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Improving Option Writing Using VSTOXX

An Empirical Study on Volatility-Timed Strategies in the European Markets

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ABSTRACT :

Tämän pro gradu tutkielman tarkoituksena on tarkastella volatiliteettiriskipreemion ilmenemistä Euroopan markkinoilla sekä osto-optioden (buy-write) ja myyntioptioiden (put-write) strategioiden riski- ja tuotto-ominaisuuksia hyödyntäen Euro Stoxx 50 indeksioptioita. Erityisesti tutkielmassa pyritään arvioimaan, voidaanko implisiittisen volatiliteetin avulla, mitattuna VSTOXX indeksillä, parantaa optiomyyntistrategioiden riskikorjattua tuottoa. Tutkielma pohjautuu aiempaan optiomyyntiin keskittyneeseen kirjallisuuteen (Malkiel et al., 2018), jonka mukaan optioiden myyminen voi parantaa sijoitusten riskikorjattua suorituskykyä erityisesti korkeiden volatiliteettijaksojen aikana.

Tämä tutkielma käynnistyy analysoimalla implisiittisen volatiliteetin ja toteutuneen volatiliteetin suhdetta regressioanalyysin avulla sekä tutkimalla volatiliteettiriskipreemion käyttäytymistä eri implisiittisen volatiliteetin tasoilla käyttäen kvartaalianalyysiä. Tämän jälkeen tutkielma etenee optiomyyntistrategioihin ja niiden analysointiin. Tarkoituksena on seurata Malkiel et al., (2018) esittämää lähestymistapaa ja rakentaa kaksi ehdollista optiomyyntistrategiaa, joissa optioiden kirjoittaminen tehdään vain silloin, kun VSTOXX indeksi ylittää tietyn raja-arvon. Näiden strategioiden suorituskykyä verrataan perinteisiin, jatkuvasti optioita myyviin buy-write ja put-write strategioihin sekä passiiviseen Euro Stoxx 50 indeksiin. Suorituskykyä mitataan riskikorjatuilla tuottosuhteilla, kuten Sharpen ja Sortinon tunnusluvuilla.

Tulokset osoittavat, että VSTOXX indeksi tyypillisesti yliarvioi tulevan volatiliteetin, mikä viittaa volatiliteettiriskipreemioon Euroopan markkinoilla. Lisäksi havaitaan, että yliarviointi kasvaa VSTOXX tason noustessa. VSTOXX indeksin taipumus yliarvioida tulevaa volatiliteettia tarjoaa perustan optiomyyntistrategioiden tuotoille. Perinteiset optiomyyntistrategiat tarjoavat verrattavissa olevat tuotot Euro Stoxx 50 indeksiin nähden, mutta paremmalla riskikorjatulla tuotolla. Ehdollisilla strategioilla, joissa optioita kirjoitetaan vain korkean implisiittisen volatiliteetin tasoilla, saavutetaan merkittävästi parempi suorituskyky niin Euro Stoxx 50 indeksiin kuin perinteisiin optiomyyntistrategioihin verrattuna. Tutkimuksen tulokset ovat linjassa aiemman kirjallisuuden kanssa ja vahvistavat havaintoja optioiden myymisen eduista kohdistamalla tarkastelun Euroopan markkinoille, jota on aiemmassa kirjallisuudessa käsitelty huomattavasti vähemmän. Tutkimus osoittaa, että implisiittisen volatiliteetin tasojen huomioiminen voi tarjota konkreettista hyötyä sijoittajille, jotka hyödyntävät optioiden kirjoittamista osana sijoitusstrategiaansa.

KEYWORDS: Option-Writing, Buy-write, Put-write, Implied volatility, VSTOXX, Volatility risk premium

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1 Introduction

Option markets offer an attractive alternative within modern finance, serving as increasingly important instruments for risk management and tools for speculation (Hull, 2017). In recent decades, many investors have shifted their focus from simply preparing to capitalize on the next bull market to prioritizing strategies that minimize portfolio volatility and improve risk-adjusted returns (Ungar and Moran, 2009). Among these strategies, the systematic selling of options, both calls and puts, has emerged as a favored approach, due to their potential to deliver attractive returns compared to index benchmarks. Option selling exploits the difference between implied volatility and realized volatility favoring option writers as they can sell relatively overpriced options and earn income from option premiums (Umarov et al., 2024).

Volatility is a central topic in financial markets, reflecting the uncertainty of an asset. One key measure of this uncertainty is implied volatility. Implied volatility reflects market expectations about future price fluctuations and serves as a widely recognized indicator of market uncertainty (Nikkinen et al., 2006). Although implied volatility is not directly observable, it can be extracted using option pricing models such as the Black-Scholes option pricing model (Äijö, 2008). Numerous empirical studies have challenged the constant volatility assumption of the Black-Scholes model, showing that implied volatility varies across maturities and strike prices (Dumas et al., 1998; Fengler et al., 2003; Vähämaa, 2004) and tends to systematically overstate realized volatility (Fleming, 1998; Malkiel et al., 2018). This overestimation is referred to as the volatility risk premium which reflects the compensation that option sellers earn for providing insurance against the market risk (Malkiel et al., 2018).

This thesis examines the relationship between implied volatility and realized volatility, as well as the performance of option writing strategies in the European markets. More specifically, this thesis applies data from the Euro Stoxx 50 index and its relative buy-write and put-write indices to investigate whether these strategies produce improved risk-adjusted returns during periods of elevated implied volatility, measured by the VSTOXX index. VSTOXX index is a European counterpart to the U.S.-based VIX index and both indices share structural similarities (Äijö, 2008). Building upon the work of Malkiel et al. (2018), who explore volatility-timed option writing strategies in U.S. markets, this study aims to assess whether similar timing signals can improve strategy performance in European markets.

1.1 Background to the Study

Implied volatility serves as a widely used tool for forecasting future market fluctuations. Studies by Blair et al., (2001), Jiang and Tiang, (2005), and Poon and Granger, (2005) find that implied volatility consistently outperforms historical volatility models in forecasting future market fluctuations. This predictive ability has led market participants to increasingly treat volatility as a separate asset class, with volatility indices being used for tactical asset allocation and strategy optimization (Siriopoulos & Fassas, 2019). For implied volatility, there are many indices that represent the overall market expectations of future volatility. Volatility indices are fundamental approaches to measure implied volatility in practice (Whaley, 2014). Perhaps the most notable volatility index that is available is the Chicago Board Options Exchange's Volatility Index (VIX), and for example Fleming et al. (1995) and Smales (2016) report its effectiveness for traders to predict expected market volatility.

Noted by Malkiel et al. (2018), the volatility risk premium is a key practical foundation for option-writing strategies. Two primary strategies are commonly used in option-writing literature, buy-write and put-write. Earlier empirical evidence supports the profitability of such option-selling strategies, with several studies documenting superior risk-adjusted performance compared to passive benchmarks and highlighting that systematic selling of options on equity indices can outperform traditional index investing (see e.g., Whaley, 2002; Feldman and Roy, 2005; Callan Associates, 2006; Kapadia and Szado, 2007). In addition to the literature focusing on systematic option-selling strategies, Malkiel et al. (2018) demonstrate that the VIX index can be used as a timing tool to improve these traditional buy-write and put-write strategies.

While most academic focus has been directed toward the U.S. market and the VIX index, European options markets have received far less attention. Limited research exists on whether the same risk-return dynamics apply when strategies are applied in the VSTOXX index, which reflects the implied volatility of the Euro Stoxx 50 index. Despite the relevance of VSTOXX in the European markets, it has received far less academic attention than the U.S.-based counterpart VIX. Given the structural similarities between VIX and VSTOXX (Äijö, 2008), extending this analysis to the European context provides less explored yet highly relevant research opportunity.

1.2 Purpose and Motivation

The purpose of this thesis is to explore the risk and return characteristics of buy-write and put-write strategies, intending to provide insights into the European options market. More specifically, this thesis seeks to evaluate whether implied volatility levels, measured through the VSTOXX index, can be effectively used to improve the risk-adjusted performance of the Euro Stoxx 50 Buy-Write and Euro Stoxx 50 Put-Write strategies. Since volatility, particularly implied volatility, plays a key role in this thesis, it is essential to examine its behavior and role in the European options market.

Prior work on volatility demonstrates that implied volatility tends to systematically overstate realized volatility, creating what is known as the volatility risk premium (see e.g., Bakshi and Kapadia, 2003; Todorov, 2010; Bollerslev et al., 2015). Much of that prior research has shown that this premium is not constant but that premiums tend to be typically larger during periods of high implied volatility (see e.g., Malkiel et al., 2018). Therefore, the first objective of this thesis is to examine the volatility risk premium in the European markets. That is, does the volatility risk premium become more pronounced during periods of high implied volatility? For this purpose and using daily volatility data over the period January 2000 to March 2024, the relationship between implied volatility, measured as VSTOXX, and realized volatility, both past and forward, for Euro Stoxx 50 is analyzed. The volatility risk premium represents the core source of return in option writing, providing a rationale for implementing option-writing strategies (Malkiel et al. 2018).

Given the volatility risk premium, the second objective of this study is to evaluate the performance of option-writing strategies in the European market. Specifically, this thesis investigates whether option writing can be improved by analyzing implied volatility levels. That is, can the Euro Stoxx 50 Buy-Write and Euro Stoxx 50 Put-Write strategies be improved by selectively entering option selling based on levels of VSTOXX? For this purpose and using monthly return data from the mentioned indices and the benchmark index Euro Stoxx 50, this thesis constructs two conditional option writing strategies over the period of January 2005 to March 2024. The study is limited to index-level strategies and does not consider individual stocks. The methodology of this paper follows a similar approach to the previous paper provided by Malkiel et al. (2018).

The study is motivated by the earlier literature on option writing, which has found that option-writing strategies offer an attractive alternative to passive-only approaches (see e.g., Whaley, 2002; Kapadia and Szado, 2007; Ungar and Moran, 2009). Moreover, the findings from Malkiel et al., (2018), which indicate that during heightened periods of implied volatility option writing is more efficient and thereby improves the overall performance of those strategies, serve as a key motivation for this thesis.

1.3 Contribution

This thesis contributes to existing literature in two primary ways. First, while prior research such as Malkiel et al. (2018) has studied the performance of conditional option-writing strategies based on VIX levels in the U.S. market, this study shifts the focus to the European context by using the VSTOXX index. Unlike VIX, which has been extensively studied, VSTOXX has received comparatively little academic attention in the context of volatility-based timing strategies, particularly those that deal with option selling on the Euro Stoxx 50 index options. Extending the work of Malkiel et al. (2018) to another relevant and highly liquid market, such as Europe, can provide interesting insights for future research by enabling comparison between two distinct, yet structurally similar markets.

Second, by analyzing the conditional performance of both buy-write and put-write strategies, rather than focusing solely on buy-write, this thesis provides a more comprehensive review of option-writing. Noted by Malkiel et al. (2018) about similar return characteristics of buy-write and put-write, several earlier studies have mainly focused only on the buy-write strategy (see e.g., Whaley, 2002; Feldman and Roy, 2005; Callan Associates, 2006). This distinction between the writing strategies is particularly relevant, as put options tend to be more mispriced than call options, therefore embedding a larger volatility risk premium (Jackwerth, 2000). That is, covering the put-write strategy in the study further highlights the potential of capturing more attractive premiums and reinforces the findings from investor behavior to overstate losses more than gains (Goetzmann et al., 2016; Ang et al., 2018) leading to excess demand for downside protection (Garleanu et al., 2009). Given this, it seems that comparing both option-writing strategies is not only relevant but essential for understanding the full return potential of option-writing.

To the best of my knowledge, there is no existing research that investigates the VSTOXX-based timing strategies for both buy-write and put-write approaches in the context of Euro Stoxx 50 index options.[1] In addition to the academic contribution, this thesis uses a comprehensive dataset spanning over two decades, allowing for an extensive analysis across different market conditions. Besides the academic contribution, the results of this thesis will have practical relevance for traders that are interested in option markets and asset managers that deal with options. As reported by Malkiel et al. (2018) concerning

[1] I am aware of a thesis by Kekki (2024), which examines the risk-adjusted performance of the Euro Stoxx 50 Buy-Write (ATM) index, finding that the index outperforms the Euro Stoxx 50 benchmark. However, the author extends his work by analyzing Buy-Write with different moneyness levels. Despite the similarities regarding the Buy-Write index, the studies employ distinct methods to examine option writing in European markets.

option writing in the U.S. markets, this thesis will provide insights into timing option selling in the European markets, using the VSTOXX index. Findings highlight that market participants may benefit from deeper analysis of VSTOXX when selecting appropriate investment approaches that fit different market conditions. More specifically, the findings from this thesis indicate that option selling in European markets becomes especially attractive during periods of high implied volatility, measured by VSTOXX.

1.4 Structure of the Study

The remaining thesis is structured as follows: Sections 2, 3, and 4 cover the theoretical foundation of this thesis, introducing options, volatility, and option-writing strategies. Section 5 reviews the key literature relevant to this thesis. Section 6 presents the data and methodology that is used for the purpose of this research. Finally, section 7 concludes the thesis, addresses the limitations, and offers recommendations for further studies.

