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BENEFITS OF VOLATILITY SPREAD TRADING ON QQQ

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ABSTRACT

This study is focused on one particular option strategy, volatility spread trading strategy. There are a large number of academic studies done and evidence about the profitability of volatility spread trading and whether it provides a signal of option mispricing on several currencies, stocks and indices. But does volatility spread trading strategy survive in real-world circumstances? This study concentrates on the authenticity of volatility spread trading returns on Invesco QQQ Trust Series 1 ETF (QQQ), which is an exchange-traded fund tracking the Nasdaq 100 index without the financial sector.

Long and short straddles are used to implement volatility spread trading strategy on QQQ in the following way: long positions in options are entered with a positive volatility spread (HV>IV), and short positions in options are taken with a negative volatility spread (HV<IV). The examination period for the study starts from May 2006 and lasts to August 2018, consisting of 147 holding periods to create long and short straddle portfolios by combining call and put options. Furthermore, the authenticity of volatility spread trading returns are considered by embedding the cost of bid-ask spreads and the impact of initial margin requirements into the results. Finally, the performance of volatility spread trading strategy is studied in bear market conditions.

Empirical findings suggest that the volatility spread is a demonstration of option mispricing, and it can be a highly profitable trading strategy in theory. However, when transaction costs are incorporated into calculations, the profitability of volatility spread trading is significantly dropped. In addition, the results indicate that volatility spread trading strategy performs better during the 2008 global financial crisis.

KEYWORDS: option returns, option strategies, volatility spread, volatility spread trading

1. INTRODUCTION

In 1973 Chicago Board Option Exchange opened and from then on option strategies have become more popular amongst investors and traders in hedge funds and in other investment institutes. The persuasive performances of different option strategies in a hedging and a speculation have also increased the demand and researches of the impact of option-based trading strategies to the performance of a portfolio. (Merton et al. 1978.) Furthermore, the global financial markets have been changing a lot since the beginning of 20th century. Particularly, the global derivatives market has been under a great regulation after the 2008 financial crisis. In addition, occasionally surging levels of volatility and an exponentially expanding derivatives market have increased the use of option strategies as part of an investment portfolio. Therefore, options and option strategies have become an important topic in the context of investing. (Aggarwal & Gupta 2013.)

Derivatives, options and more specifically option strategies are created for a hedging the underlying asset and for a speculation about the future volatility and price changes of the underlying asset (Fahlenbrach & Sandås 2010). This study concentrates on a speculative volatility spread trading strategy, which is implemented by using long and short straddles, option-based trading strategies. Volatility spread is the difference between historical volatility (HV) of the underlying asset and implied volatility (IV) derived from matched pairs of at-the-money call and put options. According to previous studies, volatility spread trading strategy is used for exploiting of option mispricing, and it has been proven to provide high monthly returns. Furthermore, volatility spread appears to work as a valid indication of option mispricing on different asset classes in various market areas (Chen & Leung 2003; Brenner et al. 2006; Goyal & Saretto 2009; Chen & Liu 2010; Do et al. 2015; McGee & McGroarty 2017). However, not much studies have been made of the benefits of volatility spread trading on ETFs.

The objectives of this study are to examine the profitability of volatility spread trading and whether it survives in real-world circumstances on Invesco QQQ Trust Series 1 ETF. QQQ is the trading symbol for the Invesco QQQ Trust Series 1 ETF, also known as PowerShares QQQ Trust, and it is issued by Invesco PowerShares. It tracks information technology, consumer discretionary, health care, consumer staples, industrials and telecommunication services sectors, and it is rebalanced quarterly as well as reconstituted annually. QQQ is one of the best established and most traded ETFs in the world, and therefore it is extremely large and liquid. Also, the wide range of available option data an actively traded options on QQQ is an important reason why this ETF is chosen for the examination. QQQ is designed to replicate the Nasdaq 100 index without the financial sector. However, QQQ is not purely a technology-based ETF. As of the 31st of August 2018, QQQ has approximately 482.1 billion US dollars' worth of assets under management. The top 3 holdings of QQQ are Apple, Amazon and Microsoft. (ETF.com 2019.)

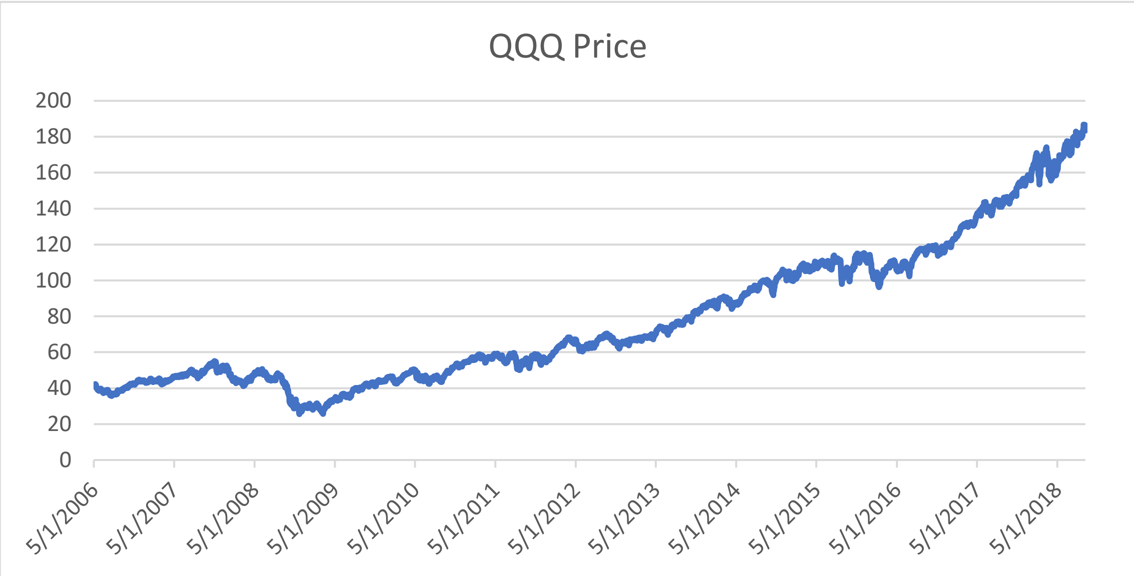

Figure 1. The daily prices of the QQQ ETF (Thomson-Reuters DataStream)

Figure 1 illustrates the performance of QQQ from the 1st of May 2006 to the 31st of August 2018. Price of QQQ has approximately increased 4.5 times from 2006 to present (August 2018), despite a significant crash during the 2008 global financial crisis. Due to a fact that QQQ is much more concentrated on its top holdings, it is more volatile than its large-cap benchmark index, MSCI USA Large Cap Index.

Table 1. Characteristics and performance of Invesco QQQ Trust Series 1 ETF between May 2006 and August 2018 (Thomson-Reuters DataStream)

	Mean	**Median**	**Std. Dev.**	**Semi-Std. Dev.**	**Skewness**	**Kurtosis**	**Sharpe ratio**	**Sortino ratio**
QQQ	1.20%	1.98%	5.63%	3.62%	-1.14	3.14	0.05	0.33

Table 1 presents the results of a pure index strategy, where a long position in the QQQ is taken and held. All numbers are monthly-based. QQQ has offered, on average, the monthly return of 1.20% with the standard deviation of 5.63%. The pure buy and hold strategy with a long position in QQQ provides Sharpe ratio of 0.05 and Sortino ratio of 0.33. The returns of QQQ are negatively skewed. Furthermore, median is almost 2 times larger than the mean, which also supports that returns of QQQ are skewed to the left.

1.1. Motivation

The motivation for the study arises from the findings of previous studies; the performance of volatility spread trading strategy works as a signal of options mispricing, and it can be a highly profitable trading strategy by effectively combining long and short straddles depending on the difference between HV and IV. Motivated by the previous studies, the forthcoming study examines the profitability of volatility spread trading strategy on QQQ and whether the strategy survives in real-world settings. The idea and theory behind volatility spread trading strategy is derived from a common finding, the mean-reversing nature of volatility. A large number of previous studies suggest that asset prices and returns eventually return back to the long-run mean or average prices and returns (Goyal & Saretto 2009; Chen & Liu 2010; Meng & Wang 2010; Do et al. 2015). In other words, a large volatility spread, which is the difference between the long-run equilibrium volatility (HV) and IV derived from call and put options, is a demonstration of option mispricing. Nevertheless, the previous studies do not suggest that IV should be the same as historical, current or realized volatility.

In the study of Goyal and Saretto (2009), they present that volatility spread trading strategy generates economically significant returns. According to their findings, the divergence between historical and implied volatilities is a clear indication of option mispricing, and further, trading long (short) straddles when volatility spread is positive (negative) produces economically significant and high returns. The reason behind the mispricing is the volatility smile, which is the variation of implied volatilities across the strike prices. This means that IV is not same for in-the-money (ITM), out-of-the-money (OTM) and at-the-money (ATM) options. For instance, a call option that is an ITM option have higher implied volatility than a call option, which is either ATM or OTM. Therefore, the higher IV of an ITM call option causes it to be more expensive than OTM and ATM call options. In addition, the findings of Goyal and Saretto (2009) are also consistent with those of Stein (1989) and Poteshman (2001), who find that investors usually overreact in the options market, especially during the remarkably large changes in the volatility of the underlying asset.

Furthermore, the findings of Goyal and Saretto (2009) are also supported by the findings of Do et al. (2015). They examine the profitability of volatility spread trading on ASX equity options between 2000 and 2012. As with Goyal and Saretto (2009), Do et al. (2015) state that the profitability of volatility spread trading demonstrates the mispricing of options. Do et al. (2015) use long and short straddles to implement volatility spread trading strategy on the ASX. A trading strategy (long straddle) that enters long positions in ATM call and put options when the volatility spread is remarkably positive generates significant abnormal returns. In addition, a trading strategy (short straddle) that takes short positions in options when the volatility spread is negative produces significant abnormal returns. According to the results of Do et al. (2015), the profitability of volatility spread trading strategy (executed with long and short straddles) imply that straddle can be a very lucrative strategy in theory. However, it is not the same in practice, because transaction costs exist. Particularly with options, transaction costs, such as bid-ask spreads and initial margin requirements dampen the returns.

Motivated by the findings of previous studies (Goyal & Saretto 2009; Murray 2013; Do et al. 2015), this study focuses on authenticity of straddle returns by taking into calculations the cost of bid-ask spreads and the impact of initial margin requirements on short positions in options. Previous studies indicate that wide bid-ask spreads have a significant downward effect to the returns of volatility spread trading. Moreover, the profitability of trading short positions in options appears to be overstated over 50% due to the initial margin requirements, which a short option trader must take into consideration. On the other hand, if the trader can effectively trade within the quoted spreads and time trades accurately, the returns of volatility spread trading strategy remains statistically significant and way above the average market returns. This study uses a same methodology as Murray (2013) and Do et al. (2015) calculating the impact of initial margin requirements on QQQ.

1.2. Structure of the thesis and hypotheses

The study has seven different sections, which are introduction, options, earlier literature, portfolio indicators and measurements, data description and methodology, empirical results and conclusions. The next section, options, concentrates on the basic terms and theories behind of the options, which are necessary for understanding complex and sometimes extremely challenging option strategies. The third section focuses on previous studies of implied volatility and volatility spread trading. The fourth section deals with crucial indicators for a risk management of the options and also measurements of the portfolio performance. The fifth section concentrates on the mathematical models and the data used in this study. The sixth section presents the returns of volatility spread trading, which is examined by using long and short straddle strategies based on the divergence between historical and implied volatilities. The straddle strategies are implemented in a continuously effective way, where new call and put options are either bought or written at the same time when the old bought or written call and put options expire. Additionally, there is examined how volatility spread trading strategy survive in real-world circumstances in the sixth section. Volatility spread trading strategy and real-world settings are explained in the 5th section. The last section concludes the results, discusses the implications of the findings as well as the shortcomings of the study.

Most of the studies on the subject have been examined on options of the biggest stock indices and major currency options, but this study concentrates on the profitability of volatility spread trading on Invesco QQQ Trust Series 1 ETF, which tracks the non-financial stocks listed on Nasdaq 100 index. According to Jiang et al. (2011), National Association of Securities Dealers Automated Quotations (Nasdaq) is much more volatile than New York Stock Exchange (NYSE). Furthermore, transaction costs measured by quoted and effective spreads are significantly higher on Nasdaq than on NYSE. These kinds of results raise the interests of an option-based strategy, which trades the volatility spread on QQQ.

All hypotheses of this study are based on earlier literature made of volatility spread trading strategy and option returns in real-world circumstances. According to the results of Goyal and Saretto (2009), the volatility spread is a signal of options mispricing. This is because a trading strategy, which effectively combines long and short straddles based on the volatility can generate very lucrative returns. It appears that trading strategy entering long positions in at-the-money (ATM) call and put options with a positive volatility spread and short positions in ATM call and put options with a negative volatility spread generates statistically and economically significant returns. In addition, the findings of Goyal and Saretto (2009) are supported by numbers of other studies (Chen & Leung 2003; Do et al. 2015; McGee & McGroarty 2017). Therefore, the first and the second hypotheses are the following:

H1: *The difference between historical volatility (HV) and implied volatility (IV) derived from ATM call and put options is a signal that options are mispriced.*

H2: *Volatility spread trading strategy, which goes long positions in options (long straddle) with a positive volatility spread (HV>IV) and enters short position in options (short straddle) with a negative volatility spread (HV<IV), generates economically significant returns.*

The third hypothesis is about the comparison of the profitability of volatility spread trading in theory and in real-world circumstances. Murray (2013) and Do et al. (2015) discover the benefits of volatility spread trading strategy is significantly overstated, when transaction costs are not taken into consideration. Do et al. (2015) implements the impact of transaction costs along similar lines as Murray (2013), whereby initial margin requirements are calculated for short positions in options. Moreover, Do et al. (2015) find that bid-ask spreads lower the returns significantly and the profitability of volatility spread trading strategy in real-world circumstances seems to depend on a trader's ability to time trades effectively and accurately within quoted spreads. Similarly, Goyal and Saretto (2009) represent that the returns of volatility spread trading are decreased when transaction costs are included. However, the results of Goyal and Saretto and Do et al. (2015) support the fact that liquidity considerations reduce, but do not eliminate the economically significant profits. Based on previous studies, the third hypothesis is the following:

H3: *Profitability of volatility spread trading strategy is dampened when bid-ask spreads and initial margin requirements are embedded into calculations.*

2. OPTIONS

This part of the study concentrates on the basics of options, as well as pricing of the options with the most famous options' pricing model, the Black-Scholes model. There are introduced the basic terms and theories of the options, and the put-call parity in this section. Furthermore, the forthcoming section includes the concepts of volatilities, with the primary concentration on implied volatility. It is necessary to know the basic terms, the nature of volatility and the Black-Scholes model, in order to understand option strategies and how options operate as the part of a portfolio. However, the complete mathematical derivation of the Black-Scholes model is not introduced in this study, since it is not the main focus. Last, long and short straddles are represented at the end of this section.

2.1. Introduction to the world of options

An option contract is an agreement between the owner of the contract, hence forward a buyer, and the writer of the option, also called a seller. There are two types of options in the option market. Call option gives the buyer the right, but not the obligation, to buy an underlying asset at the strike price within some prespecified time. Put option gives the buyer the right, but not the obligation, to sell an underlying asset at the strike price within some prespecified time. Strike price (sometimes called exercise price) is the prespecified price, which both the buyer and the writer have been accepted. (Dubofsky 1992: 11-14.)

There are four types of participants in options markets:

1. Buyers of calls
2. Sellers of calls
3. Buyers of puts
4. Sellers of puts

Buyers of options are having long positions and sellers of options are having short positions. The writer of an option will receive the commission of selling option, but writers also have further liabilities of writing the option. (Hull 2015: 10-11.) As figure 2 illustrates, the buyer of a call option believes that the underlying asset price goes up, whereas the seller wants that the stock price stays at the same level or decreases. In figure

2, the strike price of a call option is 40 and the cost of an option is 10 for the buyer of the option. The writer of a call option receives a premium of 10 from the buyer. As the price of the underlying goes over 50, the payoff is positive for the buyer and negative for the seller. On the other hand, if the price is decreasing below 40, then the option is not exercised. Thus, the buyer gets nothing with a downside of 10, whereas the seller gets the premium of writing the call option. Figure 2 is imaginary, but a realistic demonstration of the payoff diagram of a call option.

