium, which is used as a reference when calculating the return of the contract, as this is the initial funding amount. As mentioned earlier, when entering a short position, the investor is obligated to have a margin account with an appropriate amount of money deposited. Therefore, it is not relevant to use the premium as a reference when calculating the return. The return would be in the interval of 100% to negative infinity. This does not present an accurate picture of the absolute returns, which is why this calculation is avoided even though some studies present their results in this way *(Coval & Shumway, 2001).*

To illustrate the effect of the different return calculations, an arbitrary example using a net profit of $1,000 and -$1,000 is illustrated in Table 4.10.

Equation nr.	Formula for r_t	Reference amount	Net profit = $1.000 / -$1.000	
(4.1)	$\frac{Profit\backslash Loss_t}{\$100{,}000}$	$100,000	1%	-1%
(4.2) previous gain	$\frac{Profit\backslash Loss_t}{\$100{,}000 + \sum Profit\backslash loss_{t-n}}$	$100,000 + $75,000	0.6%	-0.6%
(4.2) previous loss	$\frac{Profit\backslash Loss_t}{\$100{,}000 + \sum Profit\backslash loss_{t-n}}$	$100,000 – $75,000	4%	-4%
(4.3)	$\frac{Profit\backslash Loss_t}{\text{Max(margin requirement)}_t}$	$10,000	10%	-10%
(4.4)	$\frac{Profit\backslash Loss_t}{\text{E}} = \frac{Profit\backslash Loss_t}{\text{M} * \text{S}_0}$	100 * $1,200	0.8%	-0.8%
(4.5)	$\frac{Profit\backslash Loss_t}{\text{Premium}}$	$1,000	100%	-100%

Table 4.10 – Methods of percentage return calculation

4.6 Economic interpretation of short vega profitability

Whether selling or buying volatility is the better option depends on the empirical pricing of options. One could ask the question "are options priced fairly?" and thereby answering whether they provide an edge to the buyer or seller. The logical conclusion that volatility sellers provide insurance and should receive some compensation for this seems correct. We find that the returns of the short vega strategies exhibit negative skewness and high kurtosis, as the strategies provide frequent small gains and rare large losses. By looking at higher moments of the returns, it is typically suggested that the rational investor prefer high average returns and positive skewness, while disliking high volatilities and kurtosis. Assuming the presence of a skewness preference and kurtosis aversion, this may make options relatively expensive and therefore volatility selling profitable in general. However, even without these preferences, economic theory would suggest that volatility selling should provide a positive risk premium since its losses tend to coincide with equity market losses and other bad economic states. It should be noted that a tendency for short vega option strategies to be profitable does not make them always profitable. By assuming market efficiency, investors will limit any systematic richness of options.

As stated by Ilamanen *(2011)*, the persistent significant volatility risk premium observed in the market may reflect a combination of the following three factors:

- Compensation for systematic risk (volatility risk, perhaps also jump, skew, or correlation risk)
- Price pressures from investor supply and/or demand
- Biased forecasts of realized volatility (a peso problem, an unrepresentative sample period, or learning amidst structural uncertainty)

Chapter 5 - Further research

Delta hedging

The delta hedging is done based on time variables, weekly and daily. When using this type of delta hedging the hedges are done even if the delta has not changed considerably within the frequency period, and therefore allows for "unnecessary" hedges. To reduce the cost of trading, the delta hedging can be based on other variables e.g. levels of delta. If delta reaches a predetermined level the hedge could be implemented to neutralize the delta exposure. This could be a possible subject to further research to determine if there is a better approach for delta hedging than a predetermined time variable. As seen in Figure 3.16 we find that the long strategies remain close to delta neutral throughout the holding period of the options. Only when the option combinations are very close to maturity they become exposed to delta. Therefore, it could increase the performance of these strategies if the hedge is applied when they are close to maturity, to avoid "unnecessary" costs.

Market timing indicators

The market timing indicators in this thesis are based on measures of market- and credit risk represented by VIX and CDX. In the analysis, we found evidence that the indicating delta-hedged short strategies improve the performances compared to the "always-sell" strategies. The returns on these are also statistically significant. For further research, it could be interesting analysing more market timing indicators to see if they performed better than the VIX- and CDX indicators.

An alternative indicator could be the TED spread, which also measures the credit risk in the market. It is the difference between the 3-month LIBOR rate and 3-month Treasury interest *(Hull, 2012, p. 188)*. Other alternative indicators could be stress indicators such as CISS and CFSI. CISS (Composite Indicator of Systemic Stress) reflects the current state of instability in the financial system in a single statistic by measuring the current level of frictions, stresses and strains *(European Central Bank)*. CFSI (Cleveland Financial Stress Index) tracks distress in the US financial system and do so by tracking stress in six types of markets: Credit-, equity-, foreign exchange-, funding-, real estate- and securitization markets *(Federal Reserve Bank of Cleveland)*.

The historic data of the alternative indicators from the sample period are plotted in Figure 5.1 together with the chosen indicators for this thesis: VIX and CDX. The historical data from the S&P500 is also plotted, as this is an indicator of the market level. Vertical lines are added to distinguish between the different sub-periods used in the robustness check and we see the indicators follow each other relatively to some extend.

The correlations between the indices are presented in the table below and we can see all indices have a negative correlation with the S&P500. The index that is least correlated with the S&P500 is the TED spread. As illustrated in Figure 5.1 the TED spread has been close to zero in the past seven years, which makes it harder to trade on, as it does not provide much information about the volatility in the market at the moment. An eventual average on this index would go toward zero and a moving average would be close to zero at all time in this sample period.