2 Options

To start this study, the following part focuses on introducing the concept of options, as well as the valuation of options. The focus of this thesis is on evaluating the profitability of option writing strategies, and therefore it is important to cover the fundamentals of options and introduce a widely used option pricing model Black and Scholes.

2.1 Basics of Options

Options are contracts that are traded on exchanges or in the OTC market (Hull, 2017, pp. 8). There are always two sides to every option contract, the buyer of an option and the seller of an option. The buyer of an option is referred to as the holder and the seller of an option is referred to as the writer (Hull, 2017, pp.215). Two types of options exist in the markets. The holder of a call option has the right to buy an asset at a certain price on a specific date. Conversely, the holder of a put option has the right to sell an asset at a certain price on a specific date. As stated, an option holder has the right, but not the obligation, to buy or sell an asset that is underlying in the option contract, whereas the writer is obligated to fulfill the terms of an option contract if the holder exercises the option (Hull, 2017, pp. 19). The specified price in the option contract is known as the strike price or exercise price and the date when the option contract can be exercised is known as the maturity date or expiration date (Hull, 2017, pp. 9). When two parties enter an option contract, the buyer pays a non-refundable fee, also known as the premium to the seller (Boczar, 1997).

In addition to the two types, puts and calls, options can also be categorized based on how and when they can be exercised, with each type having its own terms (Alpsten and Samanci, 2018). Options can be either American, European, or exotic options. Most of the options traded on exchanges are American-style options and can be exercised at any time up to the expiration date, whereas European-style options can be exercised only on the expiration date (Hull, 2017, pp. 9). In cases where the option does not follow the typical call or put structure, it is referred to as an exotic option (Hull, 2017, pp. 230).

The profits of put and call options come from the differences between the option's strike price and the price of the underlying asset at the time of expiration (Brenner & Subrahmanyam, 1994). According to Hull (2017), the buyer of a call option makes a profit if the price of the underlying asset increases above the strike price. In this case, the holder can exercise the option contract to purchase the asset at a lower price than its current market price and then sell the asset at the higher market price (Hull, 2017, pp. 214). The seller of a call option makes a profit only if the option expires worthless. In this case, the seller keeps the premium he or she received in advance (Hull, 2017, pp. 214).

In a put option, the buyer makes a profit if the price of the underlying asset decreases below the strike price (Hull, 2017, pp. 2014). In this case, the holder can exercise the option contract and sell the asset at a higher price and then buy it immediately back with a lower market price, generating profit (Hull, 2017, pp. 215). The seller of a put option makes a profit, if the option contract is going to expire worthless. In this case, the seller collects the premium (Hull, 2017, pp. 215). The next figure illustrates the profit pattern of all option positions; Bought and sold call option as well as bought and sold put option.

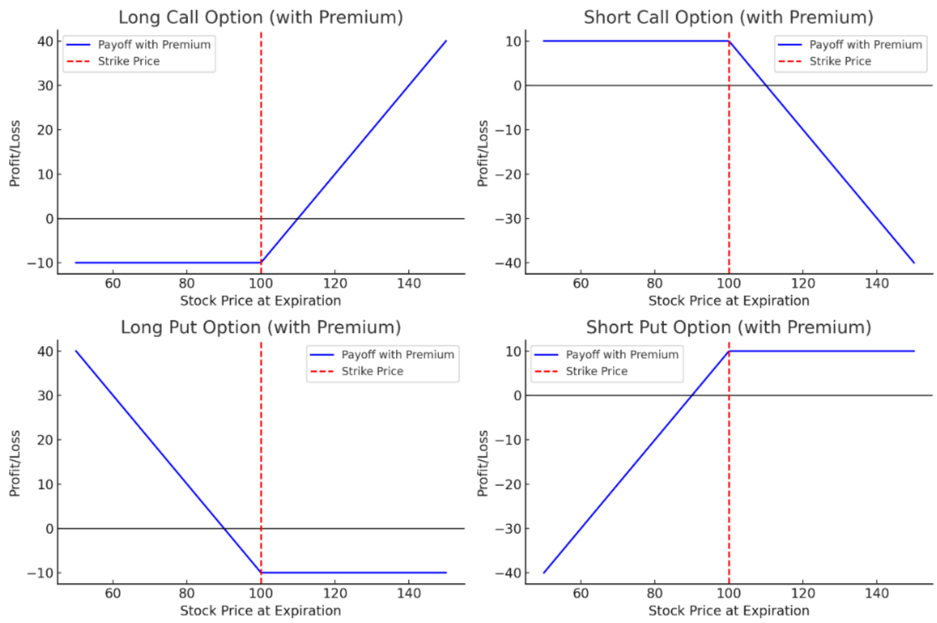

Figure 1. Option Payoffs.

As seen in the first figure, in all cases, the profit potential of the option depends on the difference between the strike price and the price of the underlying asset at the time when the option is exercised. The buyer of a call option hopes that the price of an underlying asset will be higher than the strike price, whereas the opposite position (i.e., the writer) hopes that the option expires worthless. In addition, the buyer of a put option hopes that the price of an underlying will be lower than the strike price, whereas the opposite position again, hopes that the option will expire worthless. If the underlying asset does not move in a favorable direction to the buyer, it results in a loss, that is the amount of the premium that has been paid to the seller (Hull, 2017, p. 10). It is also worth noting that when the loss for the buyer is capped to the premium paid, the seller of an option can potentially have unlimited loss (Hull, 2017).

As discussed, there are two types of options in the derivative markets and their profit potential at expiration depends largely on the difference between the strike and current market price. In addition, there are three different moneyness positions that options can have which are at-the-money (ATM), in-the-money (ITM), and out-of-the-money (OTM). According to Hull (2017), call options are ITM when the price of an underlying asset is above the strike price. Conversely, call options are regarded as being OTM, when the price of an underlying asset is below the strike price. For put options, this relationship between the strike price and the underlying asset is reversed. Both call and put options are referred to as ATM, when the price of an underlying asset is equal to the option’s strike price (Hull, 2017, pp. 220). In theory, options are always exercised on the expiration date when they are ITM and if options are OTM, they expire worthless.

2.2 Valuation of Options

According to Hull (2017), there are six factors affecting the price of stock options:

1. The current price of an underlying asset, S_0

2. The strike price, K

3. The time to expiration, T

4. The volatility of stock price, σ

5. The risk-free interest rate, r

6. The dividends that are expected to be paid.

As noted in the previous chapter, the price of an underlying asset and the strike price have an important relationship when pricing options. If the price of an underlying asset is greater than the strike price, a call option is more valuable, and if vice versa, a put option is more valuable (Hull, 2017, pp. 234). Both call and put options increase in value or, at minimum, retain their value as maturity increases (Hull, 2017, pp. 235). However, if dividends are expected to be paid, that can cause the short-life option to be worth more than the long-life option (Hull, 2017, pp. 238).

Volatility is a measure of uncertainty about future price movements and as volatility increases, the chances that the underlying asset performs poorly or well increases (Hull, 2017, pp. 236). Volatility is an important factor in option pricing as it measures the total risk that is associated with the underlying asset. A more detailed discussion of volatility is provided later in this thesis. However, according to Hull (2017), the holder of a call option benefits from increases in the underlying asset's price but faces limited downside risk, as the maximum loss is capped to the premium paid for the option. Similarly, the holder of a put option profits from price declines while still maintaining limited risk in the case of price increases. Therefore, both call and put options become more valuable as the volatility rises (Hull, 2017, pp. 236).

Interest rates are also a factor that affects option prices since they rise, investors typically demand higher returns from stocks (Hull, 2017, pp. 237). According to Hull (2017), the future cash flows received by the option holder are less in present value terms, when the interest rates increase. As a result of these two factors, call options become more valuable, whereas put options become less valuable (Hull, 2017, pp. 237). The interest rate changes over time and therefore it is a worth-mentioning factor in option pricing.

The market price of an option consists of parts called the intrinsic value and time value. The intrinsic value refers to the value if there was no expiration date and the decision to exercise the option had to be made right away (Hull, 2017, pp. 220). The intrinsic value cannot be negative and as mentioned earlier, the buyer holds the right to exercise the option without any obligation. The option also has a time value, and according to Hull (2017), the overall value of an option can be seen as the sum of its time value and intrinsic value. The time value is the rest of the whole option value beyond its intrinsic value. In conclusion, for a call and put option, the values are formed as,

$$Call = MAX\ (S - K, 0) + Time\ value \tag{1}$$

$$Put = MAX\ (K - S, 0) + Time\ value \tag{2}$$

For anyone engaging in option markets, it is important to consider that the current market price of an option often differs from its estimated theoretical value. Different option pricing models, such as the Black-Scholes-Merton model, are used to determine the theoretical value of an option. However, if traders want to exploit options in the market, they must be aware that the theoretical value of an option and the market price of an option are not always the same. Traders and investors must consider the fact that financial models may not always work as in theory and these financial models may be only cheap tricks (Le, 2015). In the next part, this thesis will discuss more about option pricing using the Black-Scholes-Merton option pricing model.

2.3 Black-Scholes-Merton Option Pricing Model

The pricing of options involved negotiations between buyers and sellers before option pricing models (Mixon, 2009). In the early 1970s, Fischer Black, Myron Scholes, and Robert Merton made a significant contribution to the field of finance with their groundbreaking model known as the Black-Scholes-Merton (or BSM) model. The model was a breakthrough in the financial world and has had a substantial influence on the way that traders price and hedge derivatives (Hull, 2017, p. 321). The BSM is a widely used model amongst option traders to price options and estimate their "fair" value in the market.

Despite being a widely used pricing model for option traders, Vähämaa (2004) notes that many studies have shown that the BSM model does not clearly describe the dynamics of option pricing. According to Shinde and Takale (2012), the BSM model assumes that the underlying asset's volatility is constant over time and that the underlying asset's price follows a random walk. The authors further explain that these assumptions imply that the price movements are unpredictable, yet the size of those movements remains consistent. If these assumptions held true, there should be a distribution in the underlying assets' price, and all these assets should have the same volatility, regardless of their strike prices and maturity (Derman et al. 1995).

The assumptions in the BSM model are clearly not in agreement with the real market and according to Bao (2022), the model has its limitations. It is believed that the reason why the BSM model cannot completely explain the features of actual option prices is due to the assumption of constant volatility (Dumas et al., 1998). Vähämaa (2004) further explains that volatility is not constant, in contrast, it varies over time. In addition to the varying nature of volatility, volatility tends to change across different strike prices and maturities (Dumas et al., 1998). This phenomenon is known as the volatility smile or volatility skew, and many previous studies report the existence of a volatility smile pattern in option markets (e.g., Bakshi et al., 1997; Goncalves and Guidolin, 2006; Li et al., 2021; Bao, 2022). These studies emphasize the fact that some of the assumptions of the BSM model (especially the constant volatility assumption) may not be valid, therefore affecting the accuracy of pricing options using the model, making it systematically bad. It is also found that higher implied volatilities result in greater mispricing by the Black-Scholes model (Nandi, 2000).

As noted earlier, the BSM model accords volatility as a key input in determining the fair market price of an option. However, while being the most important feature out of five other parameters, the significance of volatility is given that it alone cannot be directly observed (Figlewski, 1997). According to Figlewski (1997), all the other parameters in the BSM model, such as the strike price, maturity, and interest rate are accessible through the market, whereas volatility must be estimated. The author also notes that past volatility is easily retrieved from historical data, however, options are priced based on the expectations of future volatility. Therefore, volatility forecasting is an essential fundamental approach for trading options and it remains important for this thesis. Volatility forecasting will be reviewed more in the literature section.

3 Volatility

Volatility is a critical topic for anyone engaged in financial markets. In general finance, volatility is a fundamental concept that measures the degree of variation in the asset's price over time. For many, the term volatility is another word for risk, reflecting the uncertainty about returns (Figlewski, 1997). Statistically, volatility is most commonly measured as the standard deviation of returns for the asset (Daly, 2008). Volatility is usually annualized and described in percentages, for example, it is common to refer to an asset having a 30% volatility on an annual basis. A high standard deviation of an asset indicates larger price swings. Conversely, a low standard deviation of an asset suggests more stable prices. According to Figlewski (1997), a clear understanding of volatility and being able to predict it effectively is the key to success in trading.

There are several ways to represent volatility, each differing in how it is calculated. Realized volatility is a common approach for examining past market movements and trends (Seegopaul and Shuttlewood, 2024). Realized volatility (i.e., past volatility) relies on historical price data reflecting the actual performance of an asset over a given period. Forward volatility (i.e. future volatility) is a similar approach to realized volatility, calculated by using historical data. However, forward volatility aims to estimate the volatility expected over a future period (Seegopaul and Shuttlewood, 2024). In addition to realized and forward volatility, implied volatility, which is derived from option prices, serves as an important approach that will be covered later in this thesis. Implied volatility offers a forward-looking measure based on market expectations of future volatility (Seegopaul and Shuttlewood, 2024).