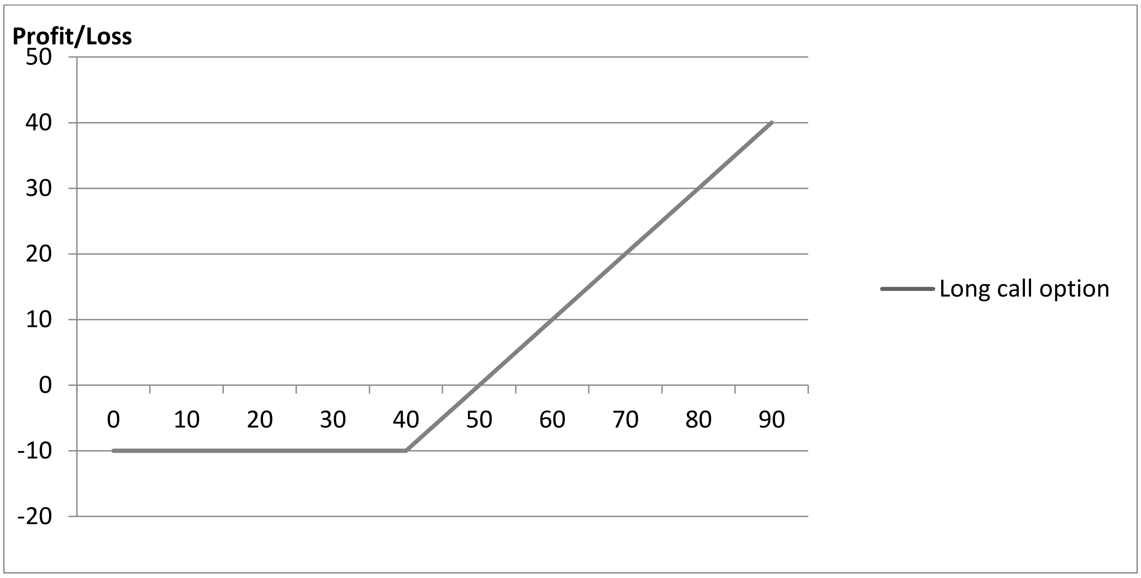

Figure 2. A long position in a call option

There are existing two main types of options on option markets that are American and European options. American option gives the buyer the right, but not the obligation, to exercise the option contract whenever they want to between the purchase and expiration date. In turn, the European option gives the buyer the right, but not the obligation, to exercise the option contract in an expiration date. European and American options have nothing to do with geographic location. (Corb 2012: 465.)

In the modern theory of options, there are three kinds of options depending on the relationship between the underlying asset price and the strike price on option's expiration date. For example, if the call option is in-the-money it means that the underlying asset price is above the strike price. Conversely, when the put option is in-the-money it means that the underlying asset price is below the strike price. In-the-money options are also known as the ITM hence forward. On the other hand, if the call option is out-of-the-money it means that the strike price is above the current price of underlying asset. In turn, if the put option is out-of-the-money it means that the strike price is below the current price of the underlying asset. From now on, the out-of-the-money option is abbreviated to OTM. Sometimes a call option can be called as a deep in-the-money option, if the underlying asset price is significantly greater than the strike price. It is also the same for put options, but naturally the other way around. (Corb 2012: 467) There are also at-the-money (ATM) options, where the underlying asset price equal to the price of the strike price (Hull 2015: 819).

There are a lot of different options in the markets nowadays, such as stock options, index options, currency options and also plenty of some other options too. One of the most common and the most widely used option is a stock option, where the underlying asset is a stock. (Hull 2015: 213.) Sometimes a stock option can be given to the executives of the firm that can be also known as executive stock options, which have become increasingly common in executives' compensation packages (Bauxauli-Soler and others 2015). Bauxauli-Soler and others (2015) study how executive stock options granted to the top management team and gender affect to the willingness of executives to take the risk. Another very common option is the stock index option, which began trading in United States on March 11, 1983. First, there were only CBOE 100 index options, later on S&P 100, which can be traded in Chicago Board Options Exchange. (Dubofsky 1992: 238.) Nowadays there are many different stock index options in the US markets, such as the Dow Jones Industrial Index (DJX), the Nasdaq-100 Index (NDX), the S&P 500 Index (SPX), and also the S&P 100 Index (OEX). Three letters in parentheses form the ticker symbol, which is structured to represent the underlying stock index ticker.

Most of the contracts are European in the US markets. (Hull 2015: 218.) Other important market places where options can be traded are: Eurex, Chicago Mercantile Exchange (CME), Korea Exchange (KRX) and NYSE Liffe, which was before London International Financial Futures and Options Exchange (LIFFE). In addition, most of the options contracts are nowadays made in over-the-counter market, OTC market, which means market where the traders are mostly corporates, hedge funds, banks and other financial institutions. Sometimes OTC trading is called as an off-exchange trading, because traders are directly negotiating with counterparties, not via an exchange. (Corb 2012: 2.)

2.2. Valuation of the options

This part of the study focuses on the pricing options as well as determining the total value of options. Put-call parity formula is for the European options and it is a simple way to derive the price of a European put option from the price of a European call option. There is also represented the famous Black-Scholes model, which is used to determine implied volatility in this study. However, it is good to remember that there are several other models existing to valuate options, not just the Black-Scholes formula. There will be some criticism and comments about the Black-Scholes model and assumptions of the model from the researchers who are highly esteemed.

2.2.1. The price and the value of an option

The same factors have an impact to a call option and a put option, but in different ways (Cox and Rubinstein 1985: 33). There are six factors affecting the price of a stock option:

1. The current stock price, S_0
2. The strike price, K
3. The time to expiration, T
4. The volatility of the stock price, σ
5. The risk-free interest rate, r
6. The dividends that are expected to be paid.

In the next two paragraphs there is an assumption that the only one of the six factors is changing, while all the other factors are constant. The current stock price is determined by the last amount that was paid by an investor during a trade. The strike price, also known as the exercise price, is the price at which a specific option contract can be exercised. Strike price is the most important determinant of the option value. Time to expiration tells how much there is time left until the expiration date. Both American call and American put options become less valuable as the time to expiration decreases. Furthermore, when the time to expiration increases, then both options become more valuable or at least do not decrease the value. (Hull 2015: 234-235.)

Volatility is a statistical measure of the dispersion of returns of the given security or the market index. In other words, volatility refers to the amount of uncertainty or risk about the size of changes in a security’s (option’s) value. Generally, if the volatility of the underlying asset increases, then the price of an option increases too. Usually, more volatility means more risk. Implied volatility and the concept of volatility have been introduced more specifically in the following chapters. The risk-free interest rate is the rate of interest that can be earned without risk. As the interest rate in economy increases, the expected return required by investors from the stock tends to increase too. At the same time the present value of any future cash flow received by the holder of an option decreases. As a rule of thumb, the value of call options is increasing when the interest rate is increasing. The value of put options is decreasing while the interest rate in economy is increasing. As a reminder, if the other factors are variable, that is assumed they are not, the situation could be totally different. Dividends that are expected to be paid means that on the ex-dividend date the price of the stock reduces. In other words, this means that the value of call options decrease and the value of put options increase. (Hull 2015: 234-238.)

Option has both intrinsic value and time value, which means that the total value of the option consists of the sum of its intrinsic value and its time value. Intrinsic value can be determined as a value that option has if it is carried out (exercised) today. This value can never be negative, because option is a right for the buyer. For a call option, intrinsic value is the greater of the excess of the asset price over the strike price and zero. For a put option, intrinsic value is greater of the excess of the strike price over the asset price and zero. Consequently, if the asset price is bigger than the strike price, the call option is ITM. On the other hand, if the strike price is bigger than the asset price, the put option is ITM. There is also a time value in the total value of an option, which is the value between the total value and intrinsic value. (Hull 2015: 220)

Figure 3. Intrinsic value and time value of a call option

The total value of an option can be also known as the premium of the option. *(Time Value = Premium – Intrinsic value)* As figure 3 illustrates, the intrinsic value and the time value construct the total value of an option. As the maturity is longer and the underlying asset's volatility is higher, the time value will be greater. In other words, there are bigger chances when the underlying asset's price is greater than the strike price as the maturity is longer. Moreover, the higher volatility increases the chances that the underlying asset's price is far above or below the strike price.

2.2.2. Put-Call Parity

The put-call parity is a formula, where the price of European put options can be derived from the price of European call option. There are two different kind of portfolios in the put-call parity. The portfolio A consists of European call option and zero-coupon bond, which provides a payoff at expiration date. The portfolio B consists of European put option and one share of the stock. There are few of assumptions in the put-call parity. First, stock pays no dividends. Secondly, call and put options have the same strike price and same time to maturity. Below is the formula for put-call parity, where c is a call option, Ke^{-rT} is the zero-coupon bond, p is a put option and S_0 is one share of the underlying asset. (Hull 2015: 241-242.)

(1) $$c + Ke^{-rT} = p + S_0$$

In an efficient capital markets put-call parity is based on simple logic, where the portfolio A consisting of a call option and a zero-coupon bond and the portfolio B including a put option and the underlying asset should have the same cash flow. The put-call parity is a relationship that must exist between the prices of European put and call options, which both have same underlying asset, strike price and expiration date or otherwise there will be a chance for an arbitrage. (Nissim & Tchahi 2011.)

2.2.3. The Black-Scholes model

The most famous options' pricing model is the Black-Scholes model, which has had a tremendous impact to the modern finance and especially on the way that traders and investors price options, and more commonly derivatives. The Black-Scholes model is based on a simple logic, where it should not be possible to make one hundred percent sure profits by combining short and long positions in options and their underlying stocks in a portfolio, if options are correctly priced in the market. The Black-Scholes model can be also known as the Black-Scholes-Merton model. (Black & Scholes 1973.) Robert C. Merton and Myron S. Scholes have received the Nobel Prize in economics in 1997 from the Black-Scholes-Merton formula (Jarrow 1999).

Black and Scholes (1973) make some assumptions about the six factors, which are affecting to the value of an option. Black and Scholes (1973) describe these added assumptions as an “ideal condition” in the market for the options and more generally for the stocks. Black and Scholes (1973) derive their formula under the following assumptions:

1. The short-term interest rate is known and is constant through time.
2. The stock price follows a random walk in continuous time with a variance rate proportional to the square of the stock price. Thus, the distribution of possible stock price at the end of any finite interval is log-normal. The variance rate of the return on the stock is constant.
3. The stock pays no dividends or other distributions.
4. The option is “European,” that is, it can be only exercised at maturity.
5. There are no transaction costs in buying or selling the stock or the option.
6. It is possible to borrow any fraction of the price of a security to buy it or to hold it, at the short-term interest rate.
7. There are no penalties to short selling. A seller who does not own a security will simply accept the price of the security from a buyer, and will agree to settle with buyer on some future date by paying him an amount equal to the price of the security on that that date.

Black and Scholes (1973) also prove that the under these assumptions the price of an option is only depending on the price of an option, time, and variables, which are known to be constants. The formulas of the Black-Scholes model for European call and put options are the following: (Hull 2015: 335-336.)

(2) $$c = S_0N(d_1) – Ke^{-rT}N(d_2)$$

(3) $$p = Ke^{-rT}N(-d_2) – S_0N(-d_1)$$

where

(4) $$d1 = \frac{\ln(S/K)+(r+\sigma 2/2)T}{\sigma T\text{^}1/2}$$

(5) $$d2 = \frac{\ln(S/K)+(r-\sigma 2/2)T}{\sigma T\text{^}1/2}$$

d2 can be also expressed as $d1 - \sigma T\text{^}1/2$

The price of a call option is c and p is the price of a put option. $N(d_1)$ and $N(d_2)$ are representing the value of the normal cumulative distribution at the value of d. In other words, $N(d_2)$ should present the probability of exercising a call option in the risk-neutral world. $N(d_1)$ is harder to interpreted, but the term $S_0N(d_1)e^{rT}$ is the expected stock price in the risk-neutral world at time T, which is the time to maturity of the option. The stock price reflects the letter S_0 at time zero, K is the strike price of an option, r is the annualized risk-free interest rate, and σ is the volatility of the stock price. (Hull 2015: 336.)

The Black-Scholes model is very remarkable and famous due to the findings of Black and Scholes (1973) make. The most unique finding is the independence of option's value from the expected return of the underlying asset and the risk premium. Although, the expected return of the option is dependent on expected proceeds of the underlying asset. (Black & Scholes 1973.) Jarrow (1999) name the most important idea of the Black-Scholes model is the possibility to build riskless portfolio in a short period of time.

The Black-Scholes model has also received plenty of criticism from its assumptions, because some of its assumptions are extremely strict. Jarrow (1999) criticize formula about two main assumptions. The first fundamental assumption is that the risk-free interest rate is constant in the market and the second fundamental assumption is relating to the volatility. According to assumptions of the Black-Scholes model, volatility it is known all the time and it is a constant. Jarrow (1999) states that the assumptions of the Black-Scholes model are too roughly simplifications of reality. Kristensen and Mele (2011) present the new developed model for options' pricing, which is based on the continuous-time model. Also, many other academic studies and researchers have used the Black-Scholes model to make new approaches to approximate asset prices, including options prices with stochastic volatility. (Kristensen & Mele 2011.)

2.3. Historical, implied and realized volatilities

In the modern theory of finance, volatility is a measure of risk, which is also known as the uncertainty of an asset. In other words, volatility demonstrates the price change of a security (or the market index), and it is sometimes referred to as the standard deviation. (Hull 2015: 431-434.) In the study of Tung and Quek (2011), they represent that the volatility is the intensity of the variation in the price of a security, which is due to market uncertainties. Therefore, trading is the capitalization of the uncertainties of the financial markets to realize investment profits in different market conditions. According to Tung and Quek (2011), volatility creates opportunities to make profit from an active trading. To sum it up, the financial markets are living of the volatility.

As mentioned before, implied volatility is derived from options and in the value of IV is embedded the market’s expectation of future price changes or more commonly the future volatility. According to Mayhew (1995), he also suggests that implied volatility is the markets’ view of prices of the options volatility. Do et al. (2015) represent in their study that the future volatility is almost impossible to forecast, because dynamics and nature of volatility are extremely challenging to understand. Many highly esteemed academic studies have confirmed that there would not be any chance to profit by trading stocks and options without volatility (Brenner et al. 2006; Goyal and Saretto 2009; Fahlenbrach and Sandås 2010; Do et al. 2015). Therefore, volatility is one of the most important things to understand in today’s finance. Fahlenbrach and Sandås (2010) suggest that option strategies and the mean-reversing nature of volatility are important topics in the practice of derivatives in today’s finance.

There are two different types of volatility spreads used in this study: the difference between historical and implied volatilities (HV-IV), and the divergence between implied and realized volatilities (IV-RV). It is necessary to distinguish between historical volatility (HV), implied volatility (IV) and realized volatility. Historical volatility is the volatility of the underlying asset in last 1, 3, 6 or 12 months, for instance. Realized volatility is the magnitude of daily price movements over a specific period. In this study, the remaining life of an option is used as an estimation period for realized volatility. Implied volatility is the estimated volatility of the underlying asset’s price, and it is the most commonly used when pricing options. It is important to remember that implied volatility is based on probability. Therefore, implied volatility is only an estimate of future prices rather than a clear indication of them. In general, implied volatility increases when markets are bearish, and decreases while the markets are bullish. This is due to the common belief that bear market conditions are riskier than bull market conditions. Concisely, implied volatility is a way of estimating the future fluctuations of an underlying asset’s worth based on certain predictive factors. (Hull 2015: 341-342.)

Traditionally, the implied volatility has been calculated by using the Black-Scholes model or the Cox-Ross-Rubinstein binomial model. Due to the strict assumptions of the Black-Scholes model, implied volatility is used as an estimator of the market of future volatility, but it is not the same as realized volatility. If the volatility of the underlying asset changes, then implied volatility is interpreted as the market forecast of average volatility of the option to the end of the validity period. In addition, implied volatility can be also utilized by pricing some exotic options, or more commonly, implied volatility can be exploited in all market areas, not only in option markets. There are also several studies that have studied implied volatility by using options on currency and commodity futures. The prices of the bond options can be used to estimate the parameters of an underlying asset term structure model. (Mayhew 1995.) Overall, historical volatility is something what has happened in the past, whereas implied volatility is forward looking estimation of future volatility (Do et al. 2015).

Dash and Moran (2005) research how the Volatility Index, hence forward VIX, correlates with the returns of hedge funds and more generally with the returns of equity markets. Dash and Moran (2005) study demonstrates how the VIX and the returns of hedge funds are negatively correlated, particularly when hedge funds returns are negative and poor. Also, many other studies show that the VIX and returns of equity market are negatively correlated (Whaley 2000; Whaley 2009).

CBOE’s VIX, is the measure of implied volatility, which has been derived from the prices of the S&P 500 index options. Despite a fact that VIX has derived from equity index options prices, it is widely used indicator for markets future volatility. Implied volatility has also achieved great appreciation among investors. Implied volatility index is calculated throughout the trading day, and it gives the real-time (minute-by-minute) snapshot of option implied volatility over the next 30 calendar days. In 2003 an amendment was made to the implied volatility, so it now includes volatility from the prices of S&P 500 index options in a wide range of strike prices. (Dash and Moran 2005.) Whaley (2000) names VIX as the “investor fear gauge.”

2.4. Option Strategies

There are nowadays existing many different kinds of option strategies in the markets. The most widely used and popular strategies are made either for a hedging or for a speculation of future volatility. In other words, speculation is speculating about the future price changes in the underlying asset. The main concentration of this section is on long and short straddles, which are used to implement volatility spread trading strategy on QQQ in this study. Straddles are speculative option strategies of future price movements in the underlying asset.

Option strategies may consist of either options or both an option and the underlying asset. With option strategies it is possible to build wide range of several profit diagrams, because there are so many ways to combine either call and put options or the underlying asset and options. There are also numbers of way to combine a written option and a bought option and also the underlying asset. The popularity of option strategies is influenced by their versatility and numerous different yield diagrams, regardless of whether the market increases or decreases. (Dubofsky 1992: 44.)