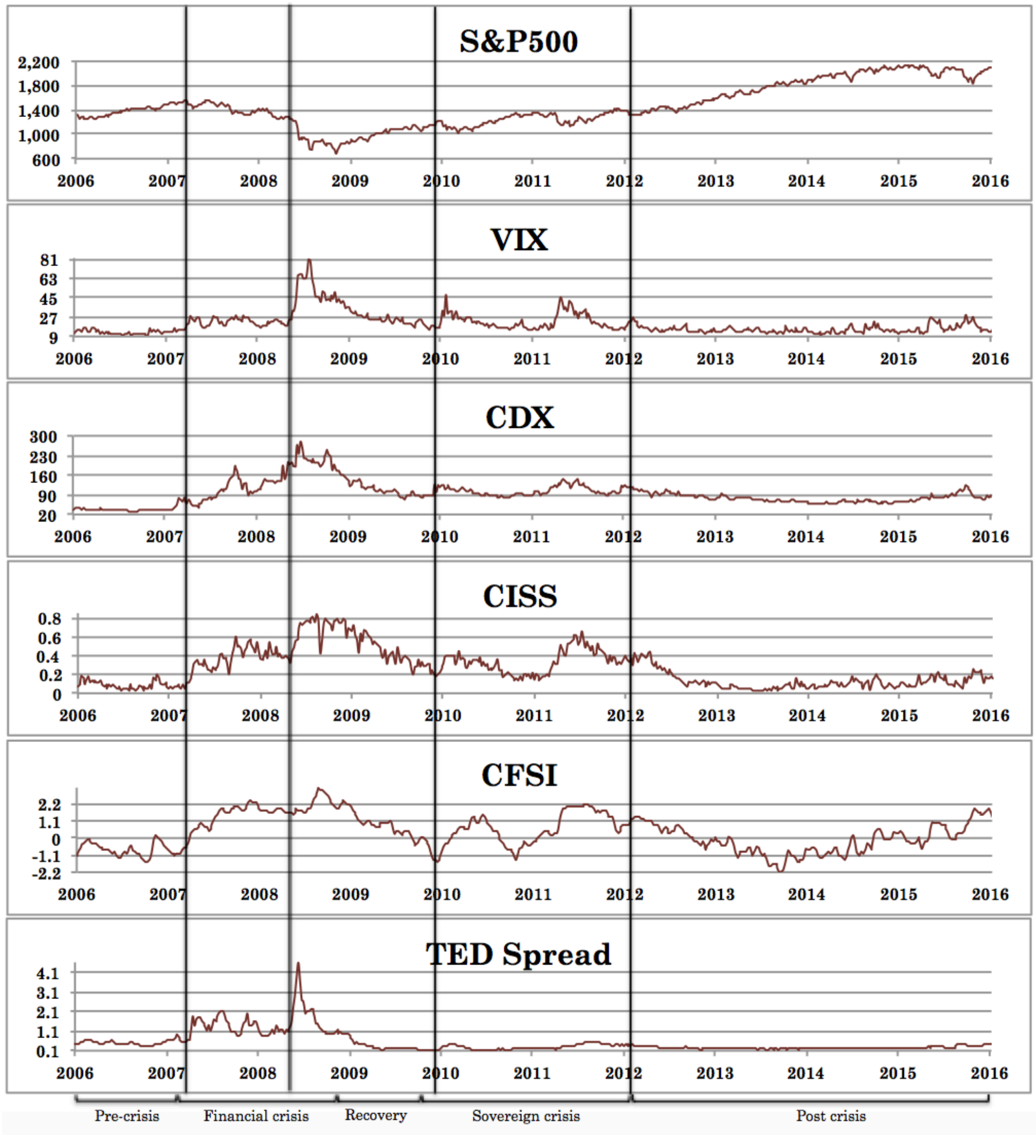

Figure 5.1 – Historical data of indicating indices

Correlation between alternative indicators						
	S&P500	**VIX**	**CDX**	**CISS**	**CFSI**	**TED spread**
S&P500	1					
VIX	-0.59	1				
CDX	-0.54	0.82	1			
CISS	-0.72	0.83	0.83	1		
CFSI	-0.45	0.65	0.71	0.81	1	
TED spread	-0.32	0.61	0.53	0.55	0.52	1

Table 5.1 – Correlation between alternative indicators

In Table 5.1 the correlation between the indices are shown. The correlations are relatively high, and the lowest correlations are the correlation against the TED spread. Again, when this index is close to zero in the majority of the sample period, it can be hard to interpret. The stress indicators, especially the CISS index, have a higher correlation with the VIX and the CDX. The CISS index must therefore capture some of the same risk the VIX- and CDX do.

Interest rate level

When comparing, the results obtained in the analysis to previous studies, it is important to note that the interest rates have varied significantly in the past. In the majority of the sample period considered in this thesis, the risk-free interest rate has been close to 0%. This means, that if the premiums received are invested at the risk-free rate during the holding period, the total return is not affected. Conversely, if the interest rates were 10%, the total return achieved by the strategy would be much higher. Further, the total premium received will increase as interest rates increase, which will enable the strategies to produce higher returns. The reason for the increased premium is that the option price increases more for the call option than it deceases for the put options, when the interest rates increases. The interest level in the economy will therefore have an impact on the returns of the strategies. Higher interest rates will increase the performance of the strategies, making economic periods with low interest rates less desirable. However, as seen in section 4.1, we find the performance of the short vega strategies are best during the recovery period in which the interest rates are very low. The interest rate level will not have a significant impact on the returns compared to the realized variance.

When considering the long iron butterfly and the long iron condor we find that they produce returns, which are very close to zero at all time. We conclude that these strategies are unattractive to use when capturing the volatility risk premium. An alternative use for these strategies could be to reinvest the premium received at the risk-free rate, when the interest rates are high. However, the performance of this strategy is outside the scope of this thesis, but could be interesting to investigate in further research.

Tax

Tax is another variable, which limits the attractiveness of the short vega strategies. Taxation on options is very complicated and is too extensive to cover in detail in this thesis. It is however, very important to consider that the returns presented in this thesis do not account for taxes as mentioned in the delimitation, section 1.3. By enforcing a tax rate of 22%, which is the current corporate tax rate in Denmark, we find that the excess returns for the market timing indicator strategies are still significant on a 5% level. This is an important finding as this would suggest that it is still profitable to capture the volatility risk premium when applying market timing indicators, even when taxation is considered.

Longer maturity options

To mitigate the problem of sharply rising deltas of the options when they get closer to maturity, we could use longer maturity options, as they would be less affected. However, this would cause the transaction costs to rise, as we would have to buy the options back in the market each month when exiting the position. Other literature finds, that using longer maturity options is not as profitable an investment strategy when trying to capture the volatility risk premium.

Different markets

In this thesis, we have focused on the S&P500 index. It could be interesting for further research to investigate whether it is more profitable to implement a short vega strategy in other equity indices. Further, it could be interesting to investigate whether it is more profitable to capture the volatility risk premium in other asset classes, by extending the analysis to incorporate different asset classes such as currencies, commodities, bonds etc. The market timing indicators used would have to be reconsidered as the VIX and CDX may not be appropriate to use for other asset classes.

Moreover, it could be interesting to extend the analysis to include individual equity options, to see if they would be more effective at capturing the volatility risk premium in the equity market. We would expect that it would be less profitable to trade the volatility risk premium in the equity market, since the volatility on single equities are higher than for the index. We find that the short vega strategies underperform when implemented in periods with high volatility. Therefore, it would not be surprising to find that the volatility risk premium on individual equities would underperform compared to the index.

Related research find that selling volatility on other asset classes earn reasonably consistent profits, whereas it is less clear that selling volatility on individual equities can earn statistically significant profits. For individual equity options, related literature finds that there is no consistent gap between the implied- and realized volatility, as there is for index options. Further it is documented, that selling volatility on index options perform best over longer periods of time compared to other asset classes.

Different instruments

In this thesis, we have tested whether certain short vega option combinations can profitably capture the volatility risk premium. However, there are other financial instruments, such as variance swaps, which can be used to capture the volatility risk premium. Variance swaps are by construction not subject to various unintended risks to which delta-hedged short vega strategies are exposed. These are risks like gamma risk between discrete rebalancing, impact of market frictions such as trading costs and illiquidity. The popularity of variance swaps has increased in recent years making the contracts more liquid. However, they are not yet available for all asset classes. It could be interesting to investigate if the variance swaps were a more profitable instrument when capturing the volatility risk premium.

Chapter 6 - Concluding remarks

We investigate whether market timing indicators and delta hedging improve the performance of short vega option strategies designed to capture the volatility risk premium. We test this by comparing initial delta neutral- and delta-hedged short vega strategies traded every month for 10 years to the equivalent strategies using market timing indicators to signal trades. We find evidence that only delta-hedged strategies provide factor exposure linked to the volatility risk premium. However, neither of the initial delta-hedged short vega strategies produce statistically significant returns.

When applying market timing indicators based on moving averages of the VIX- and the CDX index, the excess returns of the short strategies become statistically significant on a 5% level. Furthermore, the performance- and risk measures of all strategies are significantly improved. When applying market timing indicators, the short strategies produce Sharpe ratios several times bigger than to those achieved from a buy-and-hold strategy of the S&P500 index. The analysis yields strong evidence supporting the argument that the short market timing indicator strategies are very effective at capturing the volatility risk premium. The short delta-hedged strangle proves tp be the most profitable option combination. Market timing indicators significantly improves the performance of the long strategies, but not enough to produce positive Sharpe ratios. In conclusion, the long market timing indicator strategies are not suitable for capturing the volatility risk premium.

We test the performance of the strategies in different economic environments and find that short vega strategies perform best in low- and declining volatility environments. This is consistent with the implication of the best performing market timing indicators, which signals a trade when its respective average is above the current level of the index. The success of this strategy can be explained by the high mean-reverting nature of volatility.

When considering market frictions, the results of the analysis are affected. The short market timing indicator strategies are very effective at capturing the volatility risk premium, but are however very expensive to implement. The bid-ask spreads affect the premium received for the options but also the price of delta hedging. We find that the returns are robust to the costs only when using market timing indicators.