According to Seegopaul and Shuttlewood (2024), the unique behavior of volatility has led to accepting it as an asset class. The typical characteristics of volatility include its tendency to revert to the mean (Seegopaul and Shuttlewood, 2024). In addition, Vähämaa (2004) notes that volatility is a time-varying function that typically moves in the opposite direction of stock prices. As previously noted, volatility is an important variable of option prices because it is the only parameter that cannot be directly observed from the market. Moreover, traders can use the changes in volatility as an advantage. The information regarding the volatility of an underlying asset will have significant effects on options (Nandi, 2000) and therefore, understanding the volatility of an asset has become a primary concern in modern finance (Fengler et al. 2003). According to Hull (2017), traders in option markets are commonly used to work with the concept of implied volatility.

3.1 Implied Volatility

Implied volatility is a notion that is used in the financial world to describe the expected standard deviation of an asset in a predeterminant period, based on the price of its options. In other words, implied volatility, derived from option prices, offers a forward-looking measure based on market expectations of future volatility (Äijö, 2008). Option traders use implied volatility to evaluate the potential fluctuations in the underlying asset's price and it provides valuable forecastable information about options market (Zulfiqar and Gulzar, 2021). It is one of the deciding factors when valuing options (Deb et al., 2022) and traders tend to discuss the implied volatility of an option more than its actual market price (Hull, 2017, pp. 341).

The implied volatility of an option reflects the changes in its prevailing market price (Guirguis, 2023). According to Äijö (2008), to obtain implied volatility, one must solve the BSM formula for the volatility parameter of the underlying asset price dynamics, based on the option prices that are observed. The differences between the market price of an option and the theoretical price calculated by the BSM model can be attributed to the impact of implied volatility (Guirguis, 2023).

Implied volatility is a key variable in valuing options and implementing trading strategies (Chen & Zhang, 2019). Thus, implied volatility is an important parameter to consider for option traders, and in the context of this thesis. When market practitioners are expecting higher implied volatility, the price of the option is more expensive because of the price fluctuation risk and the expected premium that these practitioners demand (Goyal & Saretto, 2006; Fengler, 2003). This also applies in the other direction. When the implied volatility is low, that leads to cheaper option prices, because traders are not expecting that much premium (Deb et al. 2022). Higher implied volatility leads to higher option prices and conversely, higher option prices result in higher implied volatility (Rhoads, 2011). Therefore, implied volatility is a crucial component in options valuation as it has a direct effect on the value of an option.

Implied volatility is an important factor to be considered, especially for this thesis. As previously noted, when implied volatility is high, the option prices are also higher, making the premiums more attractive to option sellers. This observation serves as motivation when moving forward. On the other hand, when selecting the best trading strategy based on implied volatility estimation, it can also lead to significant losses, as implied volatility is a very unpredictable factor in the market (Zulfiqar & Gulzar, 2021). A deeper discussion about volatility estimation, premiums, and option writing strategies is presented later in this thesis.

3.2 Volatility Smile

As noted earlier, the volatility smile refers to the phenomenon where implied volatility for options is not constant but varies across different strike prices. According to Chaput & Ederington (2005), the reason why volatility smiles occur is miscalculating implied volatilities by using a wrong model, referring to the Black-Scholes model. As noted, the existence of volatility smile is reported in various papers (e.g., see Bakshi et al., 1997; Goncalves and Guidolin, 2006; Li et al., 2021; Bao, 2022). To explain the characteristics of the smile, Bakshi et al., (1997) note that the smile is typically observed when a call or put option moves from at-the-money to in-the-money or from at-the-money to out-of-the-money. The authors further explain that the implied volatility tends to increase when moving from at-the-money, creating a skewed shape for both options. According to Bakshi et al., (1997), the highest implied volatility levels were discovered for the deepest in-the-money call options and the deepest out-of-the-money put options. The variation in the levels of implied volatility leads to the conclusion that market participants have different expectations for future price movements in the underlying asset and that the smile pattern reflects higher implied volatility for options that are not at-the-money.

Although not analyzed in detail, the observation about the smile and the differences between moneyness levels are acknowledged in this thesis. Regarding at-the-money options, according to Fleming et al., (1996), they exhibit the highest trading volumes and the lowest bid/ask spreads, improving the pricing efficiency. This is particularly relevant given that option-writing strategies are commonly implemented using at-the-money or slightly out-of-the-money options (see e.g., Whaley, 2002; He et al., 2014; STOXX, n.d.). Given that the methodologies for U.S-based writing strategies (e.g., Malkiel et al., 2018) and the European-based writing strategies covered in this thesis may have slightly different approaches based on moneyness level, they are similar in the way that both predominantly rely on near-the-money options in practice (see e.g., CBOE, n.d.; STOXX, n.d.). Both CBOE and STOXX provide methodologies for the buy-write and put-write strategies.

Regarding the volatility smile, this thesis acknowledges the previous findings that implied volatility tends to vary with strike prices. Another important consideration relates to the pricing dynamics of options with different moneyness levels. According to Bakshi et al., (1997), options that are deeper in-the-money or out-of-the-money tend to be the most mispriced. Similarly noted by Nandi (2000), higher implied volatilities usually result in greater mispricing. This may be a somewhat important consideration for this thesis, as the study utilizes a Put-write index that sells slightly out-of-the-money options, potentially influencing the results at some level. While the volatility smile is not the main focus of this thesis, however, acknowledging this phenomenon may provide useful information for future research, particularly for those that examine different moneyness levels in option writing.

3.3 Volatility Index

As noted earlier, implied volatility and realized volatility offer two distinct but connected perspectives on market movements. As for implied volatility, there are many indices that represent the overall market expectations of future volatility. Volatility indices are fundamental approaches to measure implied volatility in practice (Whaley, 2009). Perhaps the most notable volatility index that is available is the Chicago Board Options Exchange's Volatility Index (VIX). The VIX, often referred to as a "fear gauge", captures the concept of implied volatility, measuring the expected one-month volatility of the S&P 500 index (Malkiel et al., 2018).

According to Whaley (2009), the purpose of VIX is to serve as a benchmark of anticipated short-term volatility, being an important tool for documenting market concerns. Additionally, VIX was designed to provide a foundation for writing options and futures (Whaley, 2014). As the VIX spikes around different market events, traders seek to speculate the direction of implied volatility by buying or selling depending on the current level of VIX (Whaley, 2014). The VIX is commonly used by traders to assess the overall level of uncertainty and to trade volatility itself using VIX futures and options (Whaley, 2014).

Fleming, Ostdiek, and Whaley (1995) study the statistical features of the VIX index and investigate its effectiveness for forecasting market movements. The authors report a strong negative relationship between changes in VIX and equity returns, however, further explain that as equity prices fall, VIX tends to increase more sharply than it decreases when equity prices rise. Fleming et al., (1995) also find that VIX is closely linked to future realized volatility and serves as a reliable estimate for expected market volatility. Consistent with the findings of Fleming et al., (1995), Whaley (2009) points out that VIX is a fairly reliable indicator of anticipated market volatility. The author also emphasizes the forward-looking nature of VIX. This finding is particularly relevant to this study, as the strategy construction relies on the forward-looking nature.

Additionally, a more recent study provided by Smales (2016) examines also the negative contemporaneous relationship between movements in VIX and equity returns. Smale (2016) finds the same results as Fleming et al. (1995) and Whaley (2009) about the relationship between VIX and returns. Additionally, Smales (2016) points out that VIX serves as a useful tool for traders when forecasting future returns. According to Smales (2016), traders are attracted to take short positions when implied volatility is high.

Studies by Fleming et al. (1995), Whaley (2009), and Smales (2016) provide valuable insights into implied volatility and volatility indices, contributing to the development of option writing strategies. Equivalent to the VIX index, the European version volatility index VSTOXX, measures the expected market volatility in European markets using options on the Euro Stoxx 50 index (Äijö, 2008). According to Äijö (2008), the VSTOXX is developed following a similar approach to the VIX. The VSTOXX index serves as a foundational concept for this thesis since, as discussed previously, the option prices increase when markets are nervous, resulting in larger expected premiums.

4 Option Strategies

Option strategies refer to different techniques used by investors to build investment tactics for maximizing profits and minimizing losses. In other words, option strategies are known to improve the versatility of potential returns that can be gained from investment strategies (Bookstaber and Clarke, 1984). There are numerous option strategies traders can use for hedging and speculation purposes. According to Hull (2017) the strategy choice traders make depends on their judgment about how prices will change and their willingness for risk-taking. Option strategies use different combinations of options and underlying assets in various ways to reflect the views of market movements (Hull, 2017). A conservative trader may choose a more stable butterfly spread, while a more risk-tolerant investor might prefer a straddle strategy, which offers greater potential for both profits and losses (Hull, 2017, pp. 254). The focus of this thesis lies within two option selling strategies, a buy-write and a put-write, which are covered in the following section. Market participants use option selling strategies to capture the volatility premium as a reward for bearing the risks of providing this insurance for other investors (Malkiel et al. 2018).

4.1 Option-Writing

A buy-write option strategy, also known as a covered call, involves buying individual stocks or combinations of stocks while simultaneously writing call options on those same holdings (Malkiel et al. 2018). This approach aims to generate additional income through the premiums received from selling the options while potentially reducing portfolio volatility (Callan Associates, 2006). For example, if an investor buys a share of a stock and writes a call option against the long stock position, the investor receives the premium from the buyer, which provides immediate income. According to Callan Associates (2006), in declining markets the premium earned from selling a call option provides a cushion, helping to offset the losses from the underlying asset. However, in rising market conditions, the buy-write strategy imposes a limitation on potential gains received as the buyer exercises the call option when the stock price rises (Callan Associates, 2006). Therefore, the buy-write strategy trades off the upside potential to receive a more stable income and the effectiveness of a buy-write strategy is closely tied to market conditions. The performance of a buy-write strategy in bear markets is expected to be better than the performance of a long-only position, while in bull runs, the buy-write is expected to underperform the long-only position (Callan Associates, 2006).

The put-write strategy, also known as the collateralized put, involves selling a put option contract on the underlying asset, while at the same time, setting aside cash to cover the potential purchase of that asset if the put is exercised (Ungar and Moran, 2009). While the cash is left aside for the potential purchase, it is generally invested in a risk-free asset (Lo and Liu, 2024). Like the buy-write strategy, a put-write strategy provides also access to the volatility risk premium. Similarly, investors who aim to generate additional income and improve risk-adjusted returns will have to accept the possibility of underperformance in strong bull markets (Ungar and Moran, 2009). According to Ungar and Moran (2009), the return and risk profiles are the same for put-write and buy-write strategies. The upside is capped at the premium received from the buyer of that option, while the downside risk mirrors the losses of the underlying asset, offset slightly by the option premium received (Ungar and Moran, 2009). However, the underperformance of both option writing strategies due to capped upside potential in the bull runs is often recovered quickly in the following months through the steady collection of rich option premiums (Ungar and Moran, 2009).

According to Malkiel et al. (2018), the focus has been more on the buy-write strategy in financial literature, as both strategies have very similar return characteristics. However, the study provided by Ungar and Moran (2009) reports the outperformance of the put-write strategy over the buy-write strategy, indicating that the premium received from selling put options is captured perhaps even more directly by writing put options. The authors explain this by the pricing differences in both writing strategies. The previous literature from both option-selling strategies will be reviewed more in the next part of the thesis as well as give a more detailed discussion about the volatility risk premium.

In the context of this thesis, both the buy-write and put-write strategies are used in the analysis. As such, it is important to present the theoretical framework underlying these two strategies. The next figure is intended to represent the payoff of both buy-write and put-write strategies. In Figure 2, the underlying index strike price is 50€ and both call and put options are priced at 5€, indicating the premium.

Figure 2. Payoff, Buy-write and Put-write.

The blue line represents the payoffs from a simple buy-and-hold index strategy. In this case, the investor benefits or loses in direct proportion to the index price movement. The buy-write strategy, represented by the dashed brown line, involves purchasing the index and writing a call option at 5€. The sold call results in capped profits at 5€. If the index price rises above 50€, the call option is exercised, requiring the investor to sell the index at 50€. However, the investor still retains the 5€ premium received from writing the call, which means the maximum profit achievable is 5€. If the index price falls below

50€, the investor continues to hold the index. While losses accumulate as the index declines, the 5€ premium reduces the downside exposure. The investor experiences a net loss only if the index price drops below 45€.

The put-write strategy, which follows the same dashed brown line, involves selling a put option at 5€. If the index price remains above 50€, the put expires worthless, allowing the investor to keep the full 5€ premium. However, if the index price falls below 50€, the put option is exercised, forcing the investor to buy the index at 50€. The 5€ premium cushions these losses, making the breakeven point at 45€. If the index price drops below 45€, the writer of a put begins to suffer a net loss, which continues to increase as the index declines.

According to Malkiel et al. (2018), the advantage of both option-writing strategies is that they offer comparable returns to the broader market index while reducing volatility, resulting in higher risk-adjusted returns. The authors further note that a few key features contribute to the performance of writing tactics. When the underlying asset declines, the premium received covers some losses. Additionally, put-write strategies generate yields from Treasuries, while buy-write strategies earn dividends from the underlying asset. Finally, the strategies' capped upside potential leads to reduced overall volatility of returns (Malkiel et al., 2018).