Fahlenbrach and Sandås (2010) study various option strategies on the FTSE-100 Index, and they find that directional option strategies seem to be, on average, unprofitable but volatility strategies appear to be profitable. Although, the results show that the directional option strategies seem to be unprofitable, still different kind of option strategies, including directional option strategies, are good for a hedging and especially traders who have a good sense of the future volatility. The research was performed by using the most common option strategies, such as strangles, straddles, bull and bear spreads, covered calls and protective puts.

In the study of Fahlenbrach and Sandås (2010), they present that there is a positive relationship between the use of option strategies and the bear market condition, when the volatility is surging. Furthermore, Fahlenbrach and Sandås (2010) suggest that the increased volatility creates new opportunities to buy options. Therefore, more overpriced options are existing during bearish market conditions. Also, the theory of finance suggests that when the implied volatility goes up, so does the price of an option (Dubofsky 1992: 44). Moreover, Fahlenbrach and Sandås (2010) find that implied and realized volatility are highly correlated with each other. For example, if the implied volatility increases due to impaired market sentiment, usually the realized volatility goes up as well.

2.4.1. Long and short straddles

Straddle is a speculative option strategy, which is specifically designed for bearish market conditions where share prices and market indices fluctuate substantially back and forth. On the other hand, straddle can be extremely profitable during bullish market conditions by combining long and short straddles depending on the volatility spread. (Hull 2015: 267-268.) As mentioned before, there is usually a high correlation between volatility and the bear market condition (Fahlenbrach & Sandås 2010).

Figure 4 illustrates payoff diagram of long straddle strategy, which comprises of bought call and put options with the same strike price and the expiration date. A long straddle is profitable if the underlying asset has a significant price movement. In other words, the movement needs to be more than the cost of the premiums, which is equal to the price of a call option plus the price of a put option. (Hull 2015: 267-268.) In figure 4, the underlying asset is priced at 100 dollars per share, and both call and put options are priced at 3 dollars with strike prices of 100 dollars. Long straddle will profit at expiration, if the underlying asset is priced above 106 dollars or below 94 dollars. For instance, if the underlying asset moves to 120 dollars, long straddle profits 14 dollars per share. Since each option represents 100 shares, the profit of long straddle is 1 400 dollars. To sum it all up, the long straddle has an unlimited profit and a limited risk to the amount of premiums.

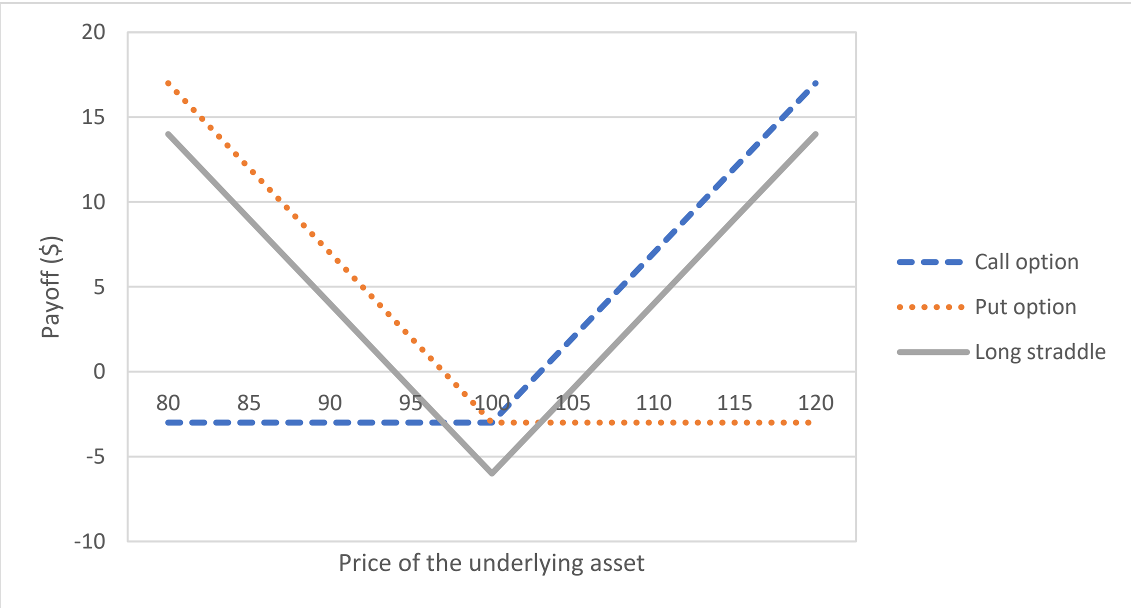

Figure 4. Payoff of long straddle with the strike price of 100 USD.

A short straddle strategy is the opposite to a long straddle strategy. Figure 5 presents payoff diagram of short straddle strategy, which is an option strategy comprised of selling both call and put options with the same strike price and expiration date. Short straddle is used during, when the volatility of the underlying asset is assumed be stable and the price of the underlying asset will not move significantly lower or higher over the lives of the option contracts. In a comparison to long straddle strategy, the upside potential for short straddle is limited to the amount of collected premiums by writing the call and put options. The potential loss can be unlimited, which makes it a riskier strategy. (Hull 2015: 267-268.)

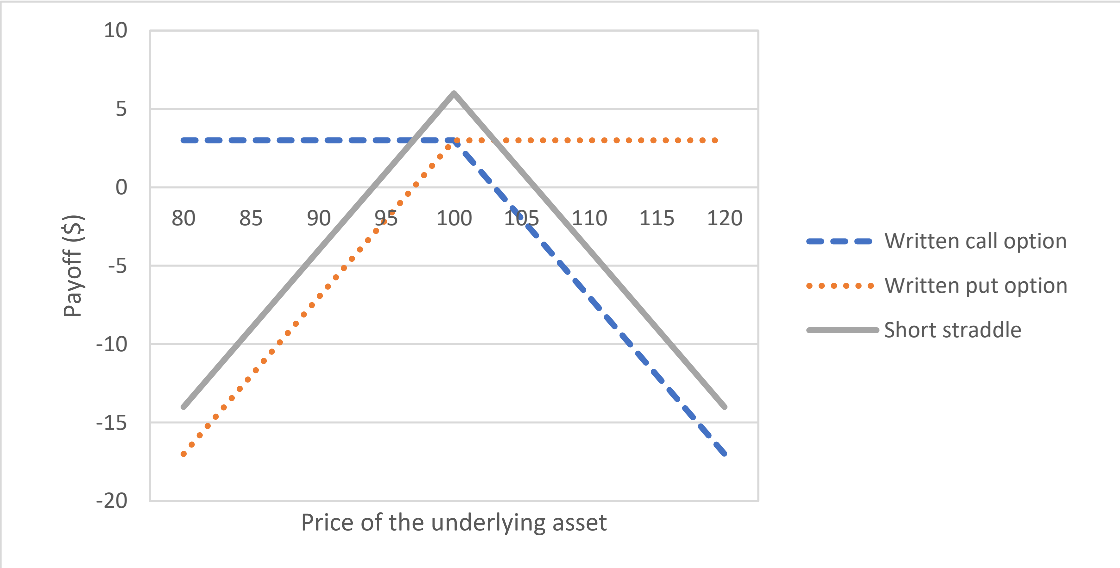

Figure 5. Payoff of short straddle with the strike price of 100 USD.

Figures 4 and 5 are imaginary, but realistic illustrations of long and short straddle strategies. A straddle is a type of option-based trading strategy that allows traders to speculate on whether a market is about to become volatile or not, without having to predict a specific price movement. A large number of previous studies of straddles have shown the profitability of long and short straddles. Particularly, effectively combining long and short straddles depending on the divergence between historical volatility and implied volatility, volatility spread, is proven to be highly profitable. As always with options, transaction costs, such as the impacts of bid-ask spreads and initial margin requirements while shorting options are significantly reducing the returns.

3. EARLIER LITERATURE

This section of the study concentrates on earlier academic literature made of volatility spread trading. Overall, the topic has been studied from somewhat different perspectives, ranging from the benefits of straddle strategies on currency future options to stock index options. This literature review focuses on a few studies that have been conducted of volatility spread trading and straddle portfolio returns to understand the topic in a greater detail. In addition, the academic literature section is divided in two different parts. The first part concentrates on the previous studies that examine the performance of volatility spread trading strategy and whether the volatility spread is a signal of option mispricing. The second part focuses on the earlier academic literature that considers the benefits of volatility spread trading strategy in real-world circumstances.

3.1. Historical performance of volatility spread trading

In the study of Chen and Leung (2003), they study the benefits of trading ATM long and short straddles using call and put options on foreign currency futures such as Canadian Dollar (CAD), Japanese Yen (JPY) and British Pound (GBP). The United States Dollar (USD) is assumed to be a domestic currency. Chen and Leung (2003) introduce two different methods for implied volatility. First, they use a direct forecasting model for implied volatility. Next, they create a conventional method. The findings of Chen and Leung (2003) suggest that the direct implied volatility forecasting model is more profitable for all currencies. Furthermore, their results present that the direct implied volatility forecasting model is economically significant for all currencies. Last, Chen and Leung (2003) take the transaction costs into consideration to illustrate the benefits of the direct implied volatility forecasting model in real-world circumstances.

Brenner et al. (2006) take a different angle of trading volatility, they study how the straddle strategy is suitable for hedging the volatility. In fact, Brenner et al. (2006) present a new derivative instrument, an option on straddle, which can be used to hedge the risk. The results of Brenner et al. (2006) suggest that the option on straddle is an appropriate way to hedge the volatility risk of the underlying asset. Furthermore, it is essential to note that the option on straddle is only sensitive to volatility. When the price of the underlying asset is significantly swinging around, then also the risk to have downside deviation increases. The findings of Brenner et al. (2006) slightly contradicts the theory that straddle strategy is only made for a speculation of future volatility. The option-based straddle strategy can be also used as a hedging strategy. However, the option on straddle is only hedging the possible volatility risk that the underlying asset may face, not the price change of the underlying asset.

In the study of Goyal and Saretto (2009), they present that volatility spread trading strategy generates economically significant returns. According to their findings, the divergence between historical and implied volatilities is a clear indication of option mispricing, and further, trading long (short) straddles when volatility spread is positive (negative) produces economically significant and high returns. The reason behind the mispricing is the volatility smile, which is the variation of implied volatilities across the strike prices. This means that IV is not same for in-the-money (ITM), out-of-the-money (OTM) and at-the-money (ATM) options. For instance, a call option that is an ITM option have higher implied volatility than a call option, which is either ATM or OTM. Therefore, the higher IV of an ITM call option causes it to be more expensive than OTM and ATM call options. In addition, the findings of Goyal and Saretto (2009) are also consistent with those of Stein (1989) and Poteshman (2001), who find that investors usually overreact in the options market, especially during the remarkably large changes in the volatility of the underlying asset.

In the study of Do et al. (2015), the estimation period starts in 2000 and lasts to 2012. They study the benefits of volatility spread trading on the ASX equity options. The outcome of Do et al. (2015) is similar to Goyal and Saretto (2009), the volatility spread appears to provide a signal of option mispricing. For example, options are overpriced when the volatility spread is negative. Oppositely, options are underpriced when the volatility spread is positive. In other words, when HV (12 months historical volatility of the underlying asset) is below IV (derived from ATM call and put options), then call and put options are underpriced. This is also in line with the theory that as IV is moving upward, then options are more likely to be overpriced.

Do et al. (2015) use long and short straddles to implement volatility spread trading strategy on the ASX. A trading strategy (long straddle) that enters long positions in ATM call and put options when the volatility spread is remarkably positive generates significant abnormal returns. In addition, a trading strategy (short straddle) that takes short positions in options when the volatility spread is negative produces significant abnormal returns. According to the results of Do et al. (2015), the profitability of volatility spread trading strategy (executed with long and short straddles) imply that straddle can be a very lucrative strategy in theory. However, it is not the same in practice, because the bid-ask spread can be large and initial margin requirements are reducing the profitability of shorted options.

Table 2. Descriptive statistics of historical, implied and realized volatilities on ASX stocks and equity options (Do et al. 2015).

	Volatility Characteristics		
	HV	IV	RV
Mean	0.3424	0.3105	0.3086
Min	0.2383	0.1954	0.1533
Max	0.5577	0.5868	0.7539
Standard Deviation	0.1088	0.1077	0.1535
Median	0.3190	0.2895	0.2757
	Volatility Correlations		
	HV	IV	RV
HV	1		
IV	0.77	1	
RV	0.61	0.76	1

Table 2 shows the sample descriptive statistics of Do et al. (2015), where is represented historical, implied and realized volatilities on the ASX stocks and equity options. Historical volatility is the volatility of the daily stock returns from the last 12 months. Implied volatility (IV) is the average implied volatility from the matched pairs of call and put options. Realized volatility (RV) is the annualized realized volatility of daily stock returns over the remaining life of the option. As table 2 points out, RV has the highest standard deviation of 0.15 and the widest range of above-mentioned volatilities. On the other hand, RV has the lowest mean. However, the results of Do et al. (2015) are in line with previous studies and the conception that IV is the smoothed expectation of RV. All three volatilities are correlated with each other, especially implied volatility is highly correlated with historical and realized volatilities. (Do et al. 2015.)

Table 3. Performances of volatility spread trading strategy on the U.S. equity options and on the ASX equity options (Goyal and Saretto 2009; Do et al. 2015).

	U.S. equity options (10-1)	ASX equity options (3-1)
Mean returns	0.227	0.157
Standard Deviation	0.251	0.438
Minimum returns	-0.271	-1.501
Maximum returns	1.492	1.389

Table 3 represents the results of Goyal and Saretto (2009) and Do et al. (2015) studies of performances of volatility spread trading on the U.S. and on the ASX equity options. All the results are monthly bases in each study. The examination periods for Goyal and Saretto (2009) is from January 1996 to December 2006, whereas Do et al. (2015) have chosen examination period from January 2000 to December 2012. The average monthly returns for the U.S. equity options is 0.227 (22.7%) and for the ASX equity options 0.157 (15.7%). Volatility spread trading strategy appears to be more profitable on the U.S. equity options than on the ASX equity options. Furthermore, the standard deviation is significantly lower on the U.S. equity options (25.1%) than on the ASX equity options (43.8%). Therefore, the results of these two studies suggest that volatility spread trading strategy on the U.S. equity options outperforms volatility spread trading on the ASX equity options. Additionally, volatility spread trading outperforms the underlying assets, producing extraordinary returns in both studies. However, these are the results before transaction costs have included into calculations.

In the study of Kapadia and Szado (2012) the examination period starts in 1996 and lasts to 2011. The main focus of the study is on the performance of covered call strategy on Russell 2000 index and the reasons behind the returns of the strategy. According to findings of Kapadia and Szado (2012), profitability and great performance on a risk-adjusted basis of covered call strategy is due the volatility spread and benefits of writing call options. It should be noted that Kapadia and Szado (2012) has a different volatility spread, where realized volatility is subtracted from implied volatility. Naturally, the results of Kapadia and Szado (2012) would be different, if the volatility spread of historical volatility and implied volatility had used instead of IV-RV.

Table 4. Volatility spreads of Russell 2000 index call options (Kapadia & Szado 2012).

	Volatility spread	
	1 Month	2 Month
5% OTM	0.014	0.015
2% OTM	0.025	0.024
ATM	0.034	0.034
2% ITM	0.046	0.043
5% ITM	0.064	0.056

Table 4 reports volatility spreads of Russell 2000 index call options with different level of moneyness and option's time to maturity. The results of Kapadia and Szado (2012) propose that options with one month's time to maturity, the time value decays at a faster rate than it does for the options with two months' time to maturity. Furthermore, the volatility appears to be larger for ITM options than for OTM options. Naturally, the volatility spread for ATM options lies between ITM and OTM options. Kapadia and Szado (2012) also present that the volatility spread is positive for Russell 2000 index options with all level of moneyness and option's time to maturity. In other words, IV is larger than RV almost all the time, and further, the mean of IV is above the mean of RV. On the other hand, Kapadia and Szado (2012) point out that RV has a higher standard deviation than IV, which is in line with the findings of Goyal and Saretto (2009) and Do et al. (2015). Furthermore, the results of Hill et al. (2006) support the fact that IV is a smoothed expectation of RV. Hill et al. (2006), and Kapadia and Szado (2012) argue that only during the highest volatility periods, RV is higher than IV. The results suggest that investors are benefitting of writing options when IV (derived from options) is above RV. Therefore, the covered call strategy is outperforming its underlying index in raw returns, and also in risk-adjusted returns.

3.2. Profitability of volatility spread trading strategy in real-world circumstances

Goyal and Saretto (2009) consider the impact of bid-ask spreads to the profitability of volatility spread trading strategy and delta-hedged call returns. There are two types of portfolios examined in their study, which are 10-1 and P-N. First, the 10-1 portfolio is formed by taking a long position in the options in decile 10 and by writing the options in decile one. Moreover, the P-N portfolio is formed by taking a long position in the options with positive volatility spread (P) and by writing the options with negative volatility spread (N). Their findings are intriguing: trading costs reduce the profitability of volatility spread trading strategy, but do not completely eliminate the profits. In addition, Goyal and Saretto (2009) discover that the profitability of option portfolios is higher for less liquid options. The results of Goyal and Saretto (2009) are represented in table 5, which demonstrates the impact of liquidity and transaction costs (bid-ask spreads) to the returns of above-mentioned option portfolios.