The margin requirements of implementing the short strategies severely affect the attractiveness as they are often of a considerable sum. The indirect cost incurred by having a margin account with a balance of several times the premium received, reduces the returns considerably. Considering the costs associated with capturing the volatility risk premium using the initial short option combinations, we find evidence to conclude that the positive returns are not caused by market inefficiencies, as the cost and risk associated with pursuing them is too high.

Theoretically the volatility risk premium obtained from index options on the S&P500 can be profitably captured only when using market timing indicators on short straddles and short strangles. However, from a practical perspective, the volatility risk premium inherent in short straddle and short strangle returns only lead to a realistic investment opportunity, if the investor face margin requirements similar to those imposed by exchanges.

Chapter 7 - Bibliography

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Chapter 8 - List of figures and tables

8.1 List of figures

8.2 List of tables

8.3 List of appendix figures

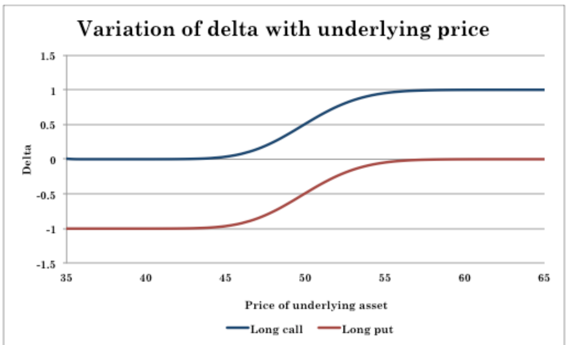
8.4 List of appendix tables

Chapter 9 - Appendix

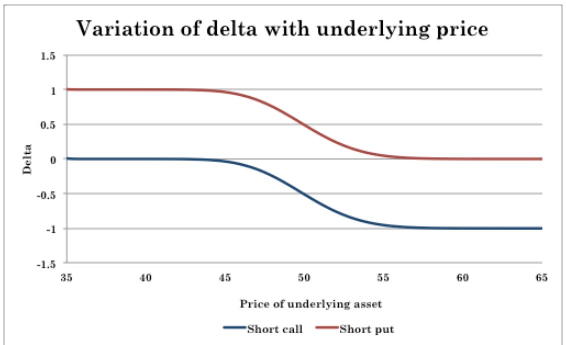
9.1 Greeks

Variation of delta for long and short options

For all illustrations, the strike price is set at 50 and varies in some illustrations, volatility is 20%, risk-free rate is 0% and dividend yield is 0%. Time to maturity is set as 1 month for some illustrations and varies in other. For Appendix Figure 9.1 when the price of the underlying equals the strike price, the delta is 0.5 for call options and -0.5 put options. When a call is ITM (underlying > strike) the delta goes toward 1 and OTM (underlying < strike) goes toward 0. For an ITM put (underlying < strike) the delta goes toward -1 and OTM (underlying < strike) goes toward 0. For Appendix Figure 9.2 the deltas are opposite for the options.

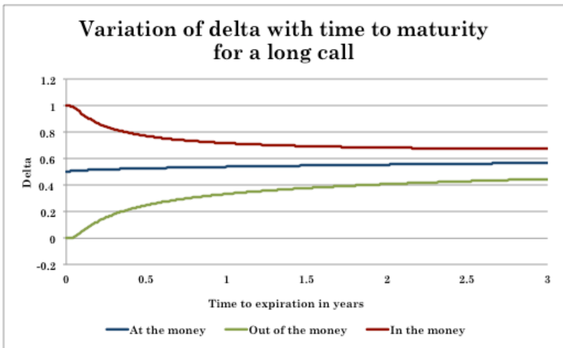


Appendix Figure 9.1 – Delta for long options

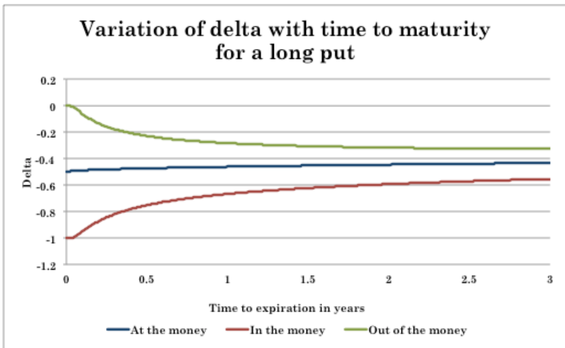


Appendix Figure 9.2 – Delta for short options

Appendix Figure 9.3 and Appendix Figure 9.4 shows the development of the delta with respect to time to maturity. This is illustrated for long options, and for short options the deltas are reverse: ITM short call goes toward 0, OTM short call goes toward 1, ITM short put goes toward 0 and OTM short put goes towards -1.



Appendix Figure 9.3 – Delta with respect to time to maturity for a long call option

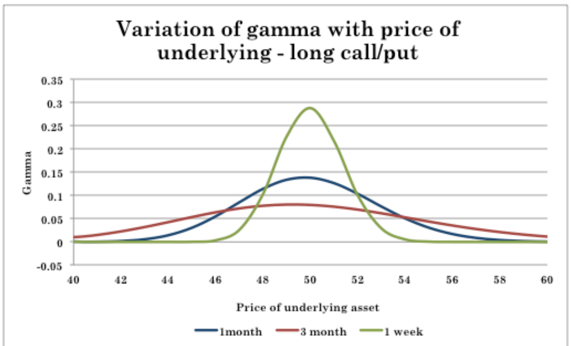


Appendix Figure 9.4 – Delta with respect to time to maturity for a long put option

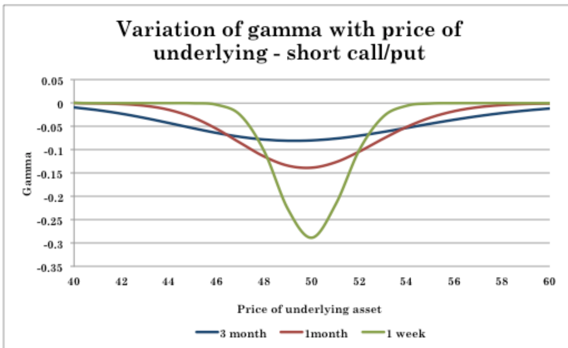
Variation of gamma for long and short options

The strike price is 50 in this example.

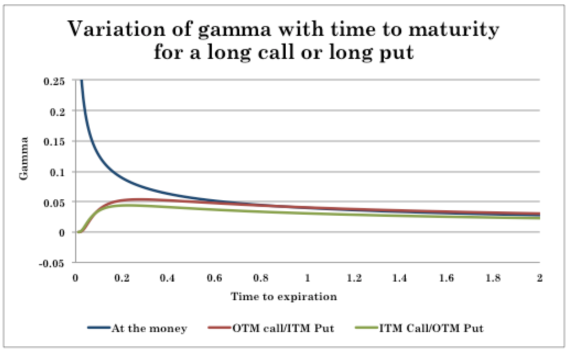
Options are more sensitive when the strike price equals the price of the underlying asset and also when the time to maturity decreases. The further ITM or OTM the more insensitive the options are to a change in the price of the underlying (closer to 0), as the probability to end in either of those scenarios are very high the more ITM or OTM the options are.



