



Vaasan yliopisto
UNIVERSITY OF VAASA

Iiris Raiskio

**Information-based trading in the option market:
The predictive power of option-to-stock volume
ratio on stock returns**

Evidence from the DAX index

School of Accounting and Finance
Master's Thesis in Finance
Master's Degree Programme in Finance

Vaasa 2026

UNIVERSITY OF VAASA**Laskentatoimen ja rahoituksen akateeminen yksikkö****Author:** Iiris Raiskio**Title of the Thesis:** Information-based trading in the option market: The predictive power of option-to-stock volume ratio on stock return: Evidence from the DAX index**Degree:** Master of Science in Economics and Business Administration**Programme:** Finance**Supervisor:** Jianan Lu**Year:** 2026**Pages:** 58

ABSTRACT:

Previous research shows that option trading activity can contain information about future stock returns. In particular, the option-to-stock volume ratio (O/S) has been found to predict stock returns in U.S. markets. This predictive relationship is often explained by the presence of informed traders, who use option markets to act on private information.

This study examines whether the O/S ratio predicts future stock returns in a European setting. The analysis focuses on firms included in the DAX index over the period 2020–2025. The empirical analysis is conducted using daily data on option and stock trading volume obtained from the EUREX exchange. The study applies both portfolio sorting and Ordinary Least Squares (OLS) regression to test the predictive power of the O/S ratio.

The results do not provide evidence that the O/S ratio predicts future stock returns in the DAX market. Neither the portfolio sorting approach nor the regression analysis shows statistically significant predictive relationships. These findings differ from earlier results reported in U.S. markets.

The results suggest that the predictive relationship between option trading activity and stock returns may depend on market-specific characteristics, such as liquidity, trading structure, and investor composition. This thesis contributes to the existing literature by providing evidence from a European market and highlights the importance of institutional context when interpreting the informational role of option trading.

KEYWORDS: Optiokaupankäyntivolyyymi, optioiden ja osakkeiden kaupankäyntivolyymin suhde (O/S), osaketuottojen ennustettavuus, informoitu kaupankäynti, DAX-indeksi

VAASAN YLIOPISTO**Laskentatoimen ja rahoituksen akateeminen yksikkö**

Tekijä:	Iiris Raiskio		
Tutkielman nimi:	Information-based trading in the option market: The predictive power of option-to-stock volume ratio on stock return: Evidence from the DAX index		
Tutkinto:	Kauppatieteiden maisteri		
Opintosuunta:	Rahoitus		
Työn ohjaaja:	Jianan Lu		
Valmistumisvuosi:	2026	Sivumäärä:	58

TIIVISTELMÄ:

Aiempi tutkimus osoittaa, että optiokaupankäynti voi sisältää informaatiota tulevista osaketuotoista. Erityisesti optioiden ja osakkeiden kaupankäyntivolyymien suhteen (O/S) on havaittu ennustavan osaketuottoja Yhdysvaltain markkinoilla. Tätä ennustavuutta selitetään usein sofistikoituneilla sijoittajilla, jotka hyödyntävät yksityistä tietoa optiomarkkinoilla.

Tässä tutkimuksessa tarkastellaan, ennustaako O/S-suhte tulevia osaketuottoja eurooppalaisessa markkinaympäristössä. Analyysi keskittyy DAX-indeksiin kuuluviin yrityksiin ajanjaksolla 2020–2025. Empiirinen analyysi perustuu päivittäiseen optio- ja osakekaupankäyntidataan, joka on saatu EUREX-pörssistä. Tutkimuksessa käytetään sekä portfolioluokittelua että Ordinary Least Squares (OLS) regressioanalyysiä O/S-suhteen ennustekyvyn arvioimiseksi.

Tulokset eivät anna näyttöä siitä, että O/S-suhte ennustaisi tulevia osaketuottoja DAX-markkinalla. Sekä portfolioluokittelu että regressioanalyysi eivät osoita tilastollisesti merkitseviä ennusteyhteyksiä. Tulokset poikkeavat aiemmista Yhdysvaltain markkinoilla tehdyistä tutkimuksista.