Table 5. Straddle and delta-hedged call returns of 10-1 and P-N portfolios after the impact of bid-ask spreads.

	10-1			**P-N**		
	MidP	50%	100%	MidP	50%	100%
	Panel A: Straddle returns					
All	0.227 (10.41)	0.126 (5.98)	0.039 (1.84)	0.138 (8.42)	0.040 (2.48)	-0.045 (-2.73)
	Based on average bid-ask spread of options					
Low	0.195 (7.27)	0.130 (4.99)	0.082 (3.17)	0.144 (6.55)	0.084 (3.92)	0.038 (1.76)
High	0.239 (8.95)	0.115 (4.51)	0.014 (0.56)	0.140 (6.19)	0.022 (0.99)	-0.078 (-3.27)
	Panel B: Delta-hedged call returns					
All	0.027 (9.33)	0.010 (3.49)	0.005 (1.82)	0.018 (7.77)	0.002 (0.82)	-0.002 (-1.11)
	Based on average bid-ask spread of options					
Low	0.024 (6.51)	0.013 (3.61)	0.010 (2.88)	0.018 (5.47)	0.008 (2.45)	0.006 (1.70)
High	0.028 (9.30)	0.007 (2.46)	0.001 (0.52)	0.019 (6.91)	-0.001 (-0.23)	-0.006 (-2.19)

Table 5 reports the average returns and t-statistics (in parentheses) of the continuous time-series of monthly returns. The sample of Goyal and Saretto (2009) is consisting of 4,344 stocks and is composed of 75,627 monthly matched pairs of ATM call and put option contracts. MidP is the mid-point price, which is the midpoint opening price for each option. Goyal and Saretto (2009) have calculated two effective spread measures equal to 50% and 100% of the quoted spread. Panel A represents the returns of straddle returns after taking the costs of bid-ask spreads into account, whereas Panel B reports the returns of delta-hedged calls. In the study of Goyal and Saretto (2009), options are divided into two categories: liquid options (Low) and less liquid options (High).

The common trend in Panel A is that straddle returns are reducing when the bid-ask spread is large for both the 10-1 and the P-N portfolios. For example, the 10-1 portfolio returns decreases substantially from the average monthly return of 22.7% to the average monthly return of 3.9%, when trading options at an effective spread equal to the quoted spread. Furthermore, returns are dampened over 10% from the mid-point price when the 50% effective spread equal to the quoted spread. Although, the average mid-point price returns stays statistically more significant than 50% and 100% returns. Based on the average bid-ask spread of options, less liquid options (high) appear to more profitable than liquid options (low) at mid-point prices. On the other hand, liquid options maintain returns better than illiquid options. For instance, liquid options yield 19.5% at MidP and 8.2% at 100%, whereas less liquid options profit 23.9% at MidP and only 1.4% as effective spread equals the quoted spread. For the P-N portfolio, liquid options are more profitable than less liquid options all the time after embedding the costs of bid-ask spreads into calculations.

The results of Panel B support the findings of Panel A, but the magnitude of returns are substantially lower. Similarly to Panel A, Panel B shows that delta-hedged call returns are naturally reduced when effective spreads are closer or equal to quoted spreads. In addition, the statistical significance appears to increase as the return surges. For example, the 10-1 portfolio yields 2.7% with t-statistics of 9.33 at MidP, and 0.5% with t-statistics of 1.82 at 100% effective spread equal to the quoted spread. Based on the average bid-ask spread of options, Panel B follows the results of Panel A. Less liquid options are more profitable than liquid options at mid-point prices, but it changes other way around as the effective spread comes closer or equal to the quoted spread. For instance, the 10-1 portfolio generates the returns of 2.4% at MidP for liquid options and 2.8% at MidP for less liquid options. Moreover, if the effective bid-ask spreads equals quoted spreads, the returns are still significant and positive at 1% for liquid options and insignificant at 0.1% for less liquid options. The P-N portfolio produces sometimes negative returns with 50% and 100% effective spread of the quoted spread with little or without statistical significance.

Murray's (2013) studies the impact of initial margin requirements to the returns of short option positions on S&P 500 and Nasdaq 100 index options. The examination period for the study is from February 1996 to October 2010. According to findings of Murray

(2013), the returns of option strategies are dampened as margin requirements are taken into consideration. Returns of short option positions and strategies (such as short straddle) are dramatically overstated. Therefore, Murray (2013) suggests that option payoffs should be scaled by the initial margin requirements to give a more realistic representation of the returns of short option positions.

Table 6. Distribution of S&P 500 and Nasdaq 100 index option returns (Murray 2013).

Position	Index	Return	Mean	Reduction	Min	Max
Short call	S&P	Price	1.32		-367	100
	Nasdaq	Price	-12.88		-615	100
	S&P	Margin	0.28	78.7	-83	27
	Nasdaq	Margin	-2.78	78.5	-125	28
Short put	S&P	Price	18.83		-639	100
	Nasdaq	Price	20.93		-630	100
	S&P	Margin	3.20	83.0	-106	21
	Nasdaq	Margin	3.73	82.2	-108	24
Short straddle	S&P	Price	10.33		-274	99
	Nasdaq	Price	4.64		-290	99
	S&P	Margin	4.03	61.0	-107	41
	Nasdaq	Margin	1.88	59.5	-110	43

Table 6 represents the distribution of short one-month ATM call and put options, and ATM straddle price and margin-based excess returns during the examination period. All values are in percent and all positions are only including ATM options. Out of the results reported in table 6, the impact of initial margin requirements appear to be bigger for short OTM call and put options, and short OTM straddles than for short ATM options and short ATM straddles. According to table 6, the profitability of writing call and put options is reduced over 50% for short straddles. Furthermore, the drop is even bigger for a single short call and put option. The returns of short straddles on Nasdaq are particularly interesting, since the forthcoming study examine the short straddles on QQQ, which tracks Nasdaq 100 index. After considering the impact of initial margin requirements the reductions in returns are 59.5% for Nasdaq and 61% for S&P 500. It should be noted, that short straddle returns are remarkably lower for Nasdaq than for S&P 500. Additionally, margin-based returns seem to have a bigger impact on the profitability of written put options than written call options.

In the study of Do et al. (2015), they divide the transaction costs in two parts; bid-ask spreads, and initial margin requirements. The focus of the study is on the verisimilitude of volatility spread trading strategy's returns. Furthermore, Do et al. (2015) study the magnitude that volatility spread trading returns are likely to be mitigated, or even negative, in real-world circumstances. According to Do et al. (2015), bid-ask spreads are relevant in volatility spread trading in at least two ways. First, bid-ask spreads are reducing the returns due to the fact that bid and ask prices are not necessarily the same price. There are existing some costs from bid-ask spreads even for the most liquid and traded assets. Secondly, bid-ask spreads may influence on the volatility spread, because IV is taken from the prices of call and put options that are between the bid price and the ask price. Therefore, implied volatility from a bid appears too low, and conversely, implied volatility from an ask appears too high. Furthermore, wide bid-ask spreads are not giving an accurate estimate of implied volatility, and hence a correct estimate of option mispricing.

Table 7. Characteristics of option bid-ask spreads (PES and PQS) on the ASX equity options (Do et al. 2015).

	Mean	Std. Dev	Min	25th	Median	75th	Max
PES	8.47	8.21	0.00	3.11	5.80	10.53	37.84
(IV)	9.13	8.59	0.00	3.39	6.45	11.76	40.00
PQS	26.98	18.60	5.89	13.59	21.74	34.29	86.96
(open)	31.63	22.38	7.17	16.25	25.49	38.60	105.88
PQS	24.12	18.33	3.03	10.91	18.92	31.40	80.00
(close)	28.54	22.28	4.44	13.20	22.22	35.75	105.88

Table 7 represents the distribution of option bid-ask spreads. Do et al. (2015) consider two types of transaction cost metrics in their estimation that are the percentage quoted spread (PQS) and the percentage effective spread (PES). The methodologies of these two transaction cost metrics are explained in detail in section five. The estimates of put options are below the estimates of call options. The results of table 7 suggest that there is not a significant difference to the magnitude of bid-ask spread whether to trade call and put options at open on trading day or at close on trading day. However, means of call and put options are slightly higher for PQS at open than PQS at close. Standard deviations are almost the same for both call and put options at open on trading day and at close on trading day. Furthermore, at the time IV is estimated and the mispricing signal is calculated, the average effective spreads are on call options 8.47% and on put options 9.13%.

The conclusive and comprehensive results of Do et al. (2015) are reported in table 8, which represents the returns of volatility spread trading strategy in real-world circumstances. The returns are all monthly and either price-based or margin-based returns. Further, bid-ask spread analysis are divided in three different panels. Panel A represents the performance of volatility spread trading strategy when the first option trade on the day is taken. There are demonstrated the hypothetical effective spreads ranging from 100% of the quoted spreads to the bid-ask midpoint in Panel B. Finally, Panel C represents the returns, when the PQS are enough narrow relative to the history of bid-ask spreads.

Table 8. Price-based and margin-based returns of volatility spread trading strategy on the ASX equity options (Do et al. 2015).

	Priced-based returns	**Margin-based returns**
Panel A: Profitability based on bid-ask quotes at time of first trade		
Mean	0.0449 (1.41)	0.0218 (1.65*)
Panel B: Scenario analysis using hypothetical effective spreads		
100%	0.0449 (1.41)	0.0218 (1.65*)
75%	0.0684 (2.14**)	0.0302 (2.26**)
50%	0.0920 (2.87***)	0.0389 (2.88***)
25%	0.1154 (3.58***)	0.0478 (3.51***)
Midpoint	0.1391 (4.30***)	0.0569 (4.14***)
Panel C: Only trade when PQS are sufficiently narrow		
< 50^{th} prctile	0.0455 (1.72*)	0.0078 (0.64)
< 25^{th} prctile	0.0802 (3.07***)	0.0214 (1.73*)
< 10^{th} prctile	0.1024 (3.83***)	0.0290 (2.33**)

According to the results of Do et al. (2015), the benefits of volatility spread trading strategy are substantially decreased as the transaction costs are embedded into calculations. For example, when the impact of bid-ask spreads is considered, volatility spread trading strategy yields a monthly return of 4.49% without any statistically significance. In addition, initial margin requirements (margin-based returns) dampen the returns more, yielding 2.18% a month with a low statistical significance of 1.65. In a comparison to the profitability of volatility spread trading without bid-ask spreads and initial margin requirements, the returns are dramatically dropped from 15.7% to 2.18%. However, the further results show the results of timing the trade smartly. There is a common trend in the returns of panel B, the returns of volatility spread trading are increasing and becoming statistically more significant when the effective spread narrows. For instance, if an option trader can trade within the effective spread of 50% of the quoted spread, strategy produces a statistically significant monthly return of 9.20% (2.87***).

Panel C represents the profitability of volatility spread trading for sufficiently narrow spreads. For an example, if the volatility spread trading strategy is only executed when the PQS are within the best 25th percentile, this more patient strategy would generate statistically significant (3.07***) monthly return of 8.02%. On the other hand, if initial margin requirements are included into the test results, returns are dampened to modest 2.14% with a low statistical significance. The study of Do et al. (2015) follows the method of Murray (2013) to calculate margin-based returns, that is, the impact of initial margins to the profitability of option trading. All margin-based returns are naturally lower than price-based returns due to the margin required to cover probable losses of short positions on options. The results of Do et al. (2015) are similar to the results of Murray (2013): incorporating initial margins into calculations the returns for short option positions are dropped from 50% to 90%.

To conclude the study of Do et al. (2015), the profitability of volatility spread is reduced as the costs of bid-ask spreads and impact of initial margin requirements are embedded into calculations. According to margin-based returns, the returns of shorting options are substantially overstated. Thus, Do et al. (2015) suggest that the profitability of volatility spread trading strategy is depending on the trader's ability to timing their trades precisely and achieve effective spreads well inside the quoted spreads.

All in all, volatility spread trading strategy provides economically significant returns with several currency, equity and index options. Furthermore, the volatility spread appears to give a signal of option mispricing, and whether to trade long or short straddles in the volatility spread trading strategy. In the real-world circumstances, the findings of previous studies recommend that benefits of volatility spread trading strategy appear to depend on the bid-ask spread and how well an option trader can achieve the effective spread within the quoted spread. On the other hand, some findings of previous studies differ from each other due to different underlying assets and methodologies that have been used to study the benefits of straddle strategy. Also, the methodologies varies when calculating implied volatility and estimating the future realized volatility. As mentioned before, the option pricing models include several assumptions that not apply in real life situations. Therefore, it is challenging or impossible to forecast future volatility exactly. (Chen and Leung 2003; Brenner et al. 2006; Goyal and Saretto 2009; Fahlenbrach and Sandås 2010; Do et al. 2015.)

4. PORTFOLIO INDICATORS AND MEASUREMENTS

This section focuses on the crucial indicators for a risk management of options and also measurements of a portfolio performance. Crucial indicators for a risk management of options are also known as Greeks. There are a lot of different types of indicators for measuring the risk of an option, but this study only concentrates on the most common indicators, which are delta, gamma, vega and theta. There are two significant portfolio performance measurements used in this study and both of those measurements are introduced further in this section.

4.1. Indicators for the option's risk management

Greeks are made for analyzing the risk of the options and they are particularly important for option traders. It is important for traders to know how the price of an option will change when the price of the underlying asset changes. (Corb 2012: 488.) Normally, the riskiness of the option is described in the partial derivatives of the Black-Scholes model. In other words, Greeks have been derived from the Black-Scholes model, and therefore the following formulas and indicators assume all the same things that the Black-Scholes model. (Ederington & Guan 2007.)

Sometimes Greeks are named as the indicators of the option sensitivities. This study is focused on the four most used Greeks amongst option traders; delta, gamma, vega and theta. However, there are also existing plenty of other indicators. Greeks can be used for an active portfolio management and create effective and/or hedged option-based trading strategies. For instance, delta-hedging is one the most used active portfolio strategies, where the risk associated with price movements in the underlying asset is reduced, or hedged away by adjusting portfolios balance buying shares or options to make the portfolio delta-neutral. All in all, it is necessary to know, especially for option traders, how the options values change as the underlying asset's price changes, and what kind of impact cause the changes in implied volatility, interest rate and time to expiration. (Corb 2012: 488.)

4.1.1. Delta

Delta is the number of units of the stock that a trader should hold for each option shorted in order to create a riskless portfolio. In other words, delta measures an option's price sensitivity relative to changes in the price of the underlying asset. Delta is also known as a hedge ratio of an option and option portfolios, and that is why it is probably the most used indicator amongst option traders for calculating the risk of an option. (Deacon & Faseruk 2000; Hull 2015: 285.) Simply explained, delta (Δ) is the change in the value of the option divided by the change in the value of the underlying asset:

(6) $$\Delta = \frac{change\ in\ option's\ value}{change\ in\ underlying\ asset's\ value}$$

Deltas for call (7) and put (8) options are following:

(7) $$\Delta = \frac{\partial c}{\partial s} = N(d1)$$

(8) $$\Delta = N(d_1) - 1$$

where ∂ = the partial derivative
$N(d_1)$ = a normal cumulative distribution at the value of d_1

For a call option the value of the delta is between the zero and one, and for a put option the value of the delta is between minus one and zero. When the delta is close to zero, it means that the small changes in the price of the underlying asset are not affecting to an option price. A portfolio with the delta of zero is said to be immune to small price changes and Deacon and Faseruk (2000) name it as a "delta-neutral" portfolio. When the delta is 1 or -1 the option's price and underlying asset's price are increasing at the same pace (Corb 2012: 489-490; Deacon & Faseruk 2000). Delta values of OTM call and put options are approaching zero as the expiration day approaches. Furthermore, delta values of ITM call and put options are getting closer to 1 and -1 as expiration day nears. According to Ederington and Guan (2007), delta is the most important risk factor of the options, and its importance rises as the "moneyness" of the option increases.

4.1.2. Gamma

Gamma measures the sensitivity of Delta in response to price changes in the underlying asset. Moreover, gamma indicates how delta changes relative to each one-point price change in the underlying asset. In other words, gamma is used to determine how stable is delta of an option. For example, if the value of gamma is increasing and way above the average, it indicates that delta could change dramatically in response to even small movements in the price of the underlying asset. Gamma is calculated as follows: (Hull 2015: 411-414.)

(9) $$\gamma = \frac{\phi(\mathrm{d1})}{S\sigma T\hat{}1/2}$$

where $$\phi(\mathrm{d1}) = \mathrm{e}^{\frac{\mathrm{d(1)}^2}{2}} * (2\pi)^{-1}/2$$

$$d1 = \frac{\ln(S/K)+(r+\sigma 2/2)T}{\sigma T\hat{}1/2}$$

In contrast to delta, gamma is higher for ATM options and lower for ITM and OTM options for both call and put options. As well as delta, the value of gamma is usually smaller when the date of expiration is further away. As expiration comes closer, the value of gamma is typically larger due to the fact that delta changes have more impact. In addition, gamma is an important metric, because it corrects convexity issues when engaging in hedging strategies. In summary, gamma and delta go hand in hand. (Hull 2015: 411-414.)