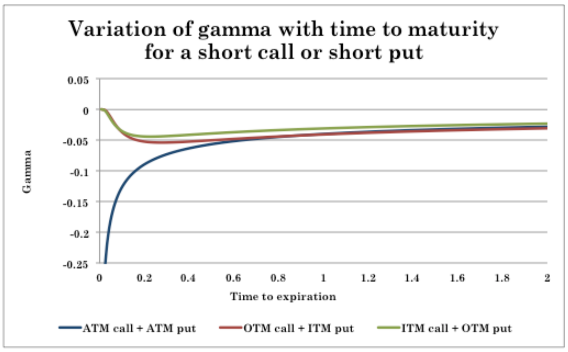
Appendix Figure 9.5 – Gamma for long options



Appendix Figure 9.6 – Gamma for short options



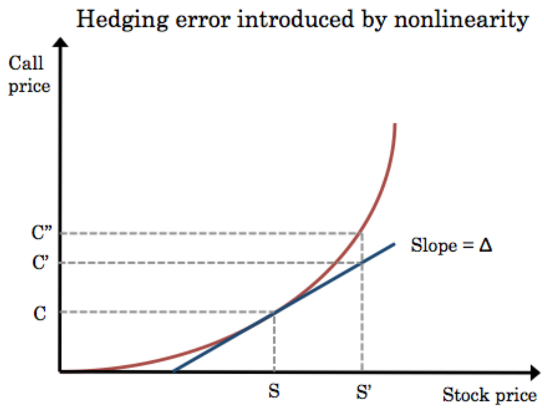
Appendix Figure 9.7 – Gamma with respect to time to maturity for a long call and put option



Appendix Figure 9.8 – Gamma with respect to time to maturity for a short call and put option

Gamma and delta hedging errors

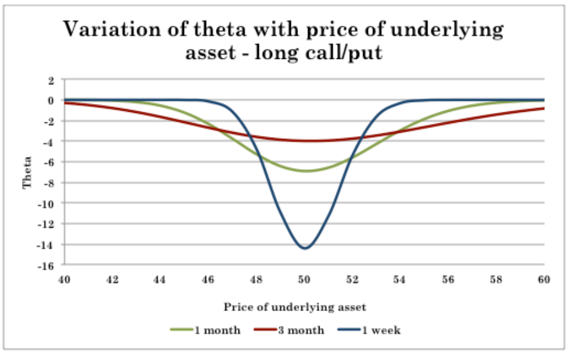
In Appendix Figure 9.9 this curvature is shown, where a delta hedge assumes that the option price moves from *C* to *C'* when the stock price moves from *S* to *S'*, where in fact the option price moves from *C to C" (Hull, 2012, p. 389).*



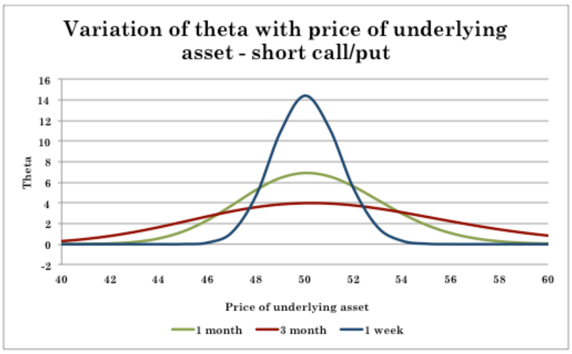
Appendix Figure 9.9 – Gamma measures the delta hedging errors caused by curvature

Variation of theta for long and short options

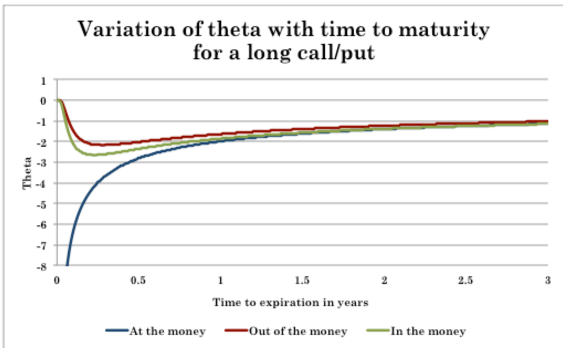
Theta is shown in the below figures. The three graphs in each figure represent different times to maturity, where the less time to maturity shows a more sensitive theta. When an option is shorted, the theta is positive and therefore when time to maturity decreases the higher is the option value.



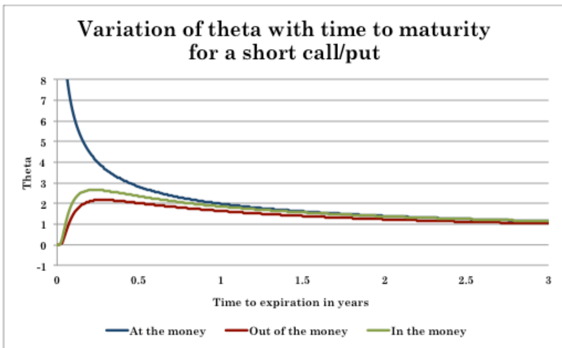
Appendix Figure 9.10 – Theta for long options



Appendix Figure 9.11 – Theta for short options



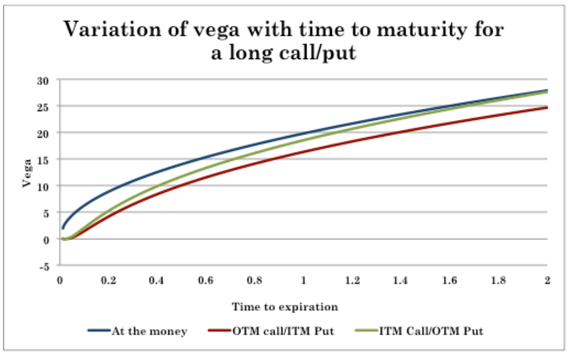
Appendix Figure 9.12 – Theta and time to maturity for long call/put



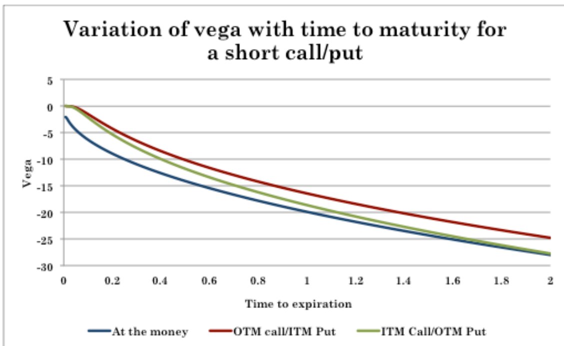
Appendix Figure 9.13 – Theta and time to maturity for short call/put

Variation of vega for long and short options

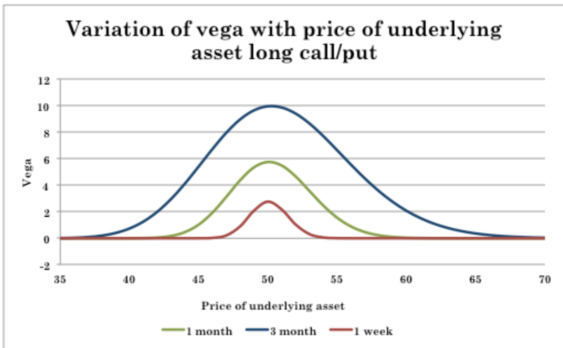
As seen in Appendix Figure 9.14 and Appendix Figure 9.15 ATM long/short options have higher/lower vega than OTM and ITM and also when the time to maturity decreases the vega decreases/increases because options are more sensitive to the volatility when time to maturity is low. If there is a jump in volatility the options do not have time to bounce back, and is therefore more sensitive.