5 Prior Literature

After reviewing the basic theoretical concepts relevant to this thesis, the following section presents a more in-depth discussion of key literature focusing on volatility and option writing. The previous literature that is relevant to this thesis is categorized into three main areas. The first section focuses on reviewing previous studies on volatility forecasting and its importance to this thesis. The idea of the first part is to provide a comprehensive overview of previous research findings and the common methods used by market participants to predict volatility in the options market. The second part of the literature covers previous studies on the volatility risk premium and its importance in option writing. Finally, the last part concludes the literature by exploring option selling strategies.

5.1 Volatility Forecasting

A vast amount of research has been conducted on volatility forecasting. Numerous methods exist for forecasting future volatility, primarily categorized into two groups that are time-series models and implied volatility derived from option prices (Ederington and Guan, 2005). Time series models are based on historical price data, while the implied volatility reflects market expectations of future volatility (Poon and Granger, 2005). The foundation of these models can be traced back to Engle's (1982) groundbreaking paper on the time series autoregressive conditional heteroskedasticity (ARCH) model, which introduced a framework for forecasting volatility based on its time-varying nature using historical information. Since ARCH, the time-varying volatility models were extended by Bollerslev (1986), who developed the generalized autoregressive conditional heteroskedasticity (GARCH) model, along with its numerous extensions, which have become widely applied approaches in volatility forecasting.

Time-series models capture the behavior of volatility by relying only on past returns (Poon and Granger, 2005). While being useful and widely employed for forecasting future volatility, the limitation of these models is that they do not capture the expectations about future market sentiment. To address this limitation, researchers and practitioners often turn to implied volatility which, as noted before, is a forward-looking measure that reflects the expectations about future movements. Very early research on this topic, conducted by Latane and Rendleman (1976), suggested that implied volatility could serve as a more accurate predictor of future volatility than historical models. The findings from Latane and Rendleman (1976) were later supported by studies such as Schmalensee and Trippi (1978) and Chiras and Manaster (1978), who recorded the forecasting superiority of implied volatility.

However, since the early findings from Latane and Rendleman (1976), Schmalensee and Trippi (1978), and Chiras and Manaster (1978), various research papers have compared the forecasting ability between implied volatility and time-series models with mixed results. According to Figlewski (1997) implied volatility is widely regarded by academics and practitioners as the best predictor of future volatility, as it integrates all publicly available information, including historical price data. Poon and Granger (2005) survey these volatility forecasting methods and the authors find that among these methods, implied volatility provides the most accurate forecasts compared to other methods. However, there is also evidence suggesting that implied volatility may not be an accurate predictor of future volatility (see e.g., Day and Lewis, 1992; Canina and Figlewski, 1993), but according to Capelle-Blancard (2001), it is accepted that implied volatility is a reliable predictor of market expectations. Supporting this conclusion about implied volatility as a reliable estimator of future volatility, several other studies demonstrate the predictive superiority of implied volatility over historical or model-based measures (Blair et al., 2001; Jiang and Tian, 2005; Malkiel et al., 2018).

An important finding in volatility research, which is especially relevant to this thesis, and as noted by Malkiel et al., (2018) is that equity market volatility reacts differently to past gains and losses. According to Fleming et al. (1995), as equity prices fall, implied volatility tends to increase more sharply than it decreases when equity prices rise. Additionally, Campbell and Hentschel (1992) investigate this asymmetric nature of stock return volatility, suggesting that negative returns lead to greater increases in future volatility than equivalent positive returns. Two primary explanations for this asymmetry include the leverage effect (Black, 1976; Christie, 1982) and the volatility feedback hypothesis (Campbell and Hentschel, 1992; Bekaert and Wu, 2000). The leverage effect claims that a decline in the stock's price raises the financial leverage of the company, making the stock riskier and leading to higher volatility. However, according to Bekaert and Wu (2000), the leverage effect is unable to fully explain the extent of volatility reactions. The broader theory behind this asymmetric response between returns and volatility is the volatility feedback effect, and according to Malkiel et al., (2018), increased volatility demands higher expected future returns to offset the greater risk, which in turn causes a decline in the current stock price following the initial rise in volatility. Both the leverage effect and the volatility feedback hypothesis help in explaining why negative returns tend to be followed by higher future volatility than equally sized positive returns.

The findings about the asymmetric dynamics of volatility may help better explain why implied volatility reflects more accurately future risk than historical movements. Moreover, understanding this asymmetry is essential when assessing the predictive performance of volatility measures. In addition to volatility dynamics covered in this chapter so far, perhaps one of the most consistent empirical findings in volatility research is that implied volatility tends to systematically overestimate future realized volatility, particularly during periods of market uncertainty (e.g., see Fleming, 1998; Malkiel et al., 2018). This overestimation forms the basis that is known as volatility risk premium (Bollerslev et al., 2015). Options reflect this premium as market participants tend to overestimate the probability of losses more than gains (Goetzmann et al., 2016). The concept of volatility risk premium is central to the rationale behind option-selling strategies (Malkiel et al., 2018) and is covered in the next section.

5.2 Volatility Risk Premium

As noted in the previous chapter, the volatility risk premium refers to the tendency for implied volatility, as reflected in option prices, to exceed corresponding realized volatility. In other words, options on equity indices are generally priced such that the expected variance of returns is higher than the actual variance that materializes (Bollerslev et al., 2015). The volatility risk premium arises because market participants require compensation for the uncertainty in asset prices caused by fluctuations in volatility (Todorov, 2010). Option sellers capture this volatility risk premium by offering protection for market downturns (Malkiel et al., 2018).

The existence of a volatility risk premium in index options is explained in both risk-based explanations and behavioral factors. From the risk-based view, the volatility risk premium is viewed as the compensation for investors bearing the volatility risk (Malkiel et al., 2018). As volatility spikes during market downturns, risk-averse investors are willing to pay this premium as insurance for their investment, causing the implied volatility to exceed the corresponding realized volatility (Bakshi and Kapadia, 2003). For instance, Bakshi and Kapadia (2003) demonstrate that overall market volatility is significantly priced by investors, whereas firm-specific volatility is not, indicating that only broad market risk is rewarded with a premium.

Equally important to the risk-based view is the behavioral explanation, which indicates that investors typically overestimate the downside risk. Goetzmann et al., (2016) document these behavioral biases for investors leaning toward pessimistic risk expectations. Their results show that about two-thirds of investors estimate a 10% probability of a severe market crash occurring within six months, while the actual probability is recorded at close to 1%. According to Ang et al., (2018), this overestimation encourages insurers to demand even higher compensation, making the spread between implied volatility and realized volatility more persistent. Together, the risk-based view and the behavioral explanation for the volatility risk premium offer an understanding of why implied volatility tends to systematically overestimate realized volatility.

Academic studies have extensively documented the volatility risk premium in equity index options. For instance, Coval and Shumway (2001) studied the delta hedged at-the-money straddle on the S&P 500 and found that the strategy yields significant positive returns. Their findings also imply that options are systematically overpriced relative to realized volatility, confirming the volatility risk premium in the S&P 500 index options. Bakshi and Kapadia (2003) conducted an analysis of selling index options, while maintaining delta-hedged position. Their results produced consistently positive gains, attributing to the negative volatility risk premium faced by the buyers of options. The authors concluded that the premium is economically large, roughly 16% of the price of an at-the-money S&P 500 call option can be attributed to the volatility risk premium. Likewise, Bollerslev et al., (2015) report that the volatility risk premium in the US markets is large and time-varying with the important conclusion that it also has predictive power regarding future returns.

Numerous relevant studies have also documented the existence of the volatility risk premium beyond U.S. markets. Londono (2015) documents volatility risk premium in several European markets with its time-varying function, however, his findings suggest that the magnitude of volatility risk premium is smaller than in U.S. markets. In contrast, more recent work conducted by Held et al., (2020), confirms that European index options exhibit a statistically significant premium that is very similar to the premium in the U.S. markets. The findings about volatility risk premium in European equity indices reported by Held et al., (2020) are particularly relevant to this thesis, as option writers in European markets likewise earn a premium comparable to that in the U.S.

The volatility risk premium has also been identified in Asian equity index options, though its magnitude and characteristics can differ from the dynamics of the U.S. and European markets. Driessen and Maenhout (2013) examined whether volatility and jump risks are priced locally or internationally using index options data from the U.S., U.K., and Japan. The authors found evidence for weaker pricing dynamics in the Japanese market, which suggests the volatility risk premium plays a less significant role in explaining option returns compared to Western markets. Yoon and Byun (2012) studied the risk-aversion and volatility risk premium between the S&P 500, Nikkei 225, and KOSPI 200, finding U.S. investors to be the most risk-averse in pricing volatility, suggesting larger premiums compared to Asian markets. The findings of Driessen and Maenhout (2013) and Yoon and Byun (2012) highlight differences in the volatility risk premium across different markets. However, they conclude that the same overall pattern holds for each market, namely, that implied volatility tends to exceed realized volatility, allowing investors globally to exploit this pattern.

The volatility risk premium in the equity index options is a well-documented phenomenon across different markets. All the covered studies in this chapter so far find that on average, the implied volatility tends to be higher than the corresponding realized volatility. This consistent pattern forms a solid foundation for exploring the option selling strategies, which aim to capture this premium.

5.3 Option-Writing

As discussed in the previous section, given that the anticipated volatility typically exceeds the realized volatility, option-writing strategies can offer better risk-return profiles compared to traditional equity investments (Malkiel et al., 2018). According to Figelman (2008), for investors to find option selling appealing, they must believe that implied volatility will, on average, exceed realized volatility going forward. The final part of the literature covers previous findings from option writing literature. While numerous studies have examined option writing, the majority have primarily concentrated on the buy-write strategy and have been largely conducted in U.S. markets, with a few exceptions. This emphasis is largely due to the similarities in the return characteristics of both option-writing approaches (Ungar and Moran, 2009; Malkiel et al., 2018).

The first buy-write index was launched by the Chicago Board Options Exchange (CBOE) in 2002, known as the Buy-Write Index (BXM), designed to track the performance of a covered call strategy using the S&P 500 Index as the underlying asset (Malkiel et al., 2018). An early analysis of the BXM conducted by Whaley (2002) examined this option-selling strategy's performance between 1988 and 2001, revealing that it achieved returns comparable to the S&P 500 index while experiencing significantly lower volatility, with a standard deviation of approximately one-third less. Like Whaley (2002), Feldman and Roy (2005) compared the BXM index to the S&P 500 index finding similar results, that the BXM index has outperformed the standard index on a risk-adjusted basis. Feldman and Roy (2005) further explain that the consistently higher implied volatility of index options, along with the assumed presence of a volatility risk premium, are key factors that may contribute to the observed outperformance of the BXM index. In addition to these findings, subsequent studies by Callan Associates (2006) and Malkiel et al. (2018), with extended analysis period, found similar results from the performance of the BXM index. These findings suggest that the BXM index is an effective alternative to traditional investments, offering improved risk-adjusted performance.

The option writing literature focuses mainly on the U.S. markets, especially in the S&P 500 index and its relative buy-write index, but there are well-documented studies across other indexes and markets. For example, Kapadia and Szado (2007) examine the risk and return characteristics of the buy-write strategy on the Russel 2000 Index, from the period 1996-2006. Similarly to the previous findings of the BXM index, Kapadia and Szado (2007) find that the buy-write strategy has consistently outperformed the Russel index on a risk-adjusted basis. The authors also evaluate the performance of the buy-write strategy in different market conditions and find that the worst market condition for the strategy is in a period of relatively low volatility. The findings are consistent with the previous findings about the volatility risk premium. According to Kapadia and Szado (2007), the buy-write strategy gains an advantage by selling call options when implied volatility exceeds the actual realized volatility. The presence of the volatility risk premium seems to play an important role in the effectiveness of the buy-write strategy, as demonstrated by Kapadia and Szado (2007).

O'Connel and O'Grady (2014) and Mugwagwa et al., (2012), study the buy-write strategy in the Australian market comparing its risks and returns to different benchmarks. The results support previous findings that index-only portfolios exhibit lower returns and higher variances than the buy-write strategy. In addition, O'Connel and O'Grady (2014) note that relatively small options markets, like Australia, often lead to mispricing in options creating even more arbitrage opportunities for investors employing the buy-write strategy. The findings of both O'Connel and O'Grady (2014) and Mugwagwa et al., (2012) are consistent with previous studies and suggest that traditional financial theories do not fully capture the complexities of real-world market behavior, allowing the buy-write strategy to generate excess returns, through the volatility risk premium.

Studies covered so far demonstrate the effectiveness of the buy-write strategy in the options market. As noted previously, the option literature mainly focuses on the buy-write strategies, and this emphasis is largely driven by the comparable return characteristics with the put-write strategy. However, regarding the put-write strategy, Ungar and Moran (2009) analyzed the performance of put-writing in comparison to other approaches during the period from 1986 to 2008 and concluded that put-writing consistently delivered better returns than the standard buy-write strategy. The risk-adjusted performance of the put-write strategy was also found to be better than the buy-write strategy. Ungar and Moran (2009), continue that the source of outperformance of the put-write strategy is linked to the mispricing of put options so that their implied volatility tends to be higher than the corresponding realized volatility of the underlying.