4.1.3. Vega

Vega (Λ) of an option is the change in the price of the option with respect to a change in implied volatility. Further, the value of vega represents the amount that the price of an option changes in response to a 1% change in volatility of the underlying asset. In other words, option traders measure the sensitivity of the price of an option to the change in volatility with the vega. For call (10) and put (11) options vega can be calculated as follows: (Corb 2012: 497.)

(10) $$\Lambda = \frac{\partial c}{\partial \sigma} = Sn\,(d_1)\,T^{1/2} > 0)$$

(11) $\Lambda = \frac{\partial p}{\partial \sigma} = Sn\ (d_1)\ T^{1/2} > 0)$

When the value of the underlying asset is close to the strike price, then vega tends to be largest (Corb 2012: 498). Furthermore, vega of an option is increasing as the time to option's maturity increases. It also appears that the long-term options are more sensitive to changes of implied volatility than the short-term options. Surging levels of volatility implies that the underlying asset is more likely to experience extreme values, a rise in volatility will correspondingly increase the value of an option. Conversely, a decrease in volatility will negatively affect the value of the option. The volatility can be either historical volatility or implied volatility. However, it is not indifferent which volatility is used, because implied volatility provides a more accurate result of a future volatility than historical volatility. Therefore, in a comparison between the implied volatility and historical volatility, implied volatility reduces more the chance of a distortion. (Cox & Rubinstein 1985; Deacon & Faseruk 2000.)

4.1.4. Theta

The sensitivity of the option value to changes in the time to expiration is called theta, which symbol is Θ from Greek's alphabets. In formulas 13 and 14 time is measured in years, but sometimes thetas can also be expressed per trading day. Definition for theta is the following: (Deacon & Faseruk 2000; Hull 2015: 409.)

(12) $\Theta = \frac{change\ in\ the\ value\ of\ an\ option}{change\ in\ time\ to\ maturity}$

Mathematically thetas for call (13) and put (14) options can be expressed as:

(13) $\Theta = \frac{\partial c}{\partial T} = -(\frac{S(0)N'(d1)\sigma}{(2T\hat{}1/2)}) - rKe^{-rT}N(d_2)$

(14) $\Theta = -(\frac{S(0)N'(d1)\sigma}{(2T\hat{}1/2)}) + rKe^{-rT}N(-d_2)$

Thetas for call and put options are usually negative, because the values of the options become less valuable as the time passes and everything else remains the same. If the theta is close to zero, then the underlying asset price tends to be low. For ATM call options, thetas are large and negative. (Hull 2015: 410.) However, couple of studies and researchers argue with the fact that thetas of the options are usually negative. For example, Emery et al. (2008) find that the theta of the call option is positive, and theta has positive correlation between the value of the call option and time to maturity. In addition, Feldman and Roy (2005) find that the covered call strategy is based on the short-term options, and they add that the one reason for the short maturity is theta. They also find that the closer to option's expiration day, the faster the time value of an option passes.

4.2. Measurements for analyzing the performance of portfolio

This study concentrates on two portfolio performance measurements, which are used to examine the performance of volatility spread trading strategy on risk-adjusted basis. The Sharpe ratio and the Sortino ratio are both risk-adjusted evaluations of return on investment, and they give an important information to investors what is the reward-to-risk ratio in their portfolios. Properly used, the Sharpe and the Sortino ratios improve the management of investment portfolios such as the efficient frontier can be improved making more globally diversified portfolios. Therefore, the Sharpe ratio and the Sortino ratio are one of the most used portfolio performance measurements amongst hedge funds and other investment funds (Sharpe 1994).

4.2.1. Sharpe ratio

William F. Sharpe (1966) introduces the Sharpe ratio, which is also known as a reward-to-risk ratio. The Sharpe ratio divides average portfolio excess return over the sample period by the standard deviation of returns over that period. It measures the reward to total volatility trade-off. Formula for the Sharpe ratio is the following: (Bodie et al. 2005: 868.)

(15) $$Sharpe\ ratio = \frac{Rp - Rf}{\sigma p}$$

where R_p = return of a portfolio
R_f = risk-free interest rate
σ_p = standard deviation of a portfolio

4.2.2. Sortino ratio

The Sortino ratio is represented by Sortino and Price (1994). It is a variation of the Sharpe ratio, and it is a useful portfolio performance measurement when portfolio returns are asymmetric and there is a negative skewness. In contrast to the Sharpe ratio, the Sortino ratio considers semi-standard deviation in the denominator instead of the standard deviation. The semi-standard deviation differentiates harmful volatility from overall volatility by using the asset's standard deviation of negative asset returns, sometimes called as a downside deviation. The Sortino ratio (16) is calculated as follows (Pedersen & Satchell 2002):

(16) $$Sortino\ ratio = \frac{Rp-t}{\theta rp\ (t)}$$

where R_p = return of a portfolio
t = target return
$\theta rp\ (t)$ = semi-standard deviation of a portfolio

The Sortino ratio's formula is sometimes modified, the risk-free rate of return is used instead of the target returns (t). There are a few things to consider in a comparison between the Sharpe ratio and the Sortino ratio. First, unlike the standard deviation which weighs extreme positive and negative outcomes equally, the semi-standard deviation is sensitive to skewness in the data as well as to the probability of negative returns. Secondly, since the Sortino ratio uses the downside deviation as its risk measure, it addresses the problem of using the standard deviation as an upside volatility is beneficial to investors. As a summary, when looking at two similar investments, a rational investor would prefer the on with the higher Sortino ratio since it means that the investment is earning more return per unit of negative risk that it takes on. (Pedersen & Satchell 2002.)

5. DATA AND METHODOLOGY

Invesco QQQ Trust Series 1, the QQQ exchange-traded fund (QQQ), is chosen for the study, because it is one of the most liquid and traded ETFs in the global financial markets. In addition, the QQQ has a wide range of option data available. Volatility spread trading strategy on ETF also differs significantly from the previous studies, which focuses on the stock index options and major currencies (Chen & Leung 2003; Brenner et al. 2006; Goyal & Saretto 2009; Do et al. 2015).

Data used in this study are collected from Thomson-Reuters DataStream. Additionally, the study uses the same methodology to calculate returns of volatility spread trading strategy as in Do et al. (2015). A large number of previous studies have also used the same methodology, namely Chen and Leung (2003), Goyal and Saretto (2009), and Murray (2013). Unlike previous studies, implied volatility has derived from the Black-Scholes model by using matched pairs of call and put options with the nearest at-the-money options and with same time to expiry. Furthermore, this study takes into consideration how volatility spread trading strategy would survive in real-world circumstances by embedding transaction costs into test results.

5.1. Data

Trading of Invesco QQQ Trust Series 1 (QQQ) call and put options (and their underlying asset) occurs on the Nasdaq during the normal trading hours. The data for the study consists of all the closing prices for the QQQ ETF between the 1st of May 2006 and the 31st of August 2018, and all call and put option closing prices for all strike prices, with the first one expiring on the 16th of June 2006 and the last one expiring on the 17th of August 2018. The examination period leaves 147 holding periods to create long and short straddle portfolios by combining call and put options. As of the 31st of August 2018, QQQ has approximately 482.1 billion US dollars' worth of assets under management. The top 3 holdings of QQQ are Apple, Amazon and Microsoft, with an approximate weight of 10% on each.

Call and put options of QQQ are American-style and cover the quantity of 100 shares. Furthermore, for all call and put option pairs with the expiration date falling on a Saturday, Friday closing prices are used. Unlike Do et al. (2015), it is assumed that one-month QQQ call and put options are sold at the closing bid/price quote and QQQ positions are bought at the last transaction price of the day. The positions are held until expiration, and the return from written call and put options are their intrinsic value.

All call and put options are the nearest at-the-money options (ATM), which are used to construct straddle portfolios. ATM call and put options are more liquid and traded than ITM and OTM options. Moreover, ATM call and put options mitigate the effect of a volatility smile, where implied volatility rises when the underlying asset of an option is further ITM or OTM. The Black-Scholes model predicts that the implied volatility curve is flat when plotted against varying strike prices. Based on the model, it would be expected that the implied volatility would be the same for all options expiring on the same date regardless of the strike price. However, in the real-world, this is not the case. Therefore, implied volatility derived from the Black-Scholes is likely to be more accurate measure of future volatility for ATM options than ITM and OTM options. (Hull 2015: 431-436.)

5.2. Methodology

The methodology of the study is divided into three sections. The first section explains how volatility spread trading strategy is constructed in this study. The second section introduces the methodology of calculating the returns of volatility spread trading strategy. The third section explains how transaction costs are taken into consideration in the results of volatility spread trading strategy. There are considered the costs of bid-ask spreads and initial margin requirements as transaction costs in this study.

5.2.1. Volatility spread trading strategy

Following Do et al. (2015), the historical volatility (HV) of the underlying asset is calculated by the standard deviation of daily stock returns over the prior 12 months and the implied volatility (IV) of each call and put option pair is calculated from the last traded option price on the portfolio-formation date. Implied volatility has derived from the Black and Scholes model, which gives the price of European-style option. However, options of QQQ ETF are American-style options. On the other hand, the Black-Scholes is suitable for American options too, because there are usually not reasons to exercise the option position before the expiration date. Early exercise would usually be caused by a weird mispricing for some technical or market-action reasons, where the theoretical option valuations are messed up. Moreover, this study assumes that positions are held until expiration. Therefore, the Black-Scholes model is used to calculate implied volatility. Furthermore, this study assumes that the Black-Scholes model is valued and values the options correctly.

Realized volatility (RV) is the annualized realized volatility of daily stock returns over the remaining life of the option. Usually, call and put options have maturities of 28 or 35 days to the expiration day. Volatility spread trading strategy is executed as follows: long positions in call and put options are taken when HV is larger than IV, and short positions in call and put options are taken as IV is above the HV. In other words, volatility spread trading strategy uses long straddles with a positive volatility spread and short straddles with a negative volatility spread. Volatilities are observed on the trading day, on the 3rd Friday of each month.

5.2.2. Returns of volatility spread trading strategy

As with Chen and Leung (2003), Goyal and Saretto (2009) and Do et al. (2015), the empirical analysis concentrates on both long and short option straddles portfolios, which are used to implement volatility spread trading strategy. For a portfolio formed on day *t*, the time *t* + *r* expiry date return on the straddle portfolio is calculated as following:

(17) $$R = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{C_{t+1}^{i} + P_{t+1}^{i}}{C_{t}^{i} + P_{t}^{i}} - 1\right)$$

where R is the straddle portfolio return, $C_{t+1}^{i} = \max(0, S_{t+1}^{i} - X^{i})$ is the payoff on expiry day *t* + *r* for a call option on the underlying asset *i* with strike price X^{i}, $P_{t+1}^{i} = \max(0, X^{i} - S_{t+1}^{i})$ is the payoff on expiry day *t* + *r* for a call option on the underlying asset i with strike price X^{i}. Furthermore, S_{t+1}^{i} is the price of the underlying asset *i* on expiry day *t* + *r*, C_{t}^{i} and P_{t}^{i} are the option premiums to enter the straddle on day *t*, and n is the number of straddles in the portfolio. Formula 17 gives the return of a long straddle position. Conversely, the return of a short straddle position is the same, but the numerator and the denominator are the other way around.

IV is derived from the last traded option price on the portfolio-formation date, and the option premiums used to calculate straddle returns (C_{t}^{i} and P_{t}^{i}) are the closing prices on the same day. Therefore, the mispricing signal is observed on the same day (moment) that HV and IV are calculated, and new pairs of call and put options are bought or written. The above-mentioned procedure of either buying or selling call and put options by the volatility spread is repeated on a monthly basis. According to the findings of Goyal and Saretto (2009) and Do et al. (2015), a large positive value of the volatility spread is a signal of an underpriced option. Moreover, a large negative value of the volatility spread is a signal of an overpriced option.

The forthcoming study and empirical findings include the results of the Vol. Spread + QQQ trading strategy. This portfolio invests 90 per cent of its weight to the QQQ (to the underlying asset) and 10 per cent of its weight to volatility spread trading strategy. The portfolio is chosen for the study, because it gives the perspective how volatility spread trading strategy operates as a part of the portfolio. For calculating returns of the Vol. Spread + QQQ portfolio, the equation 17 is adjusted in the following way:

$$(18) \qquad R_{\text{Vol.Spread+QQQ}} = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{C_{t+1}^{i} + P_{t+1}^{i}}{C_t^{i} + P_t^{i}} - 1\right) * 0.1 + \left(\frac{QQQ_t - QQQ_{t-1}}{QQQ_{t-1}}\right) * 0.9$$

The porftolio of Vol. Spread + QQQ is rebalanced on a monthly basis as the new long or short straddle position is entered.

5.2.3. Transaction costs

In this study, two types of transaction costs are taken into consideration in the empirical findings. First, to provide the outlook of the magnitude of bid-ask spreads on QQQ, trade and quote data is taken from Thomson-Reuters DataStream. Data consists of date, time, bid price and ask price, which allows to calculate correctly the impact of bid-ask spreads. In addition, the second consideration in studying the profitability of volatility spread trading strategy in real-world is the existence of initial margin requirements, which are crucial to include into calculations in the case of returns to written call and put options.

There are several different ways to calculate the impact of bid-ask spreads to the returns of any asset class. This study follows closely previous studies that uses percentage quoted spread (PQS) and the percentage effective spread (PES) to examine the impact of bid-ask spreads to the returns of options. Moreover, options are considered less liquid asset class than stocks or indices. Therefore, options are likely to have wider bid-ask spreads than their underlying asset, for instance. (Mayhew 2002; Goyal & Saretto 2009; Flint et al. 2014; Do et al. 2015.) The formula for the percentage quoted spread method at a point in time is the following:

(19) $$PQS = \frac{Ask - Bid}{Midpoint}$$

where Ask = An ask price of an option
Bid = A bid price of an option
Midpoint = A traded price of an option

There are considered two different effective spread measures equal to 50% and 100% of the quoted spread. For example, if the bid price of a call option is one dollar and the ask price of the call option is two dollars, then the buy price is 1.75 dollars and the sell price is 1.25 dollars in the 50% effective spread to the quoted spread. Further, for the 100% effective spread of the quoted spread the buy price is 2 dollars and the sell price is 1 dollar in the above-mentioned scenario.

Given the risk of substantial losses on short option positions, options writers are required to have a sufficient amount of margin in their accounts to cover potential losses (Do et al. 2015). Therefore, initial margin requirements are relevant to consider when calculating the returns of short option position in real-world circumstances. According to Goyal and Saretto (2009) and Murray (2013), the Standard Portfolio Analysis of Risk system, hence forward SPAN system, is the most popular and widely used scenario analysis algorithm for the determination of initial margin requirements. The SPAN system, through its sophisticated algorithms, sets the margin of each position in a portfolio of derivatives and other financial instruments to its calculated worst possible one-day move. The main inputs to the models are strike prices, risk-free interest rates, changes of volatility, and time to expiration.

The initial margin requirements are taken from the margin manual of Chicago Board Options Exchange (CBOE). According to the margin manual of CBOE, the initial margin requirement for the same underlying asset is the greater one of short call or short put requirements, plus the option proceeds of the other side. The requirements for short call and short put are considered as with the SPAN system, where the theoretical value of the position in each of the scenarios is compared to the price of an option. Furthermore, the largest loss among those computed in the scenario analysis is called the option risk charge, which is the same as the requirements of short call and short put option positions.

6. EMPIRICAL RESULTS

The empirical results of volatility spread trading strategy on QQQ are presented and analyzed in this section. Furthermore, performance and benefits gained of volatility spread trading strategy are compared with the results of previous studies on the subject. The empirical results are divided into two different parts. First, the performance of volatility spread trading strategy is represented. The methodologies of volatility spread trading strategy and volatility spread trading returns are presented in fifth section. There is strong evidence that volatility spread trading strategy has a similar impact on QQQ than the S&P 500 and the ASX, for instance. Volatility spread trading strategy is generating economically significant returns, when strategy goes long position in options (long straddle) with positive volatility spread (HV>IV) and enters short position in options (short straddle) with negative volatility spread (HV<IV). In addition, volatility spread appears to give a strong signal of option mispricing. Last, the benefits of volatility spread trading strategy is examined during the 2008 global financial crisis.

The second part of empirical results analyzes the performance of volatility spread trading strategy in real-world circumstances. The authenticity of volatility spread trading returns on QQQ are studied by incorporating the cost of bid-ask spreads and initial margin requirements into the empirical results. The methodologies behind bid-ask spreads and margin-based returns are introduced in the previous section, data and methodology. At the end of this section is concluded the benefits of volatility spread trading on QQQ and how it would survive in real-world settings and in a comparison to previous studies on the subject.