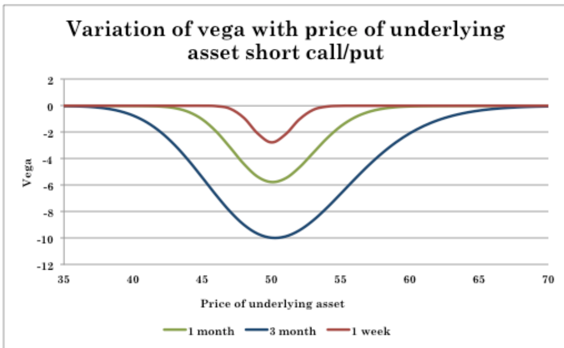
Appendix Figure 9.14 – Vega for long options



Appendix Figure 9.15 – Vega for short options



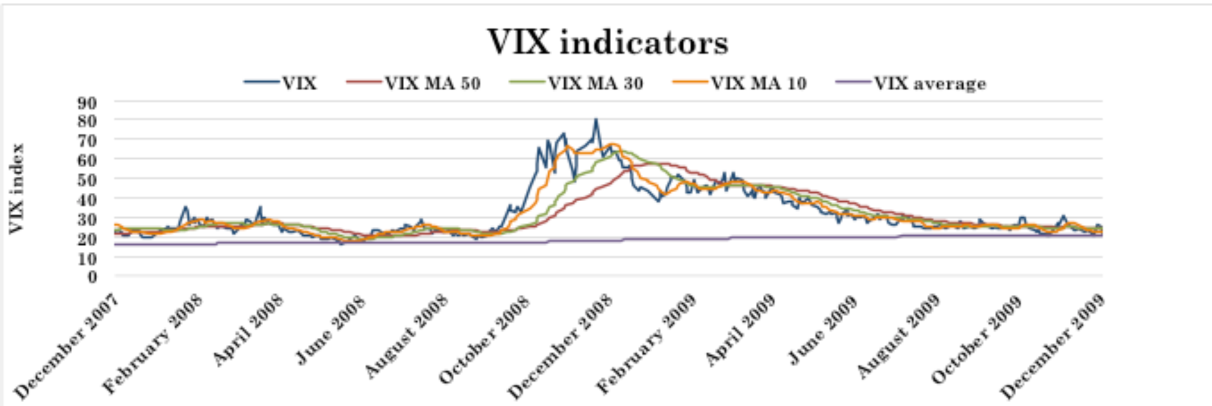
Appendix Figure 9.16 – Vega and time to maturity for long options



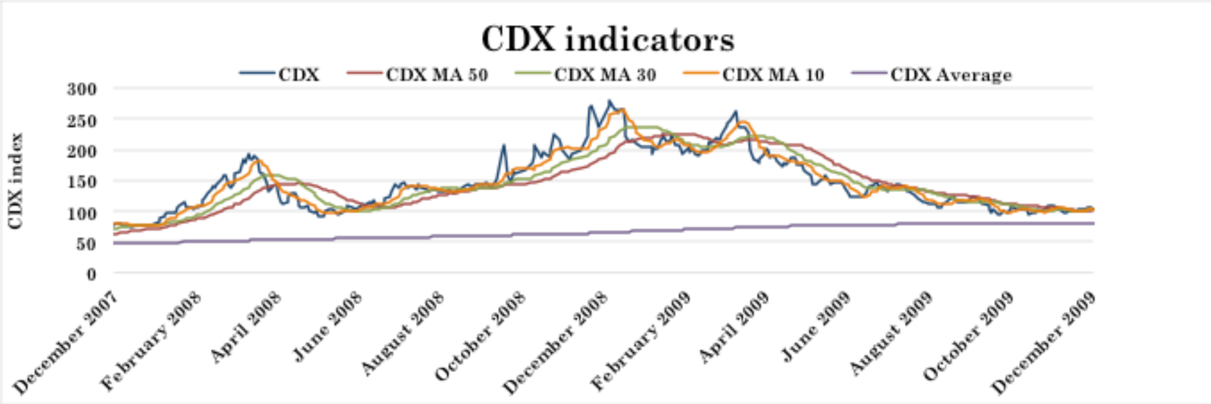
Appendix Figure 9.17 – Vega and time to maturity for short options

9.2 Market timing indicators

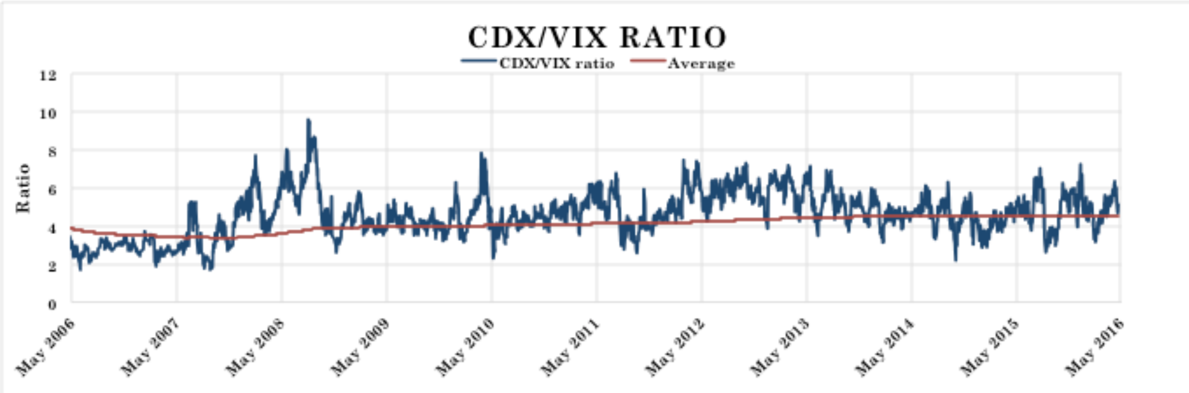
Appendix Figure 9.18 and Appendix Figure 9.19 shows the plotted indicators for the VIX and CDX index. The figures show that when the average spans over a longer period, the average gets more smooth compared to the plain index prices. A period between 2007 and 2009 is selected in the figures to get a more detailed view of the effect of the financial crisis in relation to the chosen indicators.