Malkiel et al., (2018) found similar results that the put-write strategy outperforms the buy-write strategy. The authors also extend prior literature by proposing two alternative writing strategies, where they only sell options if the prior month's implied volatility level exceeds the historical median level. Their findings revealed that the proposed strategies performed better than the original buy-write and put-write strategies. Furthermore, the authors highlight that option selling tends to be more profitable during periods of high implied volatility. According to Malkiel et al., (2018), the overestimation of implied volatility relative to realized volatility is typically greatest during these periods, making the option selling strategies more attractive in such periods. These findings from Malkiel et al., (2018) serve as a key motivation for this thesis as well.

To analyze the outcome that the put-write strategy has performed better compared to the buy-write strategy (see Ungar and Moran, 2009; Malkiel et al., 2018), Jackwerth (2000) examines the mispricing of options and finds evidence that especially out-of-the-money put options are overpriced in the market. The mispricing of options is well-studied amongst academics and researchers have proposed various reasons, especially for a put option mispricing. Bakshi and Kapadia (2003) examined the relationship between option overpricing and the volatility risk premium, highlighting the fact that investors regularly overpay to hedge against volatility risk. According to Bakshi and Kapadia (2003), investors are willing to pay a premium to gain exposure to volatility, leading to systematically higher option prices. Malkiel et al., (2018) suggest that option prices incorporate a volatility premium due to market participants' tendency to overestimate the likelihood of significant market downturns, leading to persistently higher option valuations. In addition to the option mispricing, Gârleanu et al. (2009) link the overpricing to excess demand for downside protection further reinforcing the mispricing of put options. As demonstrated by the literature in this section, investor behavior contributes to the demand for protective puts, resulting in the overpricing of put options and helping to explain why put-write strategies have historically outperformed buy-write strategies.

Beyond standard covered call or put-write strategies discussed in this chapter so far, further research has shown that adjusting the selection of options for selling can potentially improve returns. For example, McIntyre and Jackson (2007) and He, Hsu, and Rue (2014) select the options using different expiration dates and strike prices. Their studies are consistent with previous findings that writing options provide attractive risk-adjusted returns compared to traditional investments. In addition, He et al., (2014) found that using at-the-money, three-month maturities, maximizes the performance of option writing. Further research by Diaz and Kwon (2017) optimizes writing by using different combinations of strike prices, suggesting that the optimization yields better risk-return outcomes. The studies conducted by McIntyre and Jackson (2007), He et al., (2014), and Diaz and Kwon (2017) offer interesting insights into tailoring traditional buy-write and put-write strategies. While these studies have concentrated on analyzing strategies based on option structures, the focus of this thesis remains on analyzing the performance of two strategies that sell options during specific market conditions marked by heightened levels of VSTOXX.

6 Data and Methodology

As discussed earlier, option writers benefit from the disparity between implied volatility and realized volatility as it provides the advantage for generating returns through option premiums. The research design of this thesis consists of two steps that follow the approach of Malkiel et al., (2018). To examine the volatility risk premium in the context of Euro Stoxx 50 index options, three simple linear regressions, and a quartile-based volatility analysis are used to get a comprehensive view of the relationship between implied volatility, represented as VSTOXX, and the corresponding realized volatility measures. Similarly to Malkiel et al., (2018), this thesis uses daily closing data for the Euro Stoxx 50 index to calculate the realized volatilities for the past month and the next month. In addition to realized volatility measures, daily VSTOXX index values are used in this thesis. The properties of used data are covered later in this part. The volatility analysis is central to the main objective of this thesis, which examines the profitability of option-writing strategies in European markets and assesses whether these strategies can be improved from their traditional approaches by selectively entering option selling based on implied volatility levels. Followed by the volatility risk premium analysis, two additional option writing strategies are constructed and analyzed.

This study builds upon the empirical evidence found in this thesis about the volatility risk premium. That is, the first objective of the research is to examine whether the volatility risk premium becomes more pronounced during periods of high implied volatility. It is well established in the literature that volatility is time-varying (Vähämaa, 2004; Londono, 2015; Bollerslev et al., 2015; Smales, 2016) and that the tendency for implied volatility to overestimate realized volatility becomes more pronounced during high volatility periods (Fleming, 1998; Malkiel et al., 2018). This behavior of volatility provides the motivation for examining whether the risk and return characteristics of option writing can be improved in the European markets.

Empirical findings from Malkiel et al., (2018) support the rationale that timing option writing based on implied volatility levels leads to improved performance. That said, if the traditional buy-write and put-write indices generate excess returns over the benchmark Euro Stoxx 50 when moving to higher levels of VSTOXX, it follows that implementing these strategies on higher volatility conditions may be more effective.

Building upon these findings, this thesis continues to construct two conditional option writing strategies that are designed to exploit this volatility behavior. The methodology for strategy construction is explained in the following sections. In line with the approach of Malkiel et al., (2018), the analysis uses monthly closing values for all indices, as the European option-writing benchmarks follow a monthly roll process (STOXX, n.d.). In addition, STOXX provides the data and documentation on the construction methodology of both the Euro Stoxx 50 Buy-Write and Euro Stoxx 50 Put-Write.

6.1 Data Overview

This section covers the data used in this thesis, including data sources, sample periods, and structure of the dataset. The data for the empirical analysis is divided into two main components. The first dataset focuses on analyzing the relationship between implied volatility, realized volatility, and forward volatility in the European markets. The second dataset evaluates the performance of option-writing strategies under varying levels of implied volatility. All data for this thesis has been retrieved from the STOXX website and is publicly accessible.

The dataset for volatility analysis includes daily closing values for the Euro Stoxx 50 index to examine the volatility risk premium in the Eurozone. In a similar vein to the Euro Stoxx 50 index, daily values for the Euro Stoxx 50 Volatility Index (VSTOXX) are obtained. The Euro Stoxx 50 index represents the benchmark index of large-cap European equities, while the VSTOXX index reflects the implied volatility derived from options on the Euro Stoxx 50 (STOXX, n.d.). According to Stanescu and Tunaru (2013), the VSTOXX provides a forward-looking measure of market uncertainty, similar in design to the VIX index used in U.S. markets. As stated on the Eurex website, the VSTOXX index is based on options with a 30-day maturity reflecting next-month expectations of volatility in the Eurozone. Like the VIX index used in the U.S. markets, VSTOXX offers the most accurate way to engage with European volatility (Eurex, n.d.).

The sample period for the volatility analysis spans from January 2000 to March 2024. This period was selected to ensure the inclusion of multiple market environments. The study by Malkiel et al., (2018) examines the relationship between volatility measures over a period of nearly 30 years. However, due to data availability on the VSTOXX index, this thesis uses a slightly shorter time span of approximately 25 years. Daily logarithmic returns from the Euro Stoxx 50 index are used to calculate the realized volatility measures, while VSTOXX offers the measure of implied volatility.

Following the work of Malkiel et al., (2018), the following notation is used to define the volatility measures employed in this study. Let V_t denote the daily closing value of the VSTOXX index at time t, representing the implied volatility based on Euro Stoxx 50 options. The measure of past realized volatility, denoted as R_t, is calculated as the standard deviation of daily log returns of the Euro Stoxx 50 index over the past 21 trading days. Similarly, forward realized volatility, denoted as F_t, is calculated as the standard deviation of daily log returns over the subsequent 21 trading days, starting from day *t+1*. Equations 3 and 4 present the formal definitions of both volatility measures, R_t and F_t. For consistency and comparability with the VSTOXX index values, both realized volatility measures are expressed as annualized daily volatility and scaled by a factor of 100.

$$R_t = Std(r_t, r_{t-1}, \dots, r_{t-20}) \quad (3)$$

$$F_t = Std(r_{t+1}, r_{t+2}, \dots, r_{t+21}) \quad (4)$$

Table 1. Descriptive statistics for volatility measures, January 2000 to March 2024

	Past Realized Volatility	Forward Realized Volatility	VSTOXX
Mean	20,01	19,91	23,52
Median	17,06	16,97	21,36
Standard Deviation	10,89	10,88	9,41
Sample Variance	118,58	118,39	88,64
Kurtosis	5,35	5,43	4,79
Skewness	1,99	2,00	1,83
Minimum	4,72	4,72	10,68
Maximum	81,21	81,21	87,51
Count	6172	6172	6172

The descriptive statistics for volatility measures are presented in Table 1. These findings highlight the underlying characteristics of the volatility measures under analysis. Statistics help illustrate the differences between implied volatility and the two realized volatility measures, supporting the motivation for further investigation. Notably, the descriptive statistics reveal that implied volatility, as measured by VSTOXX, consistently exceeds both past and forward realized volatility, with a mean of 23,52 compared to 20,01 and 19,91, respectively. Noted by Malkiel et al., (2018), this difference between implied volatility and realized volatility indicates that option prices usually incorporate higher expectations of future volatility than is realized. This systematic overestimation suggests the presence of a volatility risk premium, which will be further examined in subsequent analyses.

The overestimation is further supported by the minimum and maximum values of the dataset. In addition, the lower standard deviation and variance of the VSTOXX indicate that implied volatility tends to be less responsive than both volatility measures. This implies the stability of timing option writing using implied volatility instead of realized volatility measures. Moreover, the distributions of all three volatility measures exhibit positive skewness and excess kurtosis, pointing to the presence of fat tails and volatility spikes, particularly observed more in realized volatility measures. The findings from descriptive statistics provide the foundation for further analysis later in this thesis.

The second dataset is used to construct and evaluate the performance of option writing strategies. It includes monthly closing values for Euro Stoxx 50 Buy-Write, Euro Stoxx 50 Put-Write, and Euro Stoxx 50 index. For all three indices, monthly logarithmic returns are calculated to assess the performance of each strategy that month. Malkiel et al., (2018) also utilize monthly return data, as this aligns with the methodologies of buy-write and put-write indices (e.g., see CBOE, n.d.; STOXX, n.d.). The observed period for the option strategies and the market index is from January 2005 to March 2024. This period was selected as the methodology of this thesis needs an additional 5 years of data from the VSTOXX index to construct two conditional strategies. That is, monthly VSTOXX values starting from January 2000 are also needed for strategy implementation. The methodology for constructing conditional strategies is covered later in the thesis. All data is retrieved from the STOXX website and is publicly available.

Both option writing indices represent the historical performance of hypothetical portfolios that follow systematic, rules-based option writing (STOXX n.d.). The Euro Stoxx 50 Buy-Write represents an investment approach that simulates the performance of a covered call strategy on the Euro Stoxx 50 index (STOXX, n.d.). This strategy involves holding the underlying index while simultaneously selling call options on it. Similarly to the BXM index under analysis in Malkiel et al., (2018), the goal is to generate additional income through option premiums while maintaining exposure to the equity market. STOXX (n.d.) provides two alternative buy-write indices. This thesis uses the Euro Stoxx 50 Buy-Write (100%), which indicates that options are written at-the-money. As noted by Fleming et al., (1996), at-the-money options contribute to more efficient pricing due to their higher liquidity and lower bid/ask spreads. Also covered earlier, Bakshi et al., (1997) highlight the role of volatility smile in shaping implied volatility across different strike prices. Taking these factors into account, the focus of the buy-write index analyzed in this thesis is purely on generating option premiums without any additional variability.

Similarly, the Euro Stoxx 50 Put-Write mirrors the performance of a collateralized put-selling strategy (STOXX, n.d.). Instead of directly investing in the Euro Stoxx 50, this approach allocates capital to risk-free assets, such as short-term money market instruments, and systematically sells put options on the Euro Stoxx 50. The premiums collected from selling puts provide a source of potential returns while maintaining a fully collateralized position (Ungar and Moran, 2009). The strategy has almost the same structure as the put-write strategy used by Ungar and Moran (2009) when analyzing the S&P 500 index put options. However, unlike the CBOE S&P 500 Put-Write Index, which sells at-the-money options, Euro Stoxx 50 Put-Write utilizes slightly out-of-the-money put options. The exception was made for the Euro Stoxx 50 Put-Write strategy as there is no index based on at-the-money writing. Therefore, this thesis follows the STOXX (n.d.) put-write methodology. The next table presents the summary statistics of the Euro Stoxx 50 index, Euro Stoxx 50 Buy-Write (Buy-Write), and Euro Stoxx 50 Put-Write (Put-Write) for the sample period of January 2005 to March 2024. These statistics serve as a foundation for more detailed performance comparisons later in this thesis.

Table 2. Summary statistics of strategies, January 2005 to March 2024.

	Euro Stoxx 50	Buy-Write	Put-Write
Mean Return	0,24 %	0,23 %	0,36 %
Median Return	0,97 %	0,75 %	0,69 %
St. Deviation	5,04 %	3,39 %	2,63 %
Sample Variance	0,25 %	0,11 %	0,07 %
Kurtosis	1,18	7,13	23,42
Skewness	-0,52	-1,74	-3,79
Min	-17,79 %	-20,85 %	-20,24 %
Max	16,60 %	7,93 %	6,04 %
N. of Obs.	231	231	231

As seen in Table 2, the Put-Write strategy exhibits the highest average monthly return, outperforming both the Euro Stoxx 50 index and the Buy-Write strategy. In terms of risk, both option-writing strategies contribute to a reduction in volatility compared to holding the index directly. Notably, the option-writing strategies display more extreme negative skewness and higher kurtosis, indicating that they are more likely to suffer from rare but very large losses than the Euro Stoxx 50 index. This is further confirmed by the extreme values, as both strategies experience the worst monthly return compared to the Euro Stoxx 50. Moreover, the lower maximum returns of the writing strategies highlight their capped upside, which reflects the nature of earning income through option premium collection (see e.g., Callan Associates, 2006).