6.1. Performance of volatility spread trading

There are three different parts in this section. The first part represents the descriptive statistics of volatility spread trading strategy on QQQ. In the second part, the general performance of volatility spread trading on QQQ is presented and analyzed in a comparison with previous studies. Furthermore, the reasons behind the profitability of volatility spread trading strategy are argued and introduced. The last part of this chapter focuses on the performance of volatility spread trading during the uncertainty. Particularly, the third part analyzes the benefits of volatility spread trading strategy during the 2008 financial crisis, and whether it improves the performance of a portfolio consisting of the long position in the QQQ ETF and long/short straddle strategy.

6.1.1. Descriptive statistics

This part concentrates on introducing descriptive statistics of three different volatilities; historical volatility, implied volatility and realized volatility. All three volatilities are calculated by following the same method as Goyal and Saretto (2009) and Do et al. (2015). Historical volatility is the volatility of the daily stock returns from the last 12 months. Implied volatility (IV) is the average implied volatility from the matched pairs of call and put options. Realized volatility (RV) is the annualized realized volatility of daily stock returns over the remaining life of the option. Figure 6 illustrates the performances and characteristics of HV, IV and RV from the 1st of January 2006 to the 31st of August 2018.

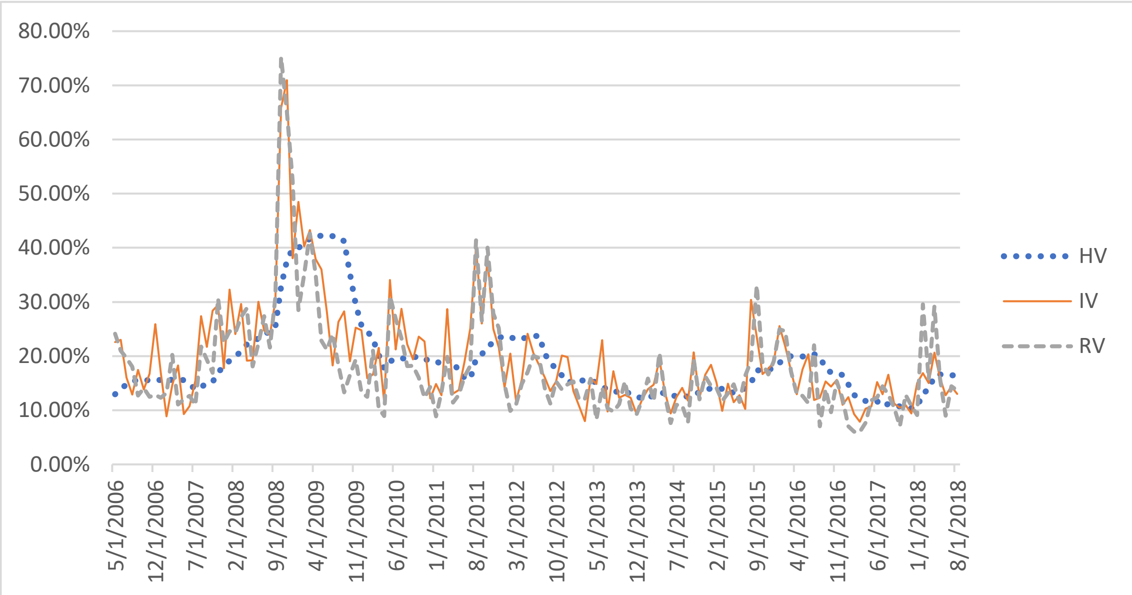

Figure 6. Volatility characteristics of QQQ from May 2006 to August 2018.

According to figure 6, IV and RV are peaking during the 2008 financial crisis, whereas HV increases more steadily between 2008 and 2009. Furthermore, the 2008 financial crisis is not having the same kind of impact to HV than to IV and to RV, which is explained by the longer time horizon of 12 months in the formula of HV. Hill et al. (2006) state that IV tends to be higher than RV almost all the time, at least in the long term.

Moreover, the findings of Hill et al. (2006) suggest that RV exceeds IV momentarily during the sudden changes in volatility levels. Usually, these sudden and significant movements in volatility occur in bear market conditions, when the volatility is having extreme changes upward. The figure 6 supports the findings of Hill et al. (2006) that in general IV is higher than RV, and only under the extreme upside movements in volatility RV surpasses IV.

All three volatilities are moving quite uniformly. Therefore, all three volatilities are expected to be positively correlated with each other. Especially, IV and RV appear to move in a same phase and following each other pretty closely. Table 9 reports the sample descriptive statistics that characterize the volatilities of QQQ ETF and its options. IV has the highest mean and median, and particularly, IV tends to be above RV. On the other hand, RV has the highest variation and the widest range of above-mentioned volatilities. The results also suggests that IV and RV have closer minimum and maximum values than HV as opposed to IV and RV. The highest values occurs during the 2008 financial crisis, which is in line with the theory that the volatility and market returns have a negative relationship. In other words, as the volatility and uncertainty in the financial market rises, the market returns are most likely negative.

Table 9. Descriptive statistics of historical, implied and realized volatilities on QQQ ETF and its options.

	Volatility Characteristics		
	HV	IV	RV
Mean	0.1893	0.1943	0.1781
Min	0.1037	0.0787	0.0601
Max	0.4232	0.7096	0.7520
Standard Deviation	0.0763	0.0971	0.0997
Median	0.1654	0.1671	0.1481
	Volatility Correlations		
	HV	IV	RV
HV	1		
IV	0.654	1	
RV	0.551	0.860	1

Additionally, the results of table 9 are in line with previous studies of Hill et al. (2006), Goyal and Saretto (2009), Kapadia and Szado (2012), and Do et al. (2015). All three volatilities are correlated with each other, especially IV and RV. In a comparison to the results of Do et al. (2015) on the ASX, the correlation between IV and RV is remarkably higher on QQQ ETF (0.86) than on the ASX (0.76). Furthermore, the ASX appears to have significantly higher variation in its daily stock returns and in IV than the QQQ ETF. This difference is explained by the difference in the markets and examination period. Despite of the 2008 financial crisis, the volatility has been low from 2009 to current. The difference between standard deviations of IV (9.71%) and RV (9.97%) is not as large as Do et al. (2015) find on the ASX. However, the results are similar with previous studies and the conception that IV is the smoothed estimation of RV.

Table 10 demonstrates the volatility spreads of QQQ ETF call and put options. Volatility spread is divided to the divergence between HV and IV following the methodology of Goyal and Saretto (2009) and Do et al. (2015), and to the difference between IV and RV as Hill et al. (2006) and Kapadia and Szado (2012). In Panel A, the matched pairs of the nearest ATM call and put options are used as an IV, whereas Panel B presents implied volatilities of call and put options separately. Naturally, the results of Panel A lie between the results of Panel B, since IV reported in Panel A is the average of call and put options.

Table 10. Volatility spreads of QQQ ETF call and put options.

	Panel A Volatility spreads for QQQ options			
	HV-IV		IV-RV	
Mean	-0.45%		1.61%	
Min	-33.36%		-14.30%	
Max	23.88%		19.98%	
Std. Dev.	7.44%		5.23%	
Median	0.44%		1.14%	
	Panel B Volatility spreads for call and put options			
	Call options		Put options	
	HV-IV	IV-RV	HV-IV	IV-RV
Mean	-0.86%	2.01%	-0.24%	1.40%
Min	-36.65%	-18.24%	-38.12%	-14.00%
Max	28.38%	27.17%	19.38%	12.79%
Median	0.49%	1.01%	0.44%	1.41%

The results of table 10 support the findings of table 9, the divergence between HV and IV (which is used to examine the volatility spread in this study) is negative. On the other hand, the median for HV-IV is positive, which indicates that HV is larger than IV more times than IV is above HV during the examination period. Also, table 10 supports that IV and RV are more correlated to each than HV and IV, because the standard deviation is lower for IV-RV than HV-IV, and further, the extreme values (Min, Max) are both larger for the spread of HV-IV than the spread of IV-RV.

The findings of Panel A are supported by earlier studies (Hill et al. 2006; Goyal & Saretto 2009; Kapadia & Szado 2012; Do et al. 2015). The results suggests that in general the spread between IV and RV is positive, reporting the mean of 1.61% and the median of 1.14%. Contrary to previous studies, IV tends to be higher for call options than for put options. Both volatility spreads for call options are farther from zero than volatility spreads for put options. Moreover, three out of four minimum and maximum numbers are larger for call options than put options. In turn, the median of IV-RV for call options is lower than the median for put options. In conclusion, call options have higher IV than put options on QQQ, and hence they capture more investor's uncertainty than put options.

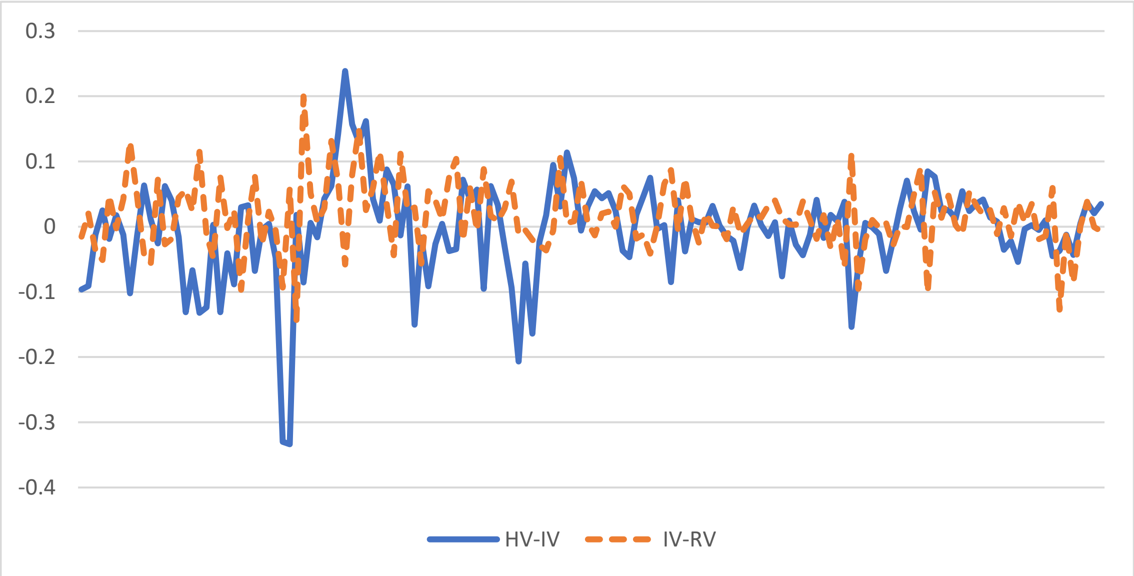

Figure 7. Volatility spreads of HV-IV and IV-RV on QQQ between May 2006 and August 2018.

To illustrate previous results of table 9 and 10, the figure 7 demonstrates the changes of volatility spreads on QQQ from May 2006 to August 2018. The figure 7 presents the fact that is reported in tables 8 and 9, the spread between HV and IV has a higher variation and its peeks are more extreme than for the spread of IV-RV. Unlike table 8 and 9, the figure 7 shows that HV-IV and IV-RV are negatively correlated as the volatility is increasing. For example, during the 2008 financial crisis IV is significantly larger than HV, whereas the divergence between IV and RV is close to zero. Nevertheless, volatility spreads are likely to be negatively correlated, since IV is part of both spreads with opposite roles.

In summary, all three volatilities appear to behave in the way that previous studies have suggested. RV has the highest standard deviation and the lowest mean, whereas IV has the highest mean. Furthermore, HV, IV and RV are positively correlated with each other, and the impact of the 2008 financial crisis can be observed from the spikes of all three volatilities. Despite of the high positive correlation (0.86) between the results of IV and RV, there are existing some differences between IV and RV. Particularly, figure 7 illustrates the behavior of volatility spread IV-RV, and there are existing large movements in the spread. According to findings of McGee and McGroarty (2017), upward bias on IV does not represent a long-term return premium. In this study, RV can be sometimes observed from IV, but IV is not the same as future realized volatility on QQQ and its ATM call and put options during the estimation period.

6.1.2. Returns of volatility spread trading strategy

According to the efficient market hypothesis and other efficient market related assumptions, it should not be possible to benefit from volatility spread trading strategy in the long run. However, several studies have shown the benefits of volatility spread trading strategy (Chen & Leung 2003; Brenner et al. 2006; Goyal & Saretto 2009; Chen & Liu 2010; Do et al. 2015; McGee & McGroarty 2017). This section of the study concentrates on the empirical findings of volatility spread trading strategy on QQQ.

The first results of volatility spread trading strategy on QQQ are presented in table 11. The table presents monthly results of three different portfolios. The first column shows the results of volatility spread trading strategy where long and short straddles are traded based on the volatility spread (HV-IV). The second column represents a pure index strategy, where a long position in the QQQ is taken and held. The third column demonstrates the performance of a portfolio including 90% weight on a long position in the QQQ and 10% weight on volatility spread trading strategy. Portfolio is rebalanced each month, when the new trade occurs. (3rd Friday of the month)

As expected, volatility spread trading strategy has the highest mean return. Although, the standard deviation for the volatility spread is around ten times larger than the standard deviations for the QQQ and the portfolio of Vol. Spread + QQQ. Nevertheless, volatility spread trading strategy has the highest Sharpe ratio of 0.23, whereas the pure long position on QQQ generates the Sharpe ratio of 0.05. In addition, the Sortino ratio of QQQ is significantly lower than the Sortino ratio for volatility spread trading strategy. The portfolio consisting of volatility spread trading and QQQ has the highest Sortino ratio of 0.63. On the other hand, these are the results before the impact of bid-ask spreads and initial margin requirements. Transaction costs are likely to have a dramatic impact on the profitability of volatility spread trading strategy and the Vol. Spread + QQQ portfolio. Moreover, transaction costs has no impact on a pure index strategy, which does not include trading on a monthly basis.

Table 11. Performances of volatility spread trading strategy, QQQ, and Vol. Spread + QQQ strategy from May 2006 to August 2018.

	Volatility spread	QQQ ETF	Vol. Spread + QQQ
Mean returns	0.1368	0.0120	0.0245
Standard Deviation	0.5641	0.0562	0.0698
DStd. Deviation	0.2258	0.0362	0.0388
Minimum returns	-0.7820	-0.2471	-0.2943
Maximum returns	1.8788	0.1415	0.1747
Median	0.0710	0.0198	0.0245
Skewness	0.8332	-1.1384	-0.7893
Kurtosis	0.6408	3.1428	2.5434
Sharpe ratio	0.2260	0.0487	0.2180
Sortino ratio	0.6058	0.3326	0.6307

As the table 11 presents, maximum and minimum returns for volatility spread trading strategy are larger than the same returns for the QQQ and for the Vol. Spread + QQQ. This is in line with standard deviations and semi-standard deviations. As presented in figure 6, the highest movements, and standard deviations, occur during the 2008 financial crisis. The same applies for the most extreme returns, minimum and maximum returns: both peaks are taken during the biggest drop in 2008 and sudden recoveries between October 2008 and February 2009 for all three portfolios.

Unexpectedly, the median of volatility spread trading strategy is over 6 percentages smaller than the mean return for the same strategy. The divergence between the median and the mean is explained by the large deviation in the returns. Particularly, some of the positive returns are extremely large, which causes the difference in the median and on average monthly returns. For example, the maximum return of volatility spread trading is 187.88% per month, whereas the minimum return is -78.20%. The same is presented in figure 8, which illustrates the monthly return distribution of volatility spread trading strategy on QQQ.

According to the results of Goyal and Saretto (2009) and Do et al. (2015), volatility spread trading strategy generates monthly return of 22% with the standard deviation of 25% on S&P 500 and yields 15% with the standard deviation of 44% on the ASX equity options. In a comparison to the performance of volatility spread trading strategy on QQQ, it appears that volatility spread trading is not as profitable for QQQ than for the S&P 500 and the ASX equity options. Furthermore, the standard deviation is a much higher for the QQQ. This is likely to be explained by the difference in the underlying assets. For instance, Do et al. (2015) use large numbers of different equity options in their study and they are likely to be correlated with each other. Whereas QQQ index options are used to implement volatility spread trading strategy in this study, not a large punch of equity options. One reason can also be the time horizon used in the study. For example, Goyal and Saretto (2009) examine the benefits of volatility spread trading strategy between 1996 and 2006, whereas Do et al. (2015) examination period starts 2000 and ends 2012. In this study, the estimation period begins from May 2006 and lasts to August 2018. In addition, this study concentrates on an index option in the US markets, where Do et al. (2015) focus on multiple equity options in the Australian markets.

To conclude the results presented in table 11, volatility spread trading strategy seems to be an extremely profitable trading strategy on QQQ. The trading strategy that enters long position in options as the volatility spread is positive and goes short position in options with a negative volatility spread generates, on average, monthly return of 13.68%. This is a clear signal that combining long and short straddles based on the difference in the volatility spread gives large positive returns. Therefore, the profitability of volatility spread trading strategy indicates that volatility spread is a valid signal of option mispricing. Furthermore, volatility spread trading strategy and the Vol. Spread + QQQ outperform the QQQ index strategy in risk-adjusted returns due to higher Sharpe and Sortino ratios. Compared to previous studies of Goyal and Saretto (2009) and Do et al. (2015), volatility spread trading strategy produces similar returns and characteristics on QQQ as on the S&P 500 and on the ASX. Albeit, the magnitude of returns is lower and standard deviation is a little higher. The performance presented in this section are the results before the transaction costs. The authenticity of returns of volatility spread trading strategy is presented and analyzed in section 6.2.