Appendix Figure 9.18 – VIX, VIX MA 50, VIX MA 30, VIX MA 10, VIX Average

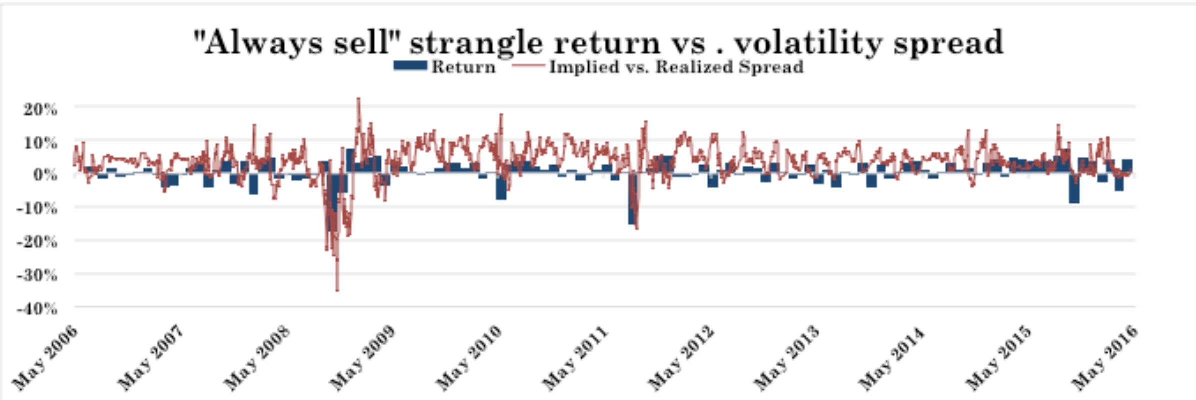


Appendix Figure 9.19 – CDX, CDX MA 50, CDX MA 30, CDX MA 10, CDX Average

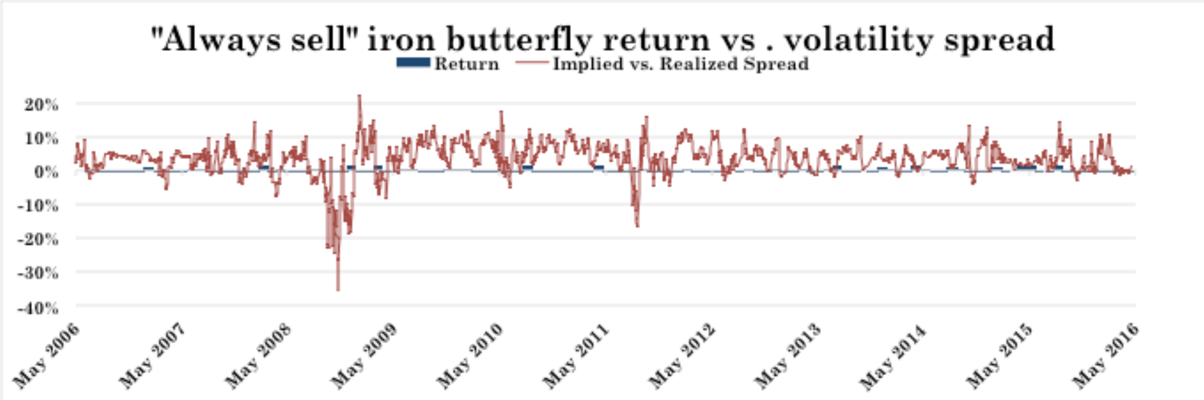


Appendix Figure 9.20 – CDX/VIX ratio and running average

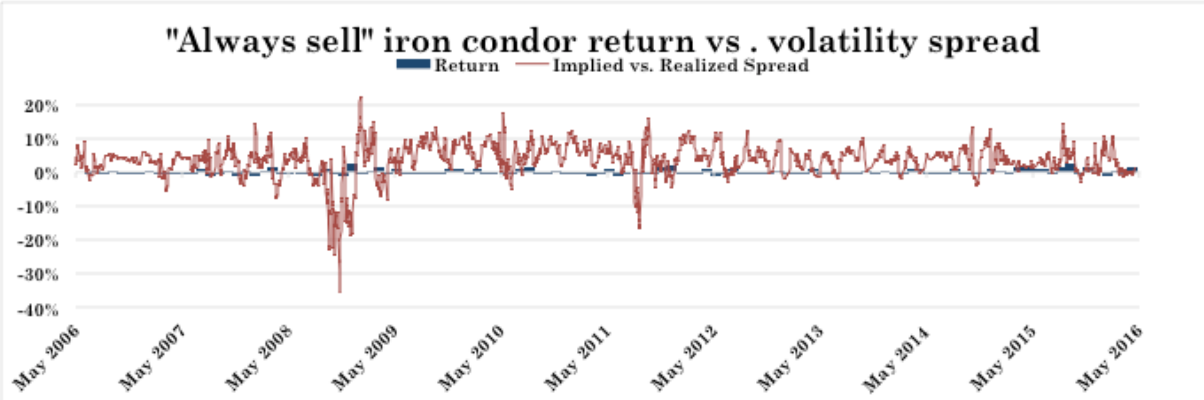
9.3 “Always sell” strategies vs. volatility spread



Appendix Figure 9.21 – “Always sell” strangle return vs. volatility spread



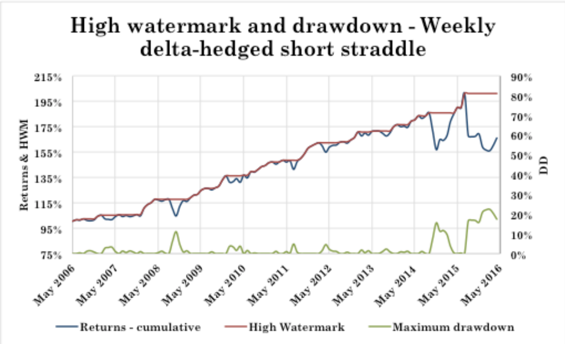
Appendix Figure 9.22 – "Always sell" iron butterfly return vs. volatility spread



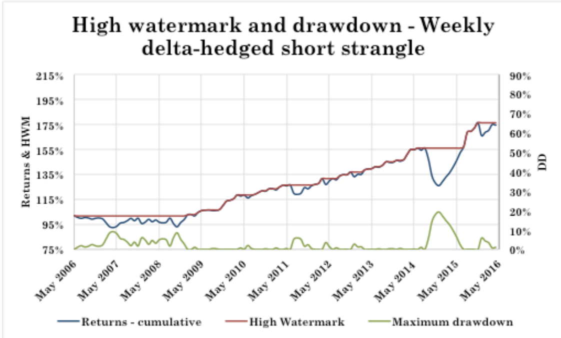
Appendix Figure 9.23 – "Always sell" strangle return vs. volatility spread

9.4 High watermark and drawdown – delta-hedged strategies

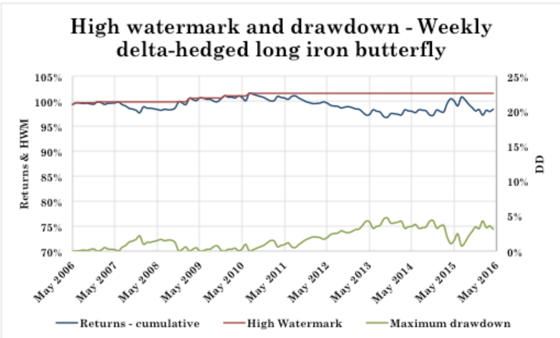
Weekly delta-hedged strategies



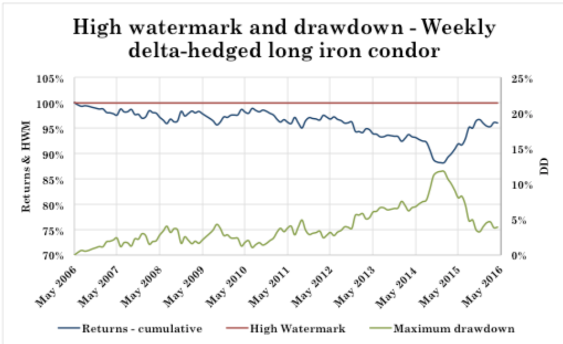
Appendix Figure 9.24 – HWM and DD weekly delta-hedged short straddle



Appendix Figure 9.25 – HWM and DD weekly delta-hedged short strangle

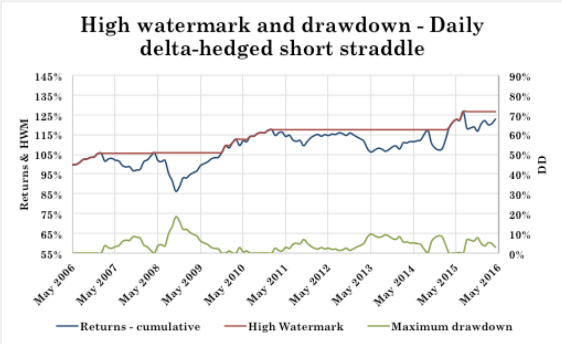


Appendix Figure 9.26 – HWM and DD weekly delta-hedged long iron butterfly

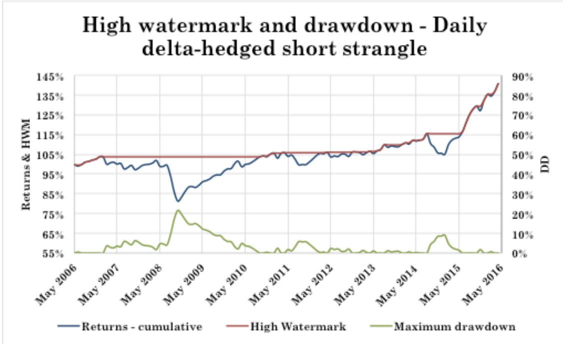


Appendix Figure 9.27 – HWM and DD weekly delta-hedged long iron condor

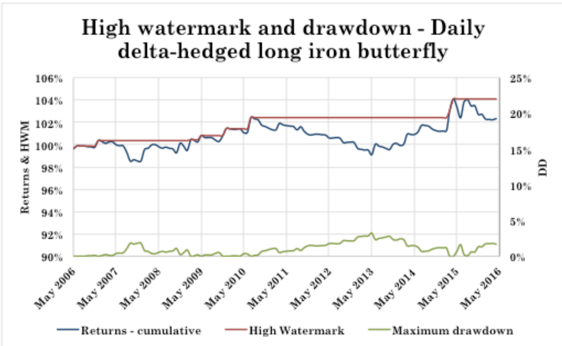
Daily delta-hedged strategies



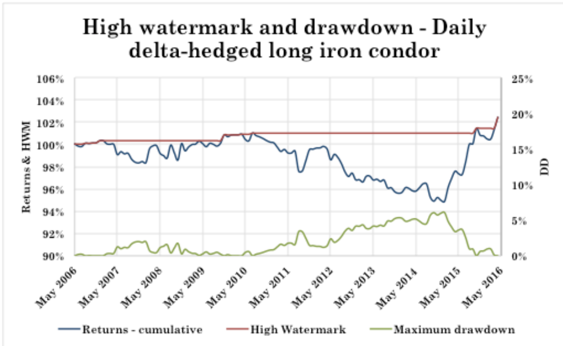
Appendix Figure 9.28 – HWM and DD daily delta-hedged short straddle