The findings in Table 2 provide a valuable foundation for the later part of the analysis, where the objective is to explore whether these traditional option-writing strategies can be further improved. Over the full sample period, both the Buy-Write and Put-Write strategies delivered returns that are comparable to, or higher than the Euro Stoxx 50 index, while significantly reducing volatility. As discussed earlier in this thesis, and noted by Malkiel et al., (2018), this indicates that option writing offers an appealing risk-reward tradeoff. However, the option-writing strategies reveal certain limitations which particularly are linked to the capped upside potential of these strategies, and according to Callan Associates (2006), the passive index therefore outperforms option-writing in bullish environments. Despite the lower average performance and higher volatility, the Euro Stoxx 50 demonstrates stronger return potential in terms of its median and maximum returns. These findings reinforce the motivation to further examine whether the performance of these traditional option-writing strategies can be improved. However, as noted previously, before delving into strategy construction, a deeper analysis of volatility risk premium is conducted.

6.2 Analysis of Volatility Risk Premium

The purpose of this chapter is to examine the volatility risk premium in the Euro Stoxx 50 index options. To assess the relationship between VSTOXX and both volatility measures, three simple linear regressions are performed. Equation 5 presents the first model where VSTOXX is used as the explained variable and past realized volatility is used as an explanatory variable. The first model examines how implied volatility in the European markets can be explained by past market movements. The first model is presented as follows:

$$V_t = \alpha + \beta R_t + \varepsilon_t \qquad (5)$$

The second regression model, presented in Equation 6, uses the forward realized volatility as an explained variable and past realized volatility as an explanatory variable. The second model investigates the persistence of volatility in the European markets and whether past market movements can explain future volatility. The second regression model is presented as follows:

$$F_t = \alpha + \beta R_t + \varepsilon_t \qquad (6)$$

The third model, presented in Equation 7, uses forward realized volatility as an explained variable and VSTOXX as an explanatory variable. In contrast to model 2, the third model assesses how implied volatility predicts the actual future volatility. As all the regression models include only one explanatory variable, they will give a clear interpretation of the direct relationship between different volatility measures. The results from this regression analysis provide an overview of how these volatility metrics relate to one another in the European market and are similarly conducted to Malkiel et al., (2018). The regression analyses form the foundation to analyze the performance of option-writing strategies later in this thesis. Finally, the third regression model is presented as follows:

$$F_t = \alpha + \beta V_t + \varepsilon_t \qquad (7)$$

Table 3 presents the regression results from the three models, summarizing the key statistical findings for all three volatility measures. The table outlines the model used along with the corresponding statistical metrics.

Table 3. Regression Analysis.

Variable	***Model (1)***	***Model (2)***	***Model (3)***
Intercept	8,31***	6,54***	-0,34
T-stat	(68,86)	(30,35)	(-1,36)
Explanatory Variable	0,76***	0,67***	0,86***
T-stat	(143,05)	(70,41)	(87,87)
N	6172	6172	6172
Adjusted R^2	0,77	0,45	0,56

**** denotes the difference is statistically significant at 99% level*

Model (1) presents the regression results where VSTOXX is explained by past realized volatility, offering evidence of a strong linear relationship between market expectations and historical price behavior. The coefficient of 0,76 indicates a positive relationship, suggesting that although VSTOXX is a forward-looking measure, it is significantly shaped by past market movements. The high adjusted R^2 of 0,77 reinforces this finding, showing that nearly 77% of the variation in VSTOXX can be explained by past realized volatility. The intercept value of 8,31 implies that even when realized volatility is zero, the VSTOXX remains relatively high. This finding is statistically significant and consistent with prior literature on the systematic overestimation of realized volatility (see e.g., Fleming, 1998), which in turn reflects the existence of a volatility risk premium embedded in Euro Stoxx 50 index options.

Model (2) explores the relationship between the forward realized volatility and past realized volatility, aiming to capture the degree of volatility persistence in the market. The coefficient of 0,67 and an adjusted R^2 of 0,45 suggest a moderate relationship. These results indicate that past volatility holds some explanatory power for future volatility, however, the lower R^2 highlights the limitations of relying solely on historical data to forecast future movements.

Model (3) evaluates the predictive power of VSTOXX over forward realized volatility, offering a comparison to Model (2). The estimated coefficient of 0,86 is higher than that of Model (2), suggesting that VSTOXX provides a stronger predictive power for future realized volatility than past volatility does. This is consistent with earlier findings that implied volatility outperforms past volatility measures when predicting future movements (see e.g., Blair et al., 2001; Jiang and Tiang, 2005). The adjusted R^2 of 0,56 further confirms the improved model fit, indicating that VSTOXX captures a greater portion of the variation in future volatility. Nevertheless, a substantial portion of the variance remains unexplained, pointing to the presence of other influential factors. Importantly, the intercept value being below one implies that while VSTOXX is positively associated with future realized volatility, it tends to systematically overestimate it, consistent with the presence of a volatility risk premium as demonstrated with Model (1).

These findings align with the results of Malkiel et al., (2018), who similarly conclude that implied volatility contains useful forward-looking information not entirely captured by past market data. However, the unexplained variance observed especially in Model (3) also emphasizes the limitations of using implied volatility alone as a forecasting tool, also noted by Malkiel et al., (2018). Overall, the regression analysis provides evidence of the volatility risk premium in the Euro Stoxx 50 index options, particularly highlighted in Model (1). The results support the widely documented pattern in which implied volatility consistently overstates realized volatility (see e.g. Fleming, 1998).

To further analyze the relationship between implied volatility and realized volatility measures, a quartile-based analysis of volatility is conducted to examine whether the degree of overstatement by implied volatility varies across different volatility regimes. The quartile-based analysis is similar to the paper Malkiel et al., (2018). The quartiles are constructed by categorizing daily VSTOXX values from January 2000 to March 2024 into four quartiles based on their distribution. Each quartile represents a range of implied volatility values, with Quartile 1 corresponding to the lowest 25% of values and Quartile 4 to the highest 25% of values. The range of each quartile specifies the minimum and maximum VSTOXX value within each quartile.

To assess the relationship, the overestimation of VSTOXX within each quartile is calculated as the difference between VSTOXX and realized or forward volatility, and the average value for each quartile is calculated to see how VSTOXX compares to both volatility measures in overall terms. As noted, this analysis provides additional insights supporting the rationale for conditioning traditional writing strategies. The following table presents the results from the quartile-based analysis over the period January 2000 to March 2024.

Table 4. VSTOXX and Volatility.

VSTOXX Quartile	Range	Realized Volatility	Forward Volatility
1	10,68-16,89	3,29	2,12
2	16,90-21,31	3,53	3,22
3	21,32-27,03	4,10	3,80
4	27,04-87,51	3,28	5,25
Overall		**3,55**	**3,60**

The results presented in Table 4 provide further evidence of the overestimation by VSTOXX over both volatility measures. Across all quartiles, on average, the VSTOXX consistently exceeds both realized and forward volatility, supporting the presence of the volatility risk premium. The overall average overestimation is approximately 3,6 points for both volatility measures. Furthermore, as VSTOXX levels increase, the overestimation relative to forward realized volatility becomes more pronounced. This indicates that during periods of higher uncertainty, the premiums from selling options tend to increase as well. The findings from Table 4 follow a similar pattern to those of Malkiel et al. (2018) in their analysis of VIX and are consistent with the broader literature on the volatility risk premium discussed earlier.

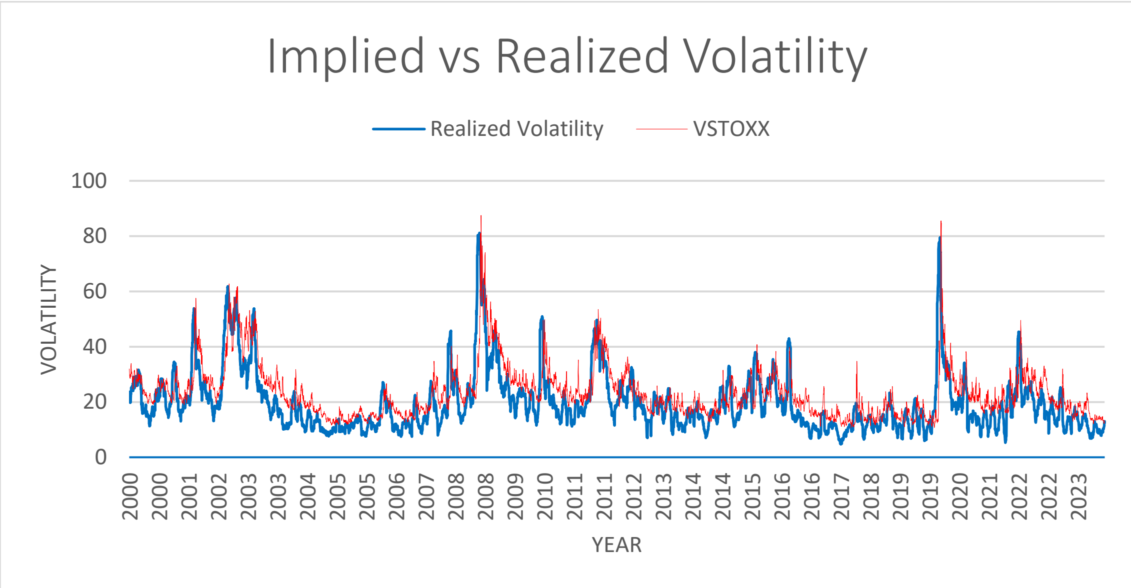

Figure 3. Implied vs Realized Volatility, January 2000 to March 2024.

Figure 3 illustrates the time series of the VSTOXX index and realized volatility for the Euro Stoxx 50 over the full sample period. While both measures move closely together, VSTOXX consistently remains above the realized volatility throughout the sample. This is observed particularly during periods of volatility spikes, such as those around the financial crises of 2008 and the COVID-19 pandemic, as illustrated. The gap between these volatility measures provides visual confirmation of the existence of volatility risk premium and supports the findings from descriptive statistics, regression analysis, and quartile-based analysis. To conclude the volatility analysis performed in this chapter, there is a consistent gap between implied volatility, measured as VSTOXX, and realized volatility. Moreover, and as noted by Malkiel et al., (2018), the overestimation of implied volatility is particularly observed during high-volatility regimes. The findings are also in line with previously documented volatility risk premium in European markets (see e.g., Londono, 2015), validating the idea that option sellers can take advantage of this volatility risk premium in European markets.

6.3 Strategy Construction

As observed in the previous analysis, VSTOXX, a measure of European implied volatility, consistently overestimates the corresponding realized volatility throughout the whole sample period. Additionally, the overestimation tends to be larger when moving to higher levels of VSTOXX. To make final conclusions about the characteristics of volatility risk premium, this thesis continues to build upon findings observed in Table 3 and Table 4. That is, when the overestimation of implied volatility is larger during heightened periods of implied volatility, option premiums are expected to be more attractive (see e.g., Malkiel et al., 2018). Therefore, it can be also expected that the Euro Stoxx 50 Buy-Write and Put-Write strategies that take advantage of this overestimation will result in better performance during higher levels of VSTOXX.

The study by Malkiel et al. (2018) shows that the performance of option-selling strategies improves as the level of VIX increases. Building on this, the analysis continues by examining whether a similar pattern holds in the European option markets by analyzing the VSTOXX index and the returns of the Euro Stoxx 50, Buy-Write, and Put-Write indices across different VSTOXX quartiles. Accordingly, the captured profits from selling options are anticipated to be greater when VSTOXX levels are higher. In other words, as VSTOXX increases, the premium received from selling options is expected to rise as well. As discussed earlier, analyzing the excess returns of Buy-Write and Put-Write over the Euro Stoxx 50, provides additional information about the volatility risk premium and whether it becomes more pronounced when entering higher volatility levels.

To examine the excess performance of the Euro Stoxx 50 Buy-Write and Euro Stoxx 50 Put-Write strategy over the Euro Stoxx 50 index, a quartile-based analysis, similar to the one used for the volatility analysis, is conducted. The excess returns for both traditional writing strategies are calculated as *Strategy Return – Euro Stoxx 50 Return*. This is computed for each month of the analysis period January 2005 to March 2024 alongside the corresponding VSTOXX values. Each observed excess return is then matched with the VSTOXX level of that month. Subsequently, the VSTOXX values for each month are divided into 4 quartiles (i.e., Q1 = the lowest 25% and Q4 = the highest 25%) based on their distribution. Finally, for both writing strategies and each VSTOXX quartile, the average excess return is computed to assess whether performance improves in higher implied volatility environments.

Table 5. Excess Performance by VSTOXX Quartile.