Tulokset viittaavat siihen, että optiokaupankäynnin ja osaketuottojen välinen ennustava yhteys riippuu markkinakohtaisista tekijöistä, kuten likviditeetistä, markkinarakenteesta ja sijoittajakunnasta. Tämä tutkielma täydentää aiempaa kirjallisuutta tarjoamalla empiiristä näyttöä eurooppalaisesta markkinasta ja korostaa institutionaalisen kontekstin merkitystä optiokaupankäynnin informaation tulkinnassa.

AVAINSANAT: Optiokaupankäyntivolyymi, optioiden ja osakkeiden kaupankäyntivolyymien suhte (O/S), osaketuottojen ennustettavuus, informoitu kaupankäynti, DAX-indeksi

Contents

1	Introduction	7
1.1	Purpose of the study	9
1.2	Structure of the study	12
2	Asymmetric information and informed trading	13
2.1	Informed and uninformed traders	13
2.2	Trading venue choice under asymmetric information	14
2.2.3	Short-selling constraints	16
3	Options theory and efficient market hypothesis	17
3.1	Introduction to options	17
3.2	Black-Scholes model	18
3.3	Efficient Market Hypothesis	20
4	Option trading activity and stock return predictability	23
4.1	Directional option volume and informational content	23
4.2	Limitations of directional option volume	25
4.3	Option-to-stock volume ratio (O/S)	27
5	Data and methodology	32
5.1	Data	32
5.2	Methodology	36
5.2.1	Portfolio sorting	38
5.2.2	Regression framework	39
5.2.3	Control variables	40
6	Empirical results	42
6.1	Portfolio sorting results	42
6.2	Regression results	44
6.3	Regression with controls	45
6.4	Discussion of results	47
7	Conclusion	51
7.2	Summary of findings	51

7.3. Contribution to literature	52
7.4. Limitations of the study	53
7.5. Recommendations for future research	53
References	55

Tables

Table 1 Descriptive statistics.	35
Table 2 Regression results.	44

1 Introduction

Derivative markets have played an important role in the financial system since the opening of the CBOE in 1973, and their use has grown rapidly over time. By 2020, the total nominal value of outstanding derivatives exceeded \$500 trillion (The Bank for International Settlements, 2021). For a number of reasons, option markets are crucial. There is a lot of demand in the options market since there are risks associated with the stock market that cannot be eliminated by stock trading. An investor may choose to trade options for informational reasons as well (Holowczak et al., 2014). Furthermore, a higher level of price efficiency in the stock market is associated with the option market. For informed traders, equity options can offer a less expensive trading option (Amin & Lee, 1997).

Because option market provides investors with instruments for risk management, speculation, and information, it is crucial to modern finance (Holowczak et al., 2014). While stocks reflect ownership in a company, options enable traders to act on their expectations of future price movements with relatively little capital due to leverage (Black, 1975). Because of these factors, traders with private information often turn to option markets. In addition, short-selling costs and constraints in equity markets may encourage informed traders to switch from stocks to options (Johnson & So, 2012).

Stock return predictability is closely related to informed trading in financial literature (Fung & Loveland, 2020). Under efficient markets, information from option trading should be quickly reflected in stock prices. However, if option volume predicts future stock returns, this suggests that some traders act on information that is not yet incorporated into prices. These traders, referred to as informed traders, use their private information about the firm when making trading decisions.

Easley et al. (1998) provide a theoretical framework for informed trading across different markets. When traders possess private information and can choose where to trade, their choice of market can influence how information is reflected in prices. However,

identifying informed traders is not straightforward, as they may hide their actions among trades made by uninformed noise traders (Kyle, 1985).