Appendix Figure 9.29 – HWM and DD daily delta-hedged short strangle



Appendix Figure 9.30 – HWM and DD daily delta-hedged long iron butterfly



Appendix Figure 9.31 – HWM and DD daily delta-hedged long iron condor

9.5 Correlations between returns and regression factors

Short straddle					
	Initial delta neutral				
	Return	Vol. measured by VIX	Credit spread	Trading volume	Market excess
Return	1				
Vol. measured by VIX	0.136	1			
Credit spread	-0.07	0.15	1		
Trading volume	-0.13	0.71	0.05	1	
Market excess	-0.20	-0.14	-0.05	-0.09	1
	Weekly delta-hedged				
	Return	Vol. measured by VIX	Credit spread	Trading volume	Market excess
Return	1				
Vol. measured by VIX	0.199	1			
Credit spread	0.03	0.15	1		
Trading volume	-0.06	0.71	0.05	1	
Market excess	-0.15	-0.14	-0.05	-0.09	1

Daily delta-hedged					
	Return	Vol. measured by VIX	Credit spread	Trading volume	Market excess
Return	1				
Vol. measured by VIX	0.16	1			
Credit spread	-0.12	0.17	1		
Trading volume	-0.12	0.72	0.05	1	
Market excess	-0.14	-0.14	-0.05	-0.09	1

Appendix Table 9.1 – Correlations between straddle return and regression factors

Short strangle					
Initial delta neutral					
	Return	Vol. measured by VIX	Credit spread	Trading volume	Market excess
Return	1				
Vol. measured by VIX	0.180	1			
Credit spread	-0.07	0.16	1		
Trading volume	-0.21	0.62	0.08	1	
Market excess	-0.20	-0.14	-0.05	-0.11	1
Weekly delta-hedged					
	Return	Vol. measured by VIX	Credit spread	Trading volume	Market excess
Return	1				
Vol. measured by VIX	0.161	1			
Credit spread	0.03	0.16	1		
Trading volume	-0.12	0.62	0.08	1	
Market excess	-0.15	-0.14	-0.05	-0.11	1
Daily delta-hedged					
	Return	Vol. measured by VIX	Credit spread	Trading volume	Market excess
Return	1				
Vol. measured by VIX	0.13	1			
Credit spread	-0.12	0.16	1		
Trading volume	-0.18	0.62	0.08	1	
Market excess	-0.14	-0.14	-0.05	-0.11	1

Appendix Table 9.2 – Correlations between strangle return and regression factors

Long iron butterfly					
	Initial delta neutral				
	Return	Vol. measured by VIX	Credit spread	Trading volume	Market excess
Return	1				
Vol. measured by VIX	0.032	1			
Credit spread	-0.02	0.15	1		
Trading volume	0.03	0.71	0.05	1	
Market excess	-0.01	-0.14	-0.05	-0.09	1
	Weekly delta-hedged				
	Return	Vol. measured by VIX	Credit spread	Trading volume	Market excess
Return	1				
Vol. measured by VIX	0.098	1			
Credit spread	0.02	0.15	1		
Trading volume	0.13	0.71	0.05	1	
Market excess	0.07	-0.14	-0.05	-0.09	1
	Daily delta-hedged				
	Return	Vol. measured by VIX	Credit spread	Trading volume	Market excess
Return	1				
Vol. measured by VIX	0.02	1			
Credit spread	-0.01	0.15	1		
Trading volume	0.09	0.71	0.05	1	
Market excess	0.06	-0.14	-0.05	-0.09	1

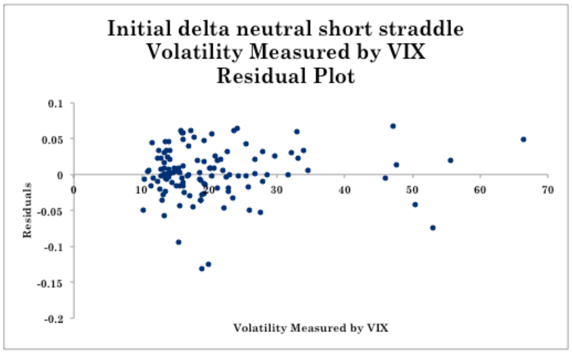
Appendix Table 9.3 – Correlations between iron butterfly return and regression factors

Long iron condor					
	Initial delta neutral				
	Return	Vol. measured by VIX	Credit spread	Trading volume	Market excess
Return	1				
Vol. measured by VIX	0.132	1			
Credit spread	-0.08	0.16	1		
Trading volume	-0.02	0.62	0.08	1	
Market excess	-0.09	-0.14	-0.05	-0.11	1
	Weekly delta-hedged				
	Return	Vol. measured by VIX	Credit spread	Trading volume	Market excess
Return	1				
Vol. measured by VIX	0.205	1			
Credit spread	-0.01	0.16	1		
Trading volume	0.03	0.62	0.08	1	
Market excess	-0.02	-0.14	-0.05	-0.11	1

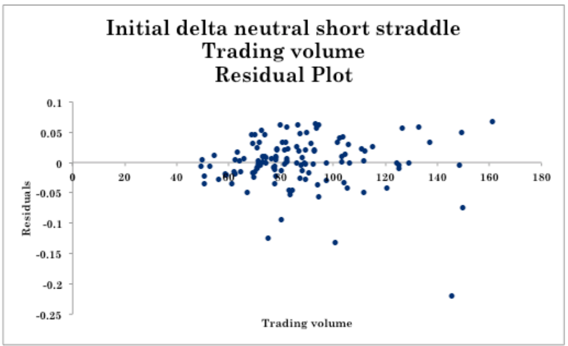
	Daily delta-hedged				
	Return	Vol. measured by VIX	Credit spread	Trading volume	Market excess
Return	1				
Vol. measured by VIX	0.06	1			
Credit spread	0.02	0.15	1		
Trading volume	0.01	0.68	0.08	1	
Market excess	0.02	-0.14	-0.05	-0.11	1

Appendix Table 9.4 – Correlations between iron condor return and regression factors

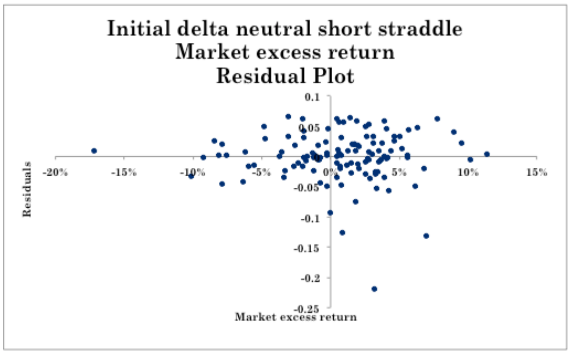
9.6 Residual plots



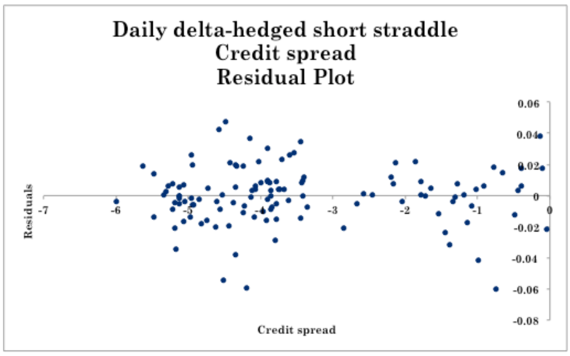
Appendix Figure 9.32 – Short straddle residual plot – Volatility measured by VIX