Excess Return By Quartile		
VSTOXX Quartile	*Buy-Write*	*Put-Write*
1	-0,97%***	-1,61%***
2	-0,32%	-0,31%
3	-0,16 %	-0,01 %
4	1,42%***	2,42%***

Table 5 presents the excess performance of both traditional option-writing strategies relative to the Euro Stoxx 50 index across different VSTOXX quartiles. As observed earlier in this thesis, the gap between VSTOXX and the actual future volatility increases when VSTOXX levels are higher. Therefore, it is expected that the performance of option-writing strategies improve as VSTOXX levels increase. This is indeed the case as seen in Table 5. Both traditional option-writing strategies underperform the market in the first three quartiles, however, outperform the market in the fourth quartile, consistently improving the performance. During the lowest volatility periods, quartile 1 and quartile 2, both strategies, on average, deliver negative excess returns, which is expected, as option premiums tend to be low during these periods, offering limited compensation for option sellers. The excess returns remain negative in the third quartile, suggesting that even in moderate volatility levels, the premium collected may not consistently compensate the option writers in the Euro Stoxx 50 index options. Notably, positive excess returns are observed in quartile 4 and these are statistically significant for both strategies (as indicated by ***). On average, the Buy-Write strategy yielded 1,42% and the Put-Write strategy yielded 2,42% of excess return relative to the Euro Stoxx 50 index during the highest VSTOXX quartile. The results from Table 5 indicate that option sellers in European markets gain meaningful compensation, on average, during periods of relatively high implied volatility, indicating the most favorable position when the gap between implied volatility and realized volatility is widest. These findings add further insights into the volatility risk premium and its behavior. Regarding the first objective of this thesis, the findings from both quartile-based analyses, Table 4 and Table 5, conclude that the volatility risk premium becomes more pronounced during higher levels of VSTOXX. First highlighted in Table 4, when studied the overestimation of VSTOXX over realized volatility measures in different quartiles, then further supported by the excess return analysis of writing strategies in different quartiles.

The strategy implementation in this thesis is heavily influenced by the results obtained from volatility analysis and the performance of traditional option-writing strategies across different quartiles of VSTOXX. Moving to the main objective, this thesis uses the information obtained from the previous tables to construct two conditional option writing strategies. Similarly to Malkiel et al. (2018), these strategies are designed to benefit from the tendency of implied volatility to overestimate realized volatility, especially during high-volatility regimes.

Followed by the work of Malkiel et al. (2018), the strategy for constructing two conditional option selling strategies aims to demonstrate that the original strategies, which constantly sell options, can be improved in the European option market. The conditional strategies use the VSTOXX index, a key measure of implied volatility in the European market, to determine optimal entry points for selling options on the Euro Stoxx 50 index. The strategies are constructed in a way that they will enter option selling when the VSTOXX level from the previous month exceeds the historical median value of the

VSTOXX. The historical median value is calculated as a rolling 5-year median for the VSTOXX index capturing the prior 5 years of data for each month to determine whether to enter option selling or remain invested in the Euro Stoxx 50. Unlike Malkiel et al., (2018), who use the full historical VIX data up to the current month to compute a historical median, this thesis applies a rolling 5-year window to calculate the historical median of VSTOXX. By using a rolling approach, it ensures that data reflects the prevailing volatility environment more accurately. The rolling window approach is also more commonly used in financial forecasting, as it helps models react better to new data and improve the reliability of predictions (Feng et al., 2024).

Starting in January 2005, this thesis uses the first 5 years of VSTOXX monthly data (January 2000 to December 2004) to calculate the historical median value. At the beginning of January 2005, if the prior-month VSTOXX value (i.e. December 2004) is above its rolling historical median (i.e. January 2000 to December 2004) options are written in that month. However, if vice versa, the strategy will be fully invested in the Euro Stoxx 50 index. The evaluation, whether to enter option selling or remain in the index is made every month as it reflects most accurately the monthly roll process of original writing strategies. As the analysis progresses month by month from January 2005 onward, the rolling 5-year median is updated by incorporating the most recent month’s data while removing the oldest observation from the window. The rationale behind this strategy is that higher implied volatility corresponds to higher option premiums, as covered earlier in this thesis (also see Malkiel et al., 2018). In the following part, the performance of both original option-writing strategies alongside the performance of constructed conditional option strategies is evaluated.

6.4 Performance Evaluation

The final step of the methodology is to present the performance statistics of all strategies, including the market index. Performance metrics that are used in this thesis are similar to Malkiel et al., (2018). The average return is defined as the average annualized monthly logarithmic return. Standard deviations are calculated using an average value from the whole sample and then annualized. The Sharpe ratio represents the amount of excess return earned for each unit of risk taken, with risk measured by the standard deviation calculated from returns. In addition to the Sharpe ratio, the Sortino ratio is used to measure the excess return relative to downside risk, where risk is defined as the standard deviation of negative returns from the whole sample. Given the historically low levels of short-term risk-free rate during the sample period of 2005-2024, the risk-free rate is assumed to be 0% for Sharpe and Sortino ratio calculations. The primary focus of this thesis is on raw returns and performance differences between all observed strategies, rather than on the precise estimation of risk-adjusted returns. Consequently, the Sharpe and Sortino ratios presented here are not intended for direct comparison with those reported in previous studies. Therefore, the simplification of assuming a 0% risk-free rate is considered appropriate. A similar approach is observed in Malkiel et al., (2018), where the emphasis is on strategy performance, and although the risk-free rate is incorporated at some level, it is not explicitly discussed.

Table 6. Comparison of the Benchmark Strategies, January 2005 to March 2024.

	Average Return	*St. Deviation*	*Sharpe Ratio*	*Sortino Ratio*
Euro Stoxx 50	2,83 %	17,46 %	0,16	0,77
Buy-Write	2,73 %	11,75 %	0,23	0,82
Put-Write	4,29 %	9,12 %	0,47	1,09

Table 6 shows the performance comparison between the benchmark indices, Euro Stoxx 50, Euro Stoxx 50 Buy-Write, and Euro Stoxx 50 Put-Write from January 2005 to March

2024. Both option-writing strategies exhibit better risk-adjusted performance, measured by Sharpe and Sortino Ratios, compared to the Euro Stoxx 50 index. Specifically, the Put-Write strategy achieved the highest average return and the lowest standard deviation resulting in the best risk-adjusted performance among these strategies. Moreover, the Buy-Write strategy, although providing a slightly lower average return than Euro Stoxx 50, still reduced volatility significantly leading to improved risk-adjusted performance. These findings highlight the attractiveness of option-selling strategies, particularly in terms of reducing volatility and improving risk-adjusted performance. The results are broadly consistent with previous studies. The Buy-Write strategy yields comparable returns to the benchmark index while reducing volatility significantly (see e.g., Whaley, 2002; Callan Associates, 2006; Kapadia and Szado, 2007), and compared to the traditional Buy-Write strategy, Put-Write delivers stronger performance (see e.g., Ungar and Moran, 2009). The findings from Table 6 reveal similar dynamics and relationships between the original writing strategies and the market index as those observed in the U.S. markets.

Table 7. Performance of All Strategies, January 2005 to March 2024.

	Average Return	*St. Deviation*	*Sharpe Ratio*	*Sortino Ratio*
Euro Stoxx 50	2,83 %	17,46 %	0,16	0,77
Buy-Write	2,73 %	11,75 %	0,23	0,82
Put-Write	4,29 %	9,12 %	0,47	1,09
Conditional Buy-Write	4,39 %	13,77 %	0,32	1,34
Conditional Put-Write	5,97 %	12,55 %	0,48	1,73

Table 7 presents the performance comparison between the market index, both original option-writing strategies, and the two conditional strategies. The results demonstrate that both conditional strategies outperform their original counterpart. The average return increases for both conditional strategies from 2,73% to 4,39% and from 4,29% to 5,97%. In terms of risk, measured by standard deviation, both strategies are slightly riskier compared to traditional strategies. However, this additional volatility is less than the additional return gained from conditioning the original strategies. Both conditional strategies, when adjusting risk and return, outperform the original strategies. This is reflected in the improvement of both the Sharpe and Sortino ratios for both strategies. Importantly, while both the Sharpe and Sortino ratios improve, the relative improvement in the Sortino Ratio, which focuses on downside risk, is more substantial. This indicates that the conditional strategies are particularly effective in reducing the impact of negative returns. These improvements in both risk-return measures represent the substantial gain in overall performance when selectively writing options, rather than writing them every month. Over the entire 231-month sample period, the conditional strategies were active in option writing for 104 months.

As noted, both conditional strategies outperform the market index and their original counterparts. These findings support the main objective that selectively writing options based on the levels of implied volatility, improves the risk-return tradeoff of original writing strategies. The results obtained here align closely with the findings from Malkiel et al., (2018); both buy-write and put-write, when conditioning them, led to higher returns, however, also resulted in increased volatility. In overall terms, both strategies improved their risk-adjusted performance, measured by Sharpe and Sortino. Notably, the Conditional Put-Write strategy offered superior performance not only in terms of return but also when adjusting for risk and downside risk. These results indicate at least a partial similarity between option-writing behavior in the European market and in the U.S. market studied by Malkiel et al., (2018).

Table 8 shows the annual performance, comparing the conditional strategies to the market index. In addition, the table presents the average VSTOXX level, a proxy for implied volatility, for each year. As discussed earlier, over the full sample period of 2005 to 2024, the conditional strategies significantly outperform the market index. The highlighted areas in gray indicate months when no options were written in that year, resulting in identical performance across all three observed strategies (i.e., Euro Stoxx 50 return). Bolded returns highlight the outperformance of conditional strategies over the Euro Stoxx 50 index in that year. Table 8 offers a deeper understanding of how the conditional strategies performed under varying levels of implied volatility.

Table 8. Annual Performance, January 2005 to March 2024.

Year	Euro Stoxx 50	Conditional Buy-Write	Conditional Put-Write	VSTOXX
2005	19,29 %	19,29 %	19,29 %	14,20
2006	14,08 %	**14,17 %**	**16,14 %**	16,40
2007	6,57 %	4,79 %	4,64 %	19,21
2008	-58,64 %	**-29,15 %**	**-14,78 %**	32,67
2009	19,17 %	18,74 %	**21,23 %**	33,36
2010	-5,98 %	**-5,29 %**	**-2,78 %**	27,53
2011	-18,70 %	**-4,42 %**	**-7,83 %**	28,52
2012	12,92 %	9,45 %	10,68 %	24,74
2013	16,51 %	16,51 %	16,51 %	19,17
2014	1,20 %	1,20 %	1,20 %	18,59
2015	3,78 %	**5,23 %**	**5,81 %**	24,40
2016	0,70 %	**4,53 %**	**7,03 %**	22,77
2017	6,28 %	6,28 %	6,28 %	14,97
2018	-15,48 %	**-11,96 %**	**-10,31 %**	17,02
2019	22,14 %	19,80 %	17,92 %	14,77
2020	-5,28 %	-18,60 %	-17,59 %	30,48
2021	19,06 %	12,74 %	9,12 %	21,80
2022	-12,49 %	**-1,90 %**	**11,46 %**	27,08
2023	17,55 %	11,37 %	9,26 %	17,11
2024	11,72 %	11,72 %	11,72 %	14,02
Average	**2,83 %**	**4,39 %**	**5,97 %**	**22,25**

There are a few important observations that can be made from Table 8. In the years when VSTOXX has been consistently high, such as in 2008-2011, 2020, and 2022, the market has expected more uncertainty about future movements. During these periods, the Euro Stoxx 50 index has yielded either extreme losses or mixed performance. However, the conditional strategies have performed substantially better, suffering less severe drawdowns, especially in 2008, or even yielded positive returns. The outperformance of conditional strategies during these high-volatility periods is explained by the option premiums received when investors seek downside protection. This aligns with previous literature (see e.g., Malkiel et al., 2018) that during times of elevated implied volatility, option premiums become more attractive and offset the downside risk of the underlying.

Conversely, during low-volatility periods, the Euro Stoxx 50 index has performed relatively well, while the conditional strategies have either underperformed or matched its performance. Especially in gray highlighted years, when the VSTOXX level is consistently below the full-period average value, the conditional strategies have remained fully in the Euro Stoxx 50 index and therefore captured attractive returns. Considering strong bull runs in the Euro Stoxx 50 index, like in 2012, 2019, and 2023, the conditional strategies have managed to yield competitive returns although underperforming the market. This underperformance is expected as during low-volatile periods, option premiums are relatively low, which limits the returns of selling options. This observation is consistent with Callan Associates (2006), who state that a passive index is likely to outperform option-writing in bullish markets. Since options are written during these periods, the results are in line with expectations (see also *Figure 2* for an illustration of the capped returns).

Interestingly, in 2022, the conditional Put-Write strategy yielded a positive annual return of 11,46% while both Euro Stoxx 50 and conditional Buy-Write yielded negative performance. This is particularly worth mentioning as during the whole analysis period observed in Table 8, this is the only year where the strategies diverged more broadly in terms of the direction of the performance. For the year 2022, both conditional strategies were active in option selling for the entire year, meaning that the performance is similar to the performance of their original strategies for that year. One possible explanation for this divergence could be that the premiums from selling put options rather than call options were much larger throughout the whole year. Moreover, the VSTOXX average value for the year 2022 remained relatively high. As noted earlier, and according to Bakshi et al., (1997), under these volatility conditions, the out-of-the-money put premiums tend to be much larger compared to at-the-money options. As the Put-Write index used in this thesis is based on slightly out-of-the-money options, it may have capitalized on these premiums better than the Buy-Write index, which uses at-the-money options. In 2008, the Conditional Put-Write demonstrated even higher outperformance over both strategies.