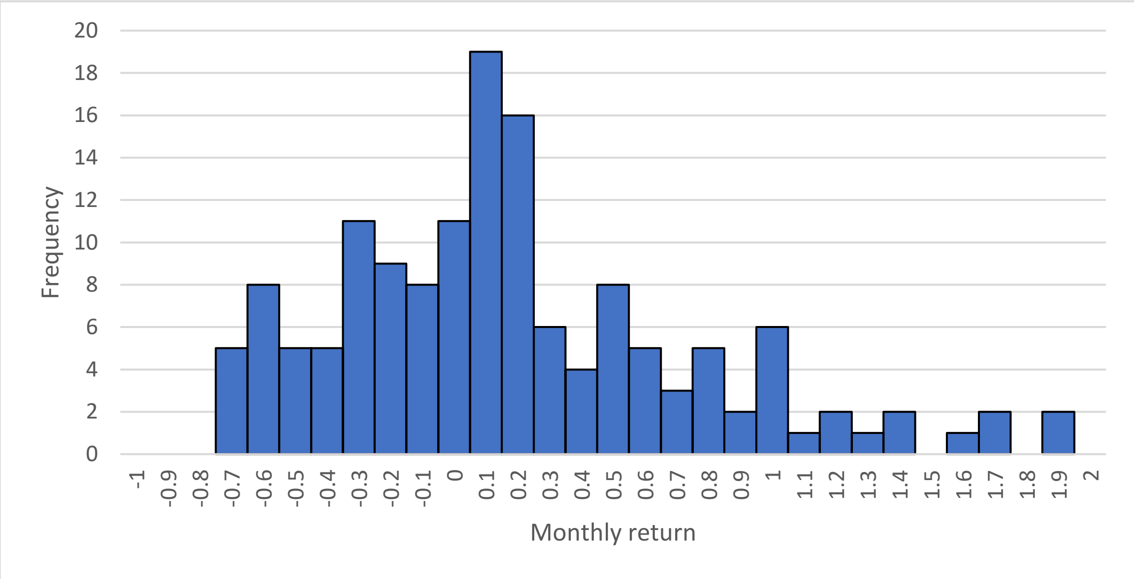

Figure 8. Monthly return distribution of volatility spread trading strategy on QQQ between May 2006 and August 2018.

Figure 8 presents the monthly return distribution of volatility spread trading strategy on QQQ from May 2006 to August 2018. As figure 8 shows, there are is large and wide deviation in monthly returns of volatility spread trading strategy. However, the most of monthly returns are between -0.1 and 0.2. Figure 8 supports the findings of table 11, the positive monthly returns of volatility spread trading strategy are more extreme than the negative monthly returns. Furthermore, figure 8 illustrates where the difference in the median of 0.071 and the mean of 0.1368 is arising from.

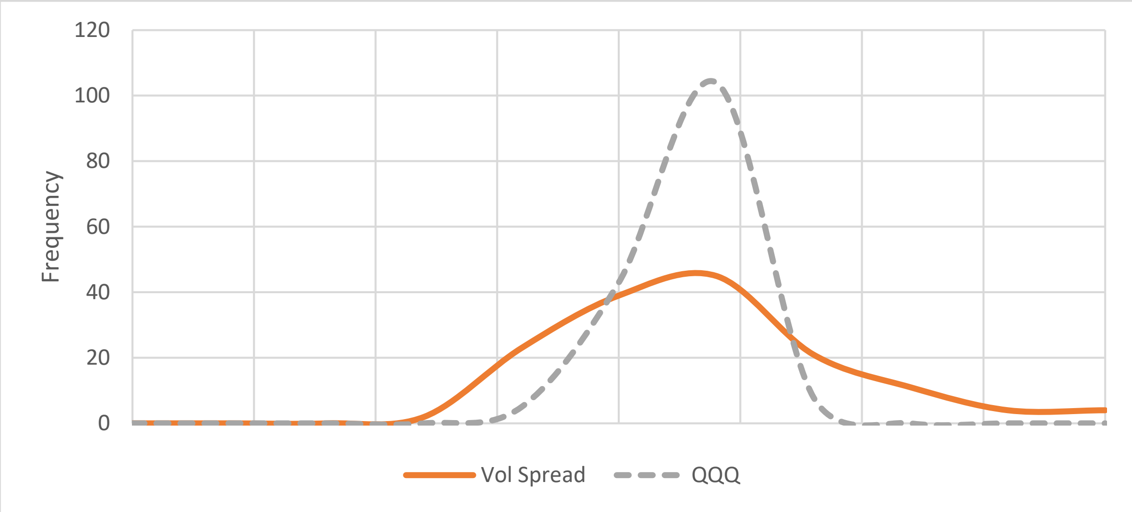

Figure 9. Monthly return distributions of volatility spread trading strategy and QQQ.

In order to illustrate the difference between monthly return distributions of volatility spread trading strategy and the QQQ, the figure 9 presents the monthly return distributions of volatility spread trading strategy and the QQQ in a same graph. Figure 9 suggests that the monthly return distribution of the QQQ has higher kurtosis and thinner tails, which causes the lower standard deviation for the QQQ compared to volatility spread trading strategy. This is also supported by the findings of the table 11, volatility spread trading strategy has a lower kurtosis than the QQQ, which explains the higher standard deviation in monthly returns. Furthermore, volatility spread trading strategy has a positive skewness of 0.83, whereas the QQQ has a negative skewness of -1.14.

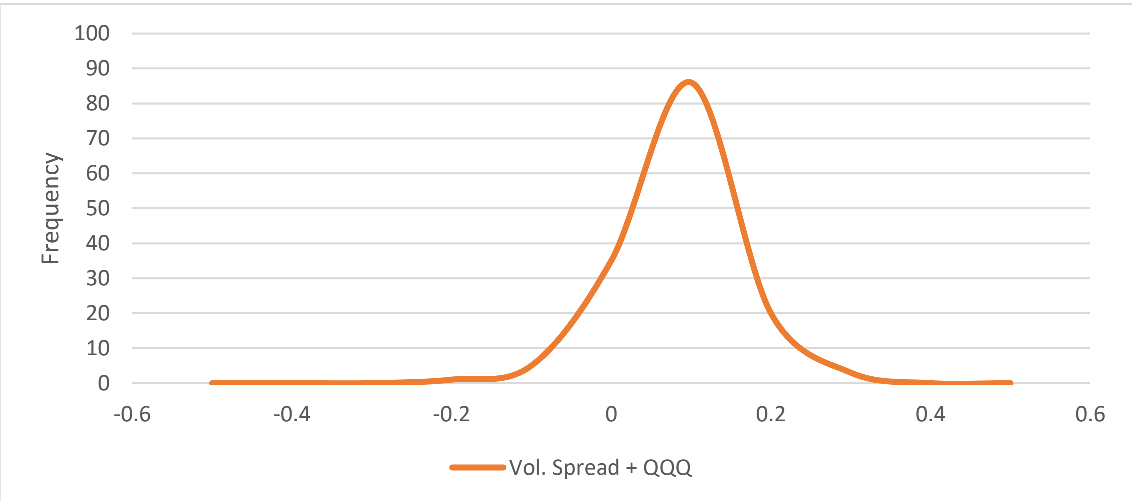

Figure 10. A Monthly return distribution of Vol. Spread + QQQ trading strategy on QQQ.

In addition to figures 8 and 9, the figure 10 presents the monthly distribution of the Vol. Spread + QQQ trading strategy starting from May 2006 and lasting to August 2018. Vol. Spread + QQQ trading strategy has a similar shape as the QQQ, where monthly returns are close to zero or slightly positive. According to table 11, the Vol. Spread + QQQ trading strategy has a negative skewness of -0.7893. Moreover, the kurtosis of Vol. Spread + QQQ trading strategy is 2.5434, which is not as high as the kurtosis of the QQQ. Figure 10 also illustrates this fact that the monthly return distribution is focused and not deviating as much as monthly returns of volatility spread trading strategy, for instance. In a summary of figures 8, 9 and 10, monthly returns of volatility spread trading strategy are deviating much more than monthly returns of the QQQ and Vol. Spread + QQQ.

6.1.3. Performance during the financial crisis

The 2008 global financial crisis has been the worst economic disaster since the Great Depression, which happened in 1929 in the US. This section concentrates on the benefits of volatility spread trading strategy during the bearish market condition that occurred between 2007 and 2009. This study assumes that the 2008 financial crisis started in July 2007 and ended in February 2009, which is also the estimation period used to examine the performance of volatility spread trading strategy during the financial crisis. As shown before, there is a positive relationship between the bear market conditions and high volatility. Therefore, the 2008 global financial crisis is an intriguing period to study the benefits of volatility spread trading strategy, which is speculating about the future volatility. Performances of volatility spread trading strategy, the QQQ and the Vol. Spread + QQQ trading strategy during a bearish market condition are presented in table 12.

Volatility spread trading strategy yields 22.61% per month between July 2007 and February 2009. However, the standard deviation increased from 56.41% to 70.61%. In a comparison to the QQQ, monthly returns of volatility spread trading strategy increase almost 9%, whereas the monthly returns of the QQQ turn to negative during the 2008 financial crisis. Furthermore, the relative increase in the standard deviation is a significantly higher for the QQQ than volatility spread trading strategy. The portfolio of Vol. Spread + QQQ generates slightly positive return of 0.12% per month with a monthly standard deviation of 11.07%.

For volatility spread trading strategy, the median of 7.1% is a significantly lower than the average return, which indicates large and extremely positive returns during the estimation period. These extreme returns, minimum and maximum returns are the same for all three strategies as presented in table 11, except maximum returns of the QQQ and the Vol. Spread + QQQ portfolio. Monthly returns are negatively skewed for the QQQ and the Vol. Spread + QQQ as in table 11. On the other hand, kurtosis is much lower for both of them. Particularly, the kurtosis of the QQQ is dropped significantly, which indicates that monthly returns have a wider deviation. Furthermore, the skewness of volatility spread trading strategy stays positive and almost at the same level as presented in table 11.

Table 12. Performances of volatility spread trading strategy, QQQ, and Vol. Spread + QQQ portfolio between July 2007 and February 2009.

	Volatility spread	QQQ ETF	Vol. Spread + QQQ
Mean returns	0.2261	-0.0238	0.0012
Standard Deviation	0.7061	0.0963	0.1107
DStd. Deviation	0.2527	0.0689	0.0772
Minimum returns	-0.7820	-0.2471	-0.2943
Maximum returns	1.8788	0.1196	0.1664
Median	0.0710	-0.0187	0.0269
Skewness	0.8405	-0.5853	-1.0691
Kurtosis	0.4745	0.1291	1.5493
Sharpe ratio	0.2953	-0.4294	-0.1477
Sortino ratio	0.8945	-0.0943	0.0046

The Sharpe and the Sortino ratios of the QQQ and the Vol. Spread + QQQ are much worse between July 2007 and February 2009. Conversely, volatility spread trading strategy during the 2008 financial crisis outperforms volatility spread trading strategy in "neutral" market conditions. For instance, the Sharpe ratio increases from 0.2260 to 0.2953 and the Sortino ratio surges from 0.6058 to 0.8945. Therefore, volatility spread trading strategy appears to provide, not just better monthly returns, but also better risk-adjusted returns. As a summary, the benefits of volatility spread trading strategy are better during the 2008 financial crisis, which indicates that volatility spread trading strategy is more effective and accurate in bear market conditions when the volatility is surging.

6.2. Authenticity of volatility spread trading returns

The reported results in the previous section are based on returns computed using the mid-point prices as the prices of call and put options. However, it may not be possible to trade at mid-point price in every circumstance. This section focuses on the verisimilitude of volatility spread trading strategy's returns. Furthermore, there are presented the scale in which volatility spread trading returns are likely to be mitigated, or even negative, in real-world circumstances. According to assumptions of the Black-Scholes model, there are no transaction costs in buying or selling the stock or the option. Nevertheless, this is not the case in the real-world circumstances. As with Goyal and Saretto (2009) and Do et al. (2015), this study concentrates on impacts of bid-ask spreads and initial margin requirements to the profitability of volatility spread trading strategy.

First, the impact of bid-ask spread to the profitability of volatility spread trading strategy is examined by using the same methodologies as Goyal and Saretto (2009) and Do et al. (2015). Next, there are incorporated the costs of initial margin requirements on short positions in options following the method introduced by Murray (2013). In addition, benefits of volatility spread trading strategy during the 2008 global financial crisis are examined in real-world circumstances. Finally, the comprehensive and complete results are presented at the end of this section. Furthermore, empirical findings are analyzed and reasons behind the performance are introduced as well as argued.

6.2.1. Bid-ask spreads

A bid-ask spread is the difference between the lowest price a seller is willing to give up the security and the highest price a buyer is willing to pay for a security. The transaction occurs when either a seller accepts the bid price, or the buyer takes the ask price. Furthermore, the price of an option is trending upward if there are more buyers than sellers, as the buyers bid the option higher. Oppositely, the price of an option is going down when sellers outnumber buyers, as the supply-demand imbalance will force the sellers to lower their price for the option. Moreover, bid-ask spreads are determined by the liquidity and supply and demand for an option. The most liquid and/or widely traded options tend to have smaller spreads, as long as there are no major supply and demand imbalances. (Hull 2015: 223.)

It is commonly well-known and proved by numerous of previous studies that bid-ask spreads are substantially larger in option markets than in stock and currency markets

(Fleming et al. 1996; Battalio & Schultz 2011). Therefore, bid-ask spreads are relevant to embedded into calculations, because they are likely two have an impact on the volatility spread trading profits in several ways. First, bid-ask spreads will reduce volatility spread trading returns by having different buying and selling prices. Secondly, bid-ask spreads are not only affecting to buying and selling prices, but also to the difference of HV and IV. For example, if the right/correct option price, and hence the true IV, lies between the bid price and the ask price, a volatility implied from the bid price appears too low. In turn, if IV is derived from ask prices, then IV appears too high. Thus, wide bid-ask spreads may give incorrect or at least suspicious signals of option mispricing.

Table 13 presents the results of volatility spread trading strategy after the impact of bid-ask spreads on QQQ during the examination period. The returns of options are calculated from the mid-point closing price (MidP) and from the effective bid-ask spread, estimated to be equal to 50% and 100% of the quoted spread. So far mid-point prices of call and put options are used to compute the performance of volatility spread trading strategy, and therefore the MidP in table 13 has the same numbers than in previous tables. After taking the impact of bid-ask spreads, volatility spread trading strategy profits monthly return of 8.77% with a standard deviation of 56.79%. In addition, the minimum return increases slightly from -78.20% to -78.52%, where the maximum return falls from 187.88% to 182.98%.

It should be noted that PES 100% does not necessarily mirror the real-world either. Sometimes trader can achieve a more effective bid-ask spread while trading call and put options. To illustrate the hypothetical situation where the trader achieves the 50% effective spread equal to the quoted spread, the middle column in table 13 shows the results of PES 50%. Naturally, the performance of the PES 50% lies between performances of the MidP and the 100% effective spread equals the quoted spread (PES 100%).

There are not huge changes in skewness and kurtosis as comparing to volatility spread trading strategy before and after the bid-ask spreads are embedded into results. Thus, the skewness of PES 100% is 0.8472 and the kurtosis is 0.6587. However, bid-ask spreads appear to have a bigger impact on risk-adjusted returns of volatility spread trading strategy. The Sharpe ratio decreases from 0.226 to 0.138 and the Sortino ratio has a similar drop from 0.6058 to 0.3574. In addition, the median of 2.53% is significantly smaller than the average monthly return of PES 100%. On the other hand, this is in line with the results of the MidP, before the costs of bid-ask spreads.

Table 13. The performance of volatility spread trading strategy on QQQ after the costs of bid-ask spreads.

	MidP	PES 50%	PES 100%
Mean return	0.1368	0.1122	0.0877
Standard Deviation	0.5641	0.5661	0.5679
DStd. Deviation	0.2258	0.2356	0.2453
Minimum return	-0.7820	-0.7836	-0.7852
Maximum return	1.8788	1.8543	1.8298
Median	0.0710	0.0446	0.0253
Skewness	0.8332	0.8402	0.8472
Kurtosis	0.6408	0.6498	0.6587
Sharpe ratio	0.2260	0.1818	0.1380
Sortino ratio	0.6058	0.4763	0.3574

When compared to previous studies of Goyal and Saretto (2009), Do et al. (2015), it appears that bid-ask spreads do not have as much impact on the profitability of volatility spread trading strategy on QQQ than on the S&P 500 and the ASX. For example, the profitability of volatility spread trading strategy drops from 22.7% to 3.9% on the S&P 500 and the Nasdaq 100 equity options. Furthermore, returns of volatility spread trading strategy on the ASX decreases from 15.71% to 4.49% in the study of Do et al. (2015).