Appendix Figure 9.33 – Short straddle residual plot – Trading volume

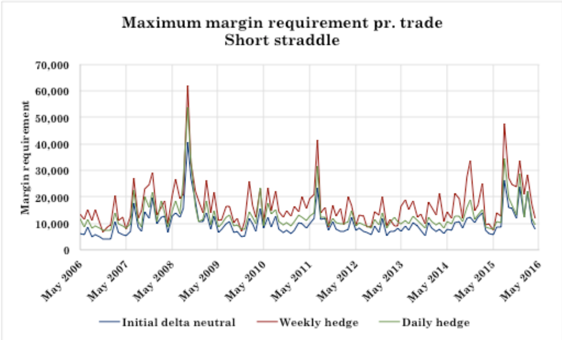


Appendix Figure 9.34 – Short straddle residual plot – Market excess return

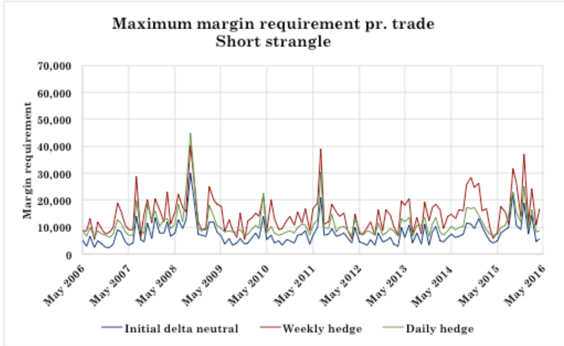


Appendix Figure 9.35 – Short straddle residual plot – Credit spread

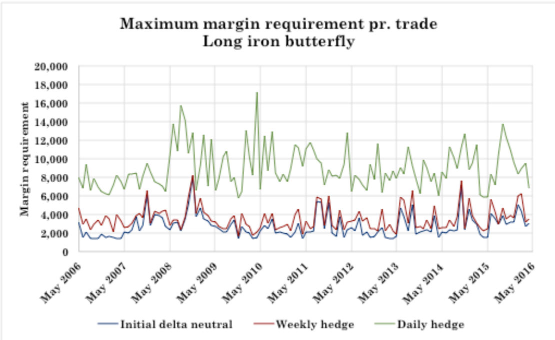
9.7 Margin requirements



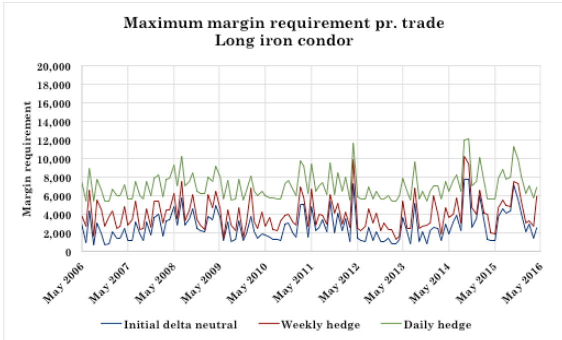
Appendix Figure 9.36 – Maximum margin requirement for short straddle



Appendix Figure 9.37 – Maximum margin requirement for short strangle

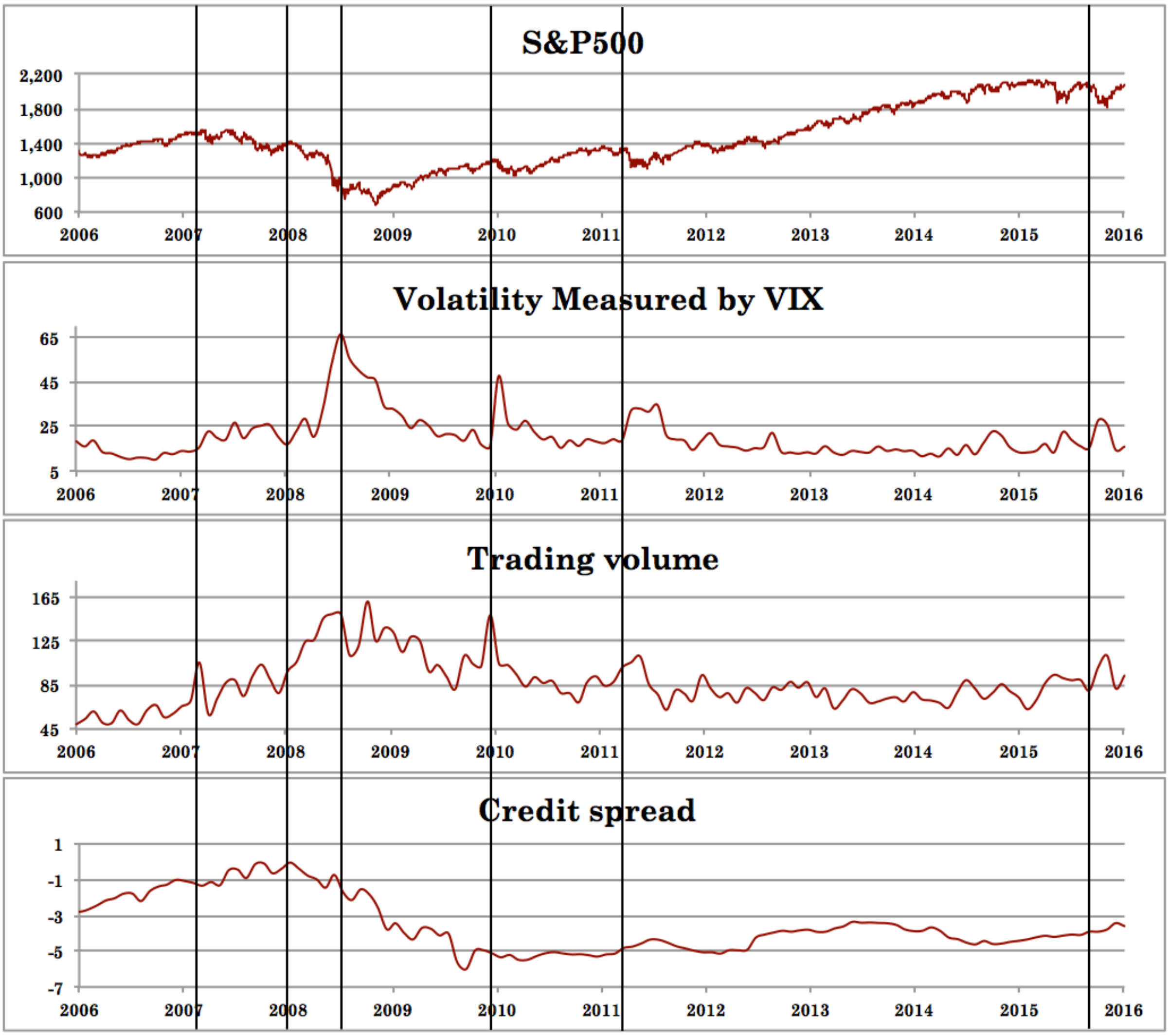


Appendix Figure 9.38 – Maximum margin requirement for long iron butterfly



Appendix Figure 9.39 – Maximum margin requirement for long iron condor

9.8 Regression variables illustrated



Appendix Figure 9.40 – Regression variables compared to each other


11.12
14.56
19.00
0.3045
0.3040