Building on the theoretical foundation established by Easley et al. in 1998, Roll et al. introduced the option-to-stock trading volume ratio (O/S) in 2010, defining it as the total option trading volume relative to the trading volume of the underlying stock. Previous research has typically looked at specific option indicators, such as call-put imbalances or shifts in implied volatility, as signs of informed trading. Although several studies have examined investor sentiment in option markets using put-call volume ratios, this methodology has a fundamental limitation because options allow investors to trade on a variety of information. Put-call ratios do not observe trade direction, so option volume does not reveal whether trades are initiated by buyers or sellers. This way, the trading activity in the options market may include other strategies than simple directional bets. For example, investors who expect stock prices to increase can take long positions in call options and short positions in put options. At the same time, investors who expect higher volatility might take long positions in both call and put options. As a result, the put-call ratio alone cannot clearly separate between optimistic and pessimistic trading activity. It may therefore fail to capture the full informational content embedded in option markets (Holowczak et al., 2014).

To overcome this limitation, this study uses the O/S ratio to examine how trading activity is distributed between the option and equity markets. Instead of trying to analyze investor expectations from individual option trades, the measure focuses on the market in which traders choose to act. This is important because information on trade direction and whether positions are opened or closed is usually not publicly available and is often limited to exclusive datasets. As a result, directional option volume measures are difficult to apply when using standard data sources (Johnson & So, 2012).

When short-selling stocks is costly or constrained, informed traders are more likely to move their negative trades from the equity market to the option market, where it is

easier to establish bearish positions. Thus, a high O/S ratio reflects negative expectations, regardless of whether traders choose puts or calls. This is because the measure captures the shift of trading activity away from the underlying stock. For this reason, this thesis uses the O/S ratio, as it provides a fuller picture of informed trading compared to traditional put–call ratios.

By focusing on the choice of trading venue rather than the direction of individual trades, the O/S ratio offers a practical way to measure informed trading using publicly available data. This thesis therefore uses the O/S ratio as the primary measure of option market activity to examine its relationship with future stock returns.

1.1 Purpose of the study

The purpose of this study is to examine whether the option-to-stock volume ratio (O/S) contains predictive information about future stock returns in the DAX index during the period 2020–2025. The German market provides an optimal setting for this analysis, as the DAX consists of some of Europe’s largest and most liquid firms. There is limited empirical evidence on whether the predictive power of the O/S ratio extends to European equity markets, as large portion of the studies on the predictive power of option volume focus on U.S. markets. This study contributes to the literature by examining whether the relationship between relative option trading activity and future stock performance also holds in a European setting. This is relevant because market structure, regulation, and investor composition differ from those in U.S. markets, which may affect how information is reflected in prices. These differences allow the study to test whether the results found in earlier research also apply outside the U.S. and remain valid in a market with its own structural characteristics.

Prior research has investigated whether activity in the options market conveys predictive information about stock returns with some mixed results. Some studies support the idea that option markets lead stock markets and that option volume could have predictive

power on stock returns. These studies argue that it is because informed traders prefer options to exploit their information (Amin and Lee, 1997; Easley et al., 1998; Pan and Poteshman, 2006; Hu, 2014). Others argue that this lead-lag effect is weak or inconsistent, such as the studies from Chan et al. (1993) and Stephan & Whaley (1990). As the current market environment is constantly changing, this thesis evaluates whether the O/S signal remains informative in the current environment, where individual investors' participation in option trading has increased significantly.

Empirical research on the interaction between option and stock markets usually falls into two main groups. One group of studies suggests that trading activity and prices in the options market contain information that can predict future movements in stock prices. On the other hand, some studies argue that options do not predict stock prices and that the influence would move in the opposite direction, from stocks to options. Researchers who disagree with the "options-lead" view often state that option prices rely on underlying stock prices and volatility, which would make it unlikely for them to systematically predict stock price changes (e.g., Chan et al., 1993; Stephan & Whaley, 1990; Muravyev et al., 2013). However, several studies suggest that it is the option trading activity, rather than the option prices themselves, that first incorporates new information, as trading behavior captures the expectations of informed investors before the information is reflected in stock prices (Easley et al., 1998). To better examine the informational role of options in predicting stock prices, this study concentrates on option and stock trading volume in relation to stock price movements.