There are few explanations for this issue. First, underlying assets differ significantly from each other. Both Goyal and Saretto (2009), and Do et al. (2015) have used equity options instead of ETF options that are used in this study. Secondly, the examination period is different in this study. For example, bid-ask spreads on the US have narrowed since the advent of decimalization in 2001. Moreover, option markets may have become more liquid in recent years. Last, Goyal and Saretto (2009) have more than 4 300 different stocks from the S&P 500 and the Nasdaq 100 in their sample and Do et al. (2015) study the benefits of volatility spread trading strategy with 89 unique stocks from the ASX. In this study, there is only one underlying asset, which is the QQQ ETF. Therefore, one reason could be the size of the sample. For instance, there may have been fewer liquid stocks and options, which are eroding the volatility spread trading profits significantly in a comparison to the one of the most liquid ETFs in the world.

Figure 11 illustrates the monthly return distribution of volatility spread trading strategy (PES100%) on QQQ between May 2006 and August 2018. As reported in table 13, monthly returns of volatility spread trading strategy are positively skewed. This can be also observed from the figure 11, where extreme positive returns are further away from zero than extreme negative returns. Furthermore, there are more extreme positive returns than extreme negative returns. The monthly return distribution of volatility spread trading strategy also shows that the vast majority of returns are close to zero or slightly positive. Naturally, monthly return distributions of volatility spread trading strategy before (figure 8) and after the costs of bid-ask spreads are likely to be very similar.

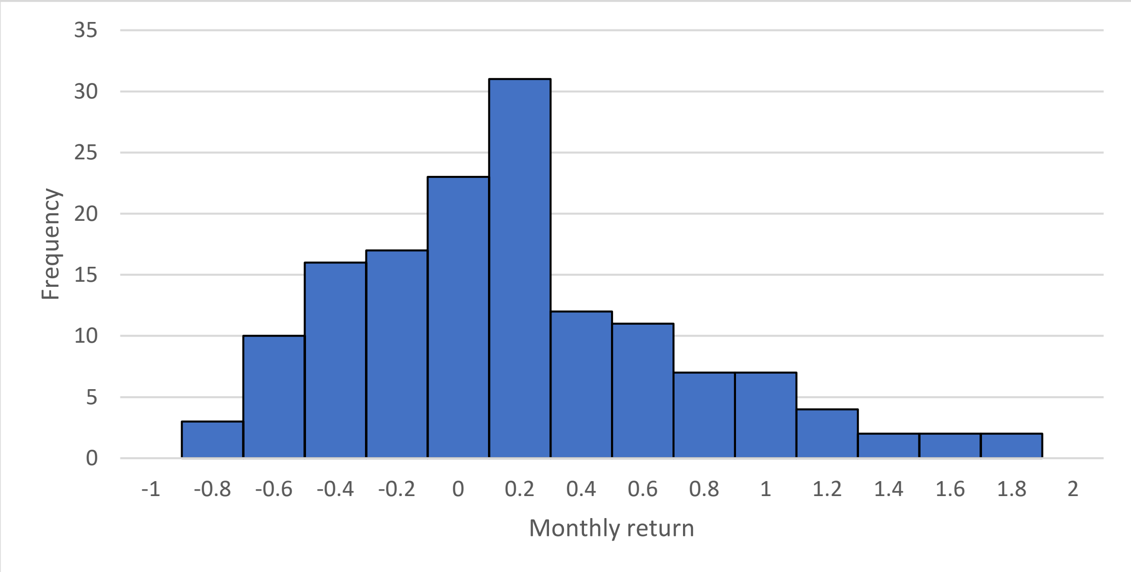

Figure 11. Monthly return distribution of volatility spread trading strategy on QQQ after the costs of bid-ask spreads.

The characteristics of bid-ask spreads on call and put options are reported in table 14, which presents the real-world data of spreads traded on QQQ options between May 2006 and August 2018. According to results of table 14, there are not a large difference between bid-ask spreads of call options and bid-ask spreads of put options. The average spread of call options is slightly higher than the average spread of put options. On the other hand, bid-ask spreads of put options tend to have a slightly higher standard deviation, and further, more extreme spreads. However, the median spread of call options and the median spread of put options are the same (0.04).

The minimum spread of put options is 0.004 and the maximum spread is 0.12, whereas the minimum spread of call options is 0.01 and the maximum spread is 0.11. Fleming et al. (1996) state that put options are usually less traded than call options, and therefore the bid-ask spread of put options is likely to be wider than the bid-ask spread of call options. Therefore, one reason for wider spreads of put options could be the difference in trading volumes of call and put options.

Table 14. Bid-ask spread characteristics of call and put options on QQQ between May 2006 and August 2018.

	Bid-Ask Spreads	
	Call options	Put options
Average	0.039	0.038
Minimum spread	0.010	0.004
Maximum spread	0.110	0.120
Median	0.040	0.040

As a summary of the impact of bid-ask spreads to the profitability of volatility spread trading strategy, it seems that bid-ask spreads reduce the profitability but do not eliminate it. A decrease in monthly returns and a slightly higher standard deviation results in lower Sharpe and Sortino ratios. Even though the bid-ask spreads mitigate the benefits of volatility spread trading strategy on QQQ, bid-ask spreads tend to have a bigger impact on previous studies of Goyal and Saretto (2009), and Do et al. (2015) due to differences in the underlying asset, the examination period and the market area.

6.2.2. Initial margin requirements

So far all the returns that are reported in this study have been price-based returns of volatility spread trading strategy on QQQ. This section considers the impact of initial margin requirements (margin-based returns) on volatility spread trading strategy from 2006 to 2018, and also during the 2008 global financial crisis. There are concluded the benefits of volatility spread trading strategy on QQQ at the end of this section.

Murray (2013) represents that price-based returns ignore the existence of initial margin requirements, which are necessary to consider while calculating the returns of short call option and put option positions. Initial margin requirements are not having an impact to long positions in call and put options. Murray (2013) suggests that initial margin requirements should be used as the denominator as calculating the profits of short option positions, because it offers a more-realistic representation of returns to short call and put option positions than the realized profit or loss divided by the initial price. This study follows closely the margin-based methodology of Murray (2013) to calculate the return of a short option position.

Usually, the exchange sets the initial margin requirements on the security. Often, it relies between 10% and 20% of the underlying asset's price for options and other derivatives. All the reported returns in this section are margin-based returns of volatility spread trading. Furthermore, initial margin requirements are taken from the margin manual of CBOE, where the initial margin requirement of QQQ short straddles is 20% of the spot price of the underlying asset on the moment that trading occurs. According to the margin manual of CBOE, the initial margin requirement for the same underlying asset is the greater one of short call or short put requirements, plus the option proceeds of the other side. (CBOE 2018.)

Table 15. Margin-based returns of volatility spread trading strategy on QQQ from May 2006 to August 2018.

	MidP	PES 100%
Mean return	0.0326	0.0219
Standard Deviation	0.4775	0.5180
DStd. Deviation	0.2258	0.2453
Minimum return	-0.7820	-0.7852
Maximum return	1.8788	1.8298
Median	0.0182	0.0143
Skewness	1.2045	1.1646
Kurtosis	2.6036	2.1116
Sharpe ratio	0.0683	0.0243
Sortino ratio	0.1445	0.0892

Margin-based returns of volatility spread trading strategy on QQQ with mid-point prices (MidP) and real bid-ask spreads (PES 100%) are presented in table 15. From May 2006 to August 2018 volatility spread trading strategy on QQQ generates a monthly return of

2.19% with a standard deviation of 51.80%. This is the return after taking transaction costs (bid-ask spreads and initial margin requirements) into account. The median of volatility spread trading strategy remains positive, even though it is 0.76% lower than the average monthly return. It should be noted that initial margin requirements decrease standard deviation for both the MidP and the PES 100%. On the other hand, margin-based returns have the same semi-standard deviation as in price-based returns. In addition, minimum and maximum returns of the MidP and the PES 100% stay same as presented in table 13.

According to the results of table 15, the Sharpe ratio of volatility spread trading strategy before the transaction costs falls from 0.2260 to the Sharpe ratio of 0.0243 in real-world circumstances. Furthermore, there is also a significant decrease in the Sortino ratio once calculating margin-based returns of volatility spread trading strategy on QQQ. Margin-based returns of volatility spread trading produce a positive skewness of 1.1646 with a kurtosis of 2.1116.

In a comparison to the previous studies of Goyal and Saretto (2009) and Do et al. (2015), the benefits of volatility spread trading strategy on QQQ in real-world settings are similar to its benefits on the US (S&P 500 and Nasdaq 100) and the ASX equity options. For example, Do et al. (2015) present the monthly return of 2.18% between 2000 and 2012 on the ASX equity options. It appears that volatility spread trading strategy is just 1% more profitable on QQQ than on the ASX in real-world circumstances. On the other hand, Do et al. (2015) report the monthly return of 5.69% for the MidP, which is substantially above the mean return of MidP (3.26%) on QQQ. One reason for the variation in returns could be the wider bid-ask spreads on the ASX equity options than on the QQQ options.

Margin-based returns of volatility spread trading strategy on QQQ during the 2008 global financial crisis are presented in table 16. The examination period starts from the June 2007 and lasts to February 2009. The results of table 16 suggest that volatility spread trading strategy is more profitable in bear market condition than in the bull market condition. The average monthly return of volatility spread trading strategy increases from 2.19% to 2.86%. However, the monthly standard deviation rises from 51.8% to 56.51% during the estimation period. In addition, the median is lower during the 2008 global financial crisis than between May 2006 and August 2018. Further, the risk-adjusted return, measured by the Sharpe ratio falls from 0.0243 to 0.0196, but the Sortino ratio increases from 0.0892 to 0.1122.

Table 16. Margin-based returns of volatility spread trading strategy on QQQ during the 2008 global financial crisis.

	MidP	PES 100%
Mean returns	0.0394	0.0286
Standard Deviation	0.5743	0.5651
DStd. Deviation	0.2527	0.2546
Minimum returns	-0.7820	-0.7852
Maximum returns	1.8788	1.8298
Median	0.0128	0.0115
Skewness	1.8169	1.7758
Kurtosis	5.5409	5.4046
Sharpe ratio	0.0381	0.0196
Sortino ratio	0.1559	0.1122

In a summary of margin-based returns of volatility spread trading strategy on QQQ, it seems that volatility spread trading profits are substantially dampened when the initial margin requirements are embedded into calculations. In a comparison to a previous study of Do et al. (2015), the performance of volatility spread trading strategy on QQQ seems to have same kind of results as volatility spread trading strategy on the ASX. Furthermore, Goyal and Saretto (2009) also present similar results, but the magnitude of volatility spread trading returns are slightly higher than the magnitude of volatility spread trading returns on QQQ and on the ASX.

Additionally, volatility spread trading strategy appears to be more profitable trading strategy during the bearish market condition, when the volatility is changing and increasing. On the other hand, the risk-adjusted return is lower in terms of the Sharpe ratio, but higher according to the Sortino ratio. It is argued that the Sortino should be preferred instead of the Sharpe ratio, because it provides a better indicator in order to measure the risk-adjusted return. This is due to the fact that the Sortino ratio considers only the downside deviation as a risk, whereas the Sharpe ratio includes standard deviations of both positive and negative returns.

One reason for the profitability of volatility spread trading strategy during the bearish market condition could be that exchanges may increase initial margin requirements to any level they seem appropriate during periods of high market volatility. Furthermore, the initial margin requirement of QQQ short straddles (20% of the spot price of the underlying asset on the moment that trading occur) may have changed between 2007 and 2009. Therefore, if the exchange have increased the initial margin requirement, then the short option returns would have decreased. Further, the change in the initial margin requirement would have resulted in lower volatility spread trading profits. This is due to the fact that short straddles are mainly used instead of long straddles during the bear market condition. This is in line with previous studies of Hill et al. (2006), and Kapadia and Szado (2012).

As a summary, volatility spread trading strategy offers better monthly returns than a simply “buy and hold” portfolio in real-world circumstances. However, the pure index strategy outperforms volatility spread trading strategy in risk-adjusted returns, when the impact of bid-ask spreads and the cost of initial margin requirements are considered. Do et al. (2015) state that the profitability of volatility spread trading strategy is depending on the trader’s ability to timing their trades precisely and achieve effective spreads well inside the quoted spreads. Also, the findings of this study suggest that the benefits of volatility spread trading strategy seem to depend on the bid-ask spread and how well an option trader can achieve the effective spread within the quoted spread.

7. CONCLUSIONS

During the past decades option strategies have become more popular and nowadays these strategies play a key role in the portfolio's risk management and speculation of the future volatility. Volatility spread trading strategy is made for speculation of future volatility and exploiting the option mispricing. This study demonstrates the attractiveness of volatility spread trading strategy on QQQ index from May 2006 to August 2018. Furthermore, the authenticity of volatility spread trading profits are examined in real-world circumstances.

First, the descriptive statistics present that all three volatilities (HV, IV and RV) are positively correlated with each other. Particularly, IV and RV are highly correlated (0.86) with each other. In addition, RV has the highest standard deviation and the lowest mean, whereas IV has the highest mean. This is in line with results of previous studies (Hill et al. 2006; Goyal & Saretto 2009; Kapadia & Szado 2012; Do et al. 2015) that IV is "a smoothed expectation of future realized volatility". Also, and the impact of the 2008 financial crisis can be observed from the peaks of all three volatilities.

As mentioned in the introduction, there are three hypotheses in this study, which are the following:

> H1: *The difference between historical volatility (HV) and implied volatility (IV) derived from ATM call and put options is a signal that options are mispriced.*
>
> H2: *Volatility spread trading strategy, which goes long positions in options (long straddle) with a positive volatility spread (HV>IV) and enters short position in options (short straddle) with a negative volatility spread (HV<IV), generates economically significant returns.*
>
> H3: *Profitability of volatility spread trading strategy is dampened when bid-ask spreads and initial margin requirements are embedded into calculations.*

This study is in line with previous studies, since volatility spread trading strategy on QQQ appears to be a highly profitable trading strategy when the transaction costs are not embedded into results. Moreover, the performance of volatility spread trading strategy on QQQ suggests that deviations of option implied volatility (IV) from long-run historical levels (HV) provides a signal of option mispricing. This is due to the finding that when IV is above HV, then options tend to be overpriced. Conversely, if IV is below HV, then options are supposed to be underpriced.

The second hypothesis is that the trading strategy, which goes long positions in options with a positive volatility spread (HV>IV) and enters short positions in options with negative volatility spread (HV<IV) produces significant monthly returns. According to several studies, there are strong evidences that volatility spread trading strategy yields economically significant returns (Chen & Leung 2003; Brenner et al. 2006; Goyal & Saretto 2009; Chen & Liu 2010; Do et al. 2015; McGee & McGroarty 2017). The results of this study follow the previous studies, volatility spread trading strategy on QQQ generates substantially high monthly returns compared to a pure index strategy. For an example, volatility spread trading strategy with matched pairs of ATM call and put options offers a monthly return of 13.68% during the examination period, whereas the pure index strategy yields a monthly return of 1.20%. In other words, the volatility spread trading strategy effectively combines long and short straddles based on the sign between HV and IV. However, the benefits of volatility spread trading strategy are substantially dampened when the impact of bid-ask spreads and costs of initial margin requirements are considered.

The third hypothesis is that whether the benefits of volatility spread trading strategy are reduced or eliminated when bid-ask spreads and initial margin requirements are incorporated into calculations. The findings of this study are similar to the studies of Goyal and Saretto (2009) and Do et al. (2015), because transactions costs dampen volatility spread trading returns, but do not eliminate them. For instance, volatility spread trading return drops from 13.68% to 2.19% when both bid-ask spreads and initial margin requirements are taken into account. On the other hand, bid-ask spreads have bigger impact on the profitability of volatility spread trading strategy in the previous studies (Goyal & Saretto 2009; Do et al. 2015) than in this study on QQQ.

In addition, volatility spread trading strategy during the 2008 global financial crisis appears to outperform the same strategy in bull market condition. Volatility spread trading strategy produces higher monthly returns between June 2007 and February 2009 than during the estimation period (2006-2018), which is likely to be explained by the changes in volatility. For example, IV seems to be above HV almost all the time during the 2008 global financial crisis, which suggests that short straddles are mostly used instead of long straddles. Nevertheless, it should be noted that the median of volatility spread trading strategy during the crisis falls below the median of the whole estimation period.

In a summary, the difference between HV and IV appears to provide a valid signal of option mispricing. Moreover, volatility spread trading strategy generates great monthly returns, when trading strategy enters long (short) straddles with a positive (negative) volatility spread (HV -IV). However, comparing the magnitude of volatility spread trading returns of price- and margin-based returns presents the extent to which price-based returns exaggerates volatility spread trading profits. As with Murray (2013), findings of this study suggest that short option returns are substantially overstated, when short option profits are estimated as a proportion of the initial option premium. Furthermore, after embedding the impact of bid-ask spreads, the profitability of volatility spread trading strategy is dropped, but not as much as in the previous studies of Goyal and Saretto (2009), and Do et al. (2015).

For the forthcoming studies, it would be interesting to examine active volatility spread trading strategies on different ETFs and market areas. As with Goyal and Saretto (2009), instead of using long and short straddles on a monthly basis, delta-hedged straddles on QQQ would give a different outcome. Furthermore, active volatility spread trading strategies would increase trading profits. Although, active trading strategies with options can be highly profitable, but due to the impact of transaction costs, the returns may significantly drop in real-world settings.

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