Table 4 and Table 5 can also be examined to help explain the outperformance of the Conditional Put-Write in 2008 and 2022. When observing the highest VSTOXX quartile in Table 4 and comparing it with the average VSTOXX value from Table 8 for the years 2008 and 2022, it becomes evident that VSTOXX, on average, remained in the highest quartile during these years. Furthermore, the excess return of the Put-Write strategy over the Euro Stoxx 50 shown in Table 5 further supports the finding that in the highest quartile, the Put-Write strategy significantly outperformed the Euro Stoxx 50.

The next figures illustrate the cumulative performance of all strategies over the sample period of January 2005 to March 2024. The cumulative performance is calculated from the observed monthly returns, all strategies starting from an initial value of 100. The figures offer visual insights into how the conditional strategies have performed relative to both the market index and the original option-writing strategies.

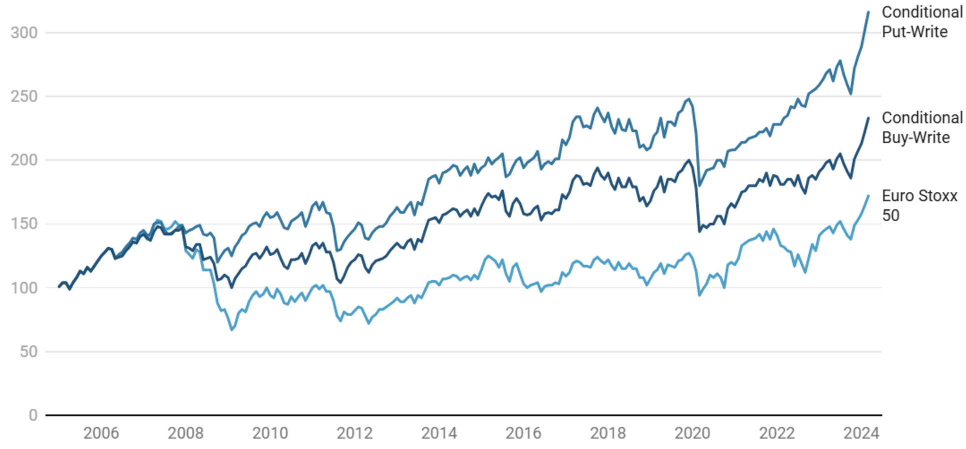

Figure 4. Euro Stoxx 50 and Conditional Strategies.

Figure 5. Buy-Write vs Conditional Buy-Write.

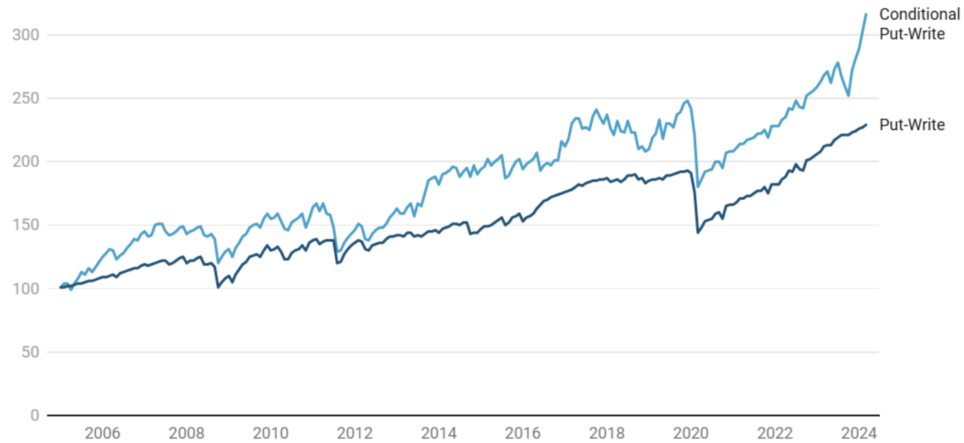

Figure 6. Put-Write vs Conditional Put-Write.

Over this nearly two-decade observation period, the conditional strategies start to diverge significantly compared to original writing strategies and the market index, providing insight into how these strategies perform under varying market conditions. In Figure 4, following a period of identical performance of all strategies, the conditional strategies remain clearly above the market index for the rest of the sample period, resulting in a much higher cumulative return. Most notably, and as observed earlier, the conditional Put-Write is the clear outperformer, achieving a cumulative return of 215,5%, while the conditional Buy-Write ends at 132,8% and Euro Stoxx 50 at 72,26%. As seen in Figure 5 and Figure 6, the improvement of conditional writing strategies compared to original strategies is clear. Both conditional strategies remain above their original strategies for the entire sample period. Regarding the findings from Table 8, particularly for the years 2008 and 2022, Figure 4 illustrates that being active in put-writing during these years was especially more favorable than being in buy-write or remaining in a passive index.

7 Conclusion

This paper studies the volatility risk premium in European markets and the risk and return characteristics of buy-write and put-write strategies. More specifically, this thesis seeks to evaluate whether implied volatility levels, measured through the VSTOXX index, can be effectively used to improve the risk-adjusted performance of the Euro Stoxx 50 Buy-Write and Euro Stoxx 50 Put-Write strategies. This study is motivated by earlier studies on the option writing literature and follows closely the U.S.-based study by Malkiel et al., (2018). The evidence in the U.S. markets showed that option-writing strategies offer an attractive alternative to passive-only approaches (see e.g., Whaley, 2002; Kapadia and Szado, 2007; Ungar and Moran, 2009), and that implied volatility can be used to improve the performance of these option-writing strategies (see Malkiel et al., 2018).

In order to better understand the rationale behind option writing noted by Malkiel et al. (2018), this thesis starts by investigating the relationship between implied volatility, measured as VSTOXX, and the corresponding realized volatility measures in European markets. Therefore, the first empirical question this study aims to answer is: *Does the volatility risk premium become more pronounced during periods of high implied volatility?.* To extend the research and build upon the findings from the first empirical question, this thesis continues to construct two conditional option writing strategies that take advantage of VSTOXX levels and then further investigate their risk-return performance. The second and the main empirical question this thesis seeks to answer is: *Can the Euro Stoxx 50 Buy-Write and Euro Stoxx 50 Put-Write strategies be improved by selectively entering option selling based on levels of VSTOXX?*

Regarding the first research question, the empirical findings from volatility indicate that VSTOXX consistently overestimates future volatility, leading to a positive volatility risk premium in the European markets. Additionally, the results indicate that as moving to higher levels of VSTOXX, that overestimation grows. This is emphasized as when moving to higher VSTOXX quartiles, the overestimation of VSTOXX over realized volatility measures becomes more pronounced. With the premiums as a key source of return, this overestimation is further indicated by the excess performance of option-writing strategies in the highest quartile of VSTOXX. The observed findings align closely with the findings provided by Malkiel et al., (2018).

Regarding the second research question, the empirical findings demonstrate that traditional buy-write and put-write strategies offer comparable returns to the Euro Stoxx 50, however, providing better risk-adjusted returns. These results are consistent with previous literature studying traditional option-writing strategies (see e.g., Whaley 2002, Callan Associates, 2006; Kapadia and Szado, 2007). Additionally, the construction of two conditional option-writing strategies, where options are written only when VSTOXX is above its historical 5-year rolling median value, the performance of these strategies improved significantly, outperforming the Euro Stoxx 50 index and the original option-writing strategies. This improvement in option writing is also in line with the study of Malkiel et al., (2018).

Overall, the findings from this paper contribute to the broader literature on option writing by demonstrating how the implied volatility index in the European market can be used to improve returns from traditional writing approaches. In addition, this thesis provides insights into the volatility risk premium observed in European markets, suggesting that market participants may benefit from the premiums received from selling options, especially during periods of market stress, as indicated by high VSTOXX levels. Moreover, covering the put-write strategy in the study further highlights the findings from investor behavior of overestimating significant losses (see e.g., Goetzmann et al., 2016 and Ang et al., 2018). The outperformance of the put write is heavily linked to the findings from put option mispricing (Jackwerth, 2000, Ungar and Moran, 2009) and investors demanding protection for downside exposure (Garleanu et al., 2009), making the put option premiums more attractive, especially during periods of high market stress. The outperformance of the put write may also have been influenced by the volatility smile, as noted by Bakshi et al., (1997), however, further analysis of the smile was not conducted in this thesis.

The results of this paper have practical implications for traders and portfolio managers who use buy-write and put-write strategies in their portfolio selection, particularly in the European markets. Similar to what Malkiel et al., (2018) observed in the U.S. markets, this study shows that the performance of traditional buy-write and put-write strategies can be improved in the European markets by conditioning the strategies based on the level of implied volatility, measured by VSTOXX. In particular, the results suggest that market participants can improve risk-adjusted performance by being more active in option selling during high-volatility periods. This supports the idea that market participants may benefit from a deeper analysis of VSTOXX when selecting appropriate investment approaches that fit different market conditions in the European markets. Therefore, optimizing writing strategies based on the expectations of future market movements rather than following a passive-only method, can help reduce the exposure to risk while potentially yielding more attractive returns.

7.1 Addressing Limitations

While this thesis offers valuable insights, two important limitations should be considered. In the real world, transaction costs are unavoidable for every market participant. Fleming et al., (1996) consider two components of transaction costs that are market liquidity and bid/ask spread. The authors find that the stock index market is more liquid than index option markets. Moreover, their findings indicate that the bid/ask spreads are larger for index options than stock indices. However, regarding options, at-the-money options have the highest volume in trading and the lowest bid/ask spread, improving pricing efficiency (Fleming et al., 1996). This is particularly relevant given that option-writing strategies are typically implemented using at-the-money options or slightly out-of-the-money options (see e.g. Whaley, 2002; He et al., 2014; STOXX, n.d.).

The findings from Fleming et al., (1996) indicate that larger transaction costs are observed in the options market. While this thesis does not account for transaction costs, this observation from Fleming et al., (1996) should be acknowledged, as it may have a large impact on the profitability of option writing strategies. However, as noted by Malkiel et al., (2018) in their study, the authors are aware of one fund that has implemented the buy-write strategy in the emerging markets and found superior Sharpe and Sortino over the underlying ETF despite the presence of transaction costs. Given that options typically involve higher transaction costs, option-selling strategies can still result in superior performance.

Another limitation concerns the data availability, particularly for the Euro Stoxx 50 Put-Write index. Unlike the CBOE S&P 500 Put-Write index used in studies like Ungar and Moran (2009) and Malkiel et al., (2018) that employs at-the-money options, the Euro Stoxx 50 Put-Write is constructed using slightly out-of-the-money put options. Due to the lack of a similar at-the-money put-write index for the European market, this study had to rely on the methodology provided by STOXX (n.d.). This thesis is aware of the structural deviations, especially the volatility smile (Bakshi et al., 1997) that may affect the return characteristics and comparability of writing strategies. However, as noted earlier, option-writing strategies are commonly implemented using either at-the-money or slightly out-of-the-money options. In addition, prior research on option writing reviewed in this thesis does not extensively examine the implications of the volatility smile.

7.2 Further Research

The focus of this thesis has been on Euro Stoxx 50-based option writing strategies, following closely the approach of Malkiel et al., (2018). As noted earlier, this thesis does not account for transaction costs. Instead of a theoretical focus, further research could make more practical considerations by incorporating transaction costs. By incorporating transaction costs, the study would add more practical relevance to the option-writing literature. Additionally, this thesis considers only the VSTOXX index as an entry indicator to enter option-selling. The regression results in Table 3 highlight the limitations of using implied volatility alone, as a substantial portion of the variability in future movements remains unexplained. Moreover, as observed in Table 8 and mentioned e.g., by Callan

Associates (2006), option writing usually underperforms passive index during bullish periods because of the capped returns. These suggest that further research could incorporate additional variables beyond volatility measures, to improve the timing of the strategies and probably make them even more effective.

As reviewed earlier, prior research has shown that adjusting the strike prices and/or maturities of options can improve the performance of option-selling strategies (see e.g., McIntyre and Jackson, 2007; He et al., 2014; Diaz and Kwon, 2017). While this thesis has focused on traditional option-writing strategies with minimal variation, further research could examine whether adjusting the selection of strikes and maturities would also benefit from a conditional strategy approach based on the level of implied volatility. In addition to the volatility smile (Bakshi et al., 1997), if selected strike prices for strategy implementations are deeper out-of-the-money, one could further analyze how the steepness of the smile could affect the strategy returns during periods of high implied volatility versus periods of low implied volatility.

As observed in Table 7, the conditional strategies clearly improve the risk-adjusted performance of both original writing strategies, as measured by the Sharpe and Sortino ratio. However, a notable finding from Table 7, also observed in the paper of Malkiel et al., (2018) is that Sortino ratios increase substantially more than Sharpe ratios. For instance, in the conditional Buy-Write strategy, the Sortino ratio increased by over 63% compared to a 39% increase in Sharpe. In the conditional Put-Write strategy, the Sharpe ratio increased only by 2% while the increase in the Sortino ratio was approximately 58%. This indicates that both conditional option-writing strategies are particularly effective at reducing downside risk. Based on this observation, one could examine in more detail, whether conditional strategies systematically avoid large drawdowns, which could explain the larger improvement in Sortino over Sharpe.

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