As mentioned earlier, if a trader possesses information about equity, options provide one of the most effective ways to leverage that information. Because informed traders seek to maximize their profits, their activity in derivative markets is reflected in option volume. Therefore, including option volume into the analysis may offer more accurate insights into the true value of the underlying asset than analyses based solely on the asset itself. As a result, this study focuses on the trading ratio between the option market

and the stock market to capture informed investor behavior and the potential information content related to future stock returns. This leads to the first hypothesis:

H_1 : The option-to-stock volume ratio contains predictive information about subsequent stock returns.

This study expects that if option volume will at least partially reflect new information about the stock price, there are informed traders trading in the options market. Conversely, if option trading mainly reflects uninformed speculation and increases price volatility, it could add noise to the market and lower stock values (Roll et al., 2009).

As explained earlier, one of the main issues in the studies examining information flow between the stock and option markets is how to aggregate the information from the multiple option contracts that are underlying the same stock. By focusing on the O/S ratio, this thesis seeks to find out whether increased trading activity in the options market is linked to future stock performance. Prior research shows that when the relative trading volume is bigger in the option market compared to the stock market (high O/S ratio), it reflects the presence of traders who hold negative private information and prefer to express it through options due to short-selling costs in the equity market. In contrast, when the stock market trading volume is bigger than in options market (low O/S ratio), this tends to reflect more positive information. These differences in where informed traders choose to trade can affect subsequent equity returns, which suggests that the relative allocation of trading volume across markets contains predictive information. Thus, the second hypothesis is formulated as follows:

H_2 : Stocks with lower option-to-stock volume ratios earn higher future returns than stocks with higher option-to-stock volume ratios.

1.2 Structure of the study

This study is organized as follows. Chapter two presents the theoretical background of the thesis. It discusses asymmetric information and the role of informed and uninformed traders. It also explains how traders choose between equity and option markets. Chapter three introduces option markets and the key theoretical concepts. These include the Black–Scholes model and the Efficient Market Hypothesis. It is followed by chapter four, which reviews the existing literature on option trading activity and stock return predictability. It also introduces the *O/S* ratio as the main measure used in this study. Chapter five describes the data and methodology, where the data construction is presented. It also presents the empirical approach used in the analysis. Chapter six presents the empirical results of the study. The final chapter concludes the study and discusses the main findings.

2 Asymmetric information and informed trading

Financial markets are characterized by different levels of information asymmetry between market participants. The efficient market hypothesis assumes that asset prices reflect all available information (Fama, 1970). However, financial literature shows that some traders have access to private information that is not immediately incorporated into prices (Leland & Pyle, 1977; Kyle, 1985). This information asymmetry leads to informed trading, which plays an important role in price discovery and short horizon return predictability (Kyle, 1985; Easley et al., 1998).

Asymmetric information is especially important when traders can choose between different markets. When both equity and option markets are available, informed traders decide where to trade based on expected profits, market frictions, and the characteristics of each instrument (Easley et al., 1998; Black, 1975). As a result, trading activity itself can reveal information about traders' private beliefs through observable volume patterns across markets, even when the direction of individual trades is not known. This thesis builds on this idea by examining how the allocation of trading volume between option and stock markets is related to future stock returns.

2.1 Informed and uninformed traders

The distinction between informed and uninformed traders is central in market microstructure theory. Informed traders are investors who have private information about the future value of an asset and trade to take advantage of this information (Kyle, 1985). In contrast, uninformed traders, often called noise traders, trade for reasons that are not related to private information. These reasons can include liquidity needs, hedging, or portfolio rebalancing (Black, 1986; Easley et al., 1996).

Kyle (1985) models informed traders as risk-neutral agents who know the true value of an asset and trade strategically to maximize profits while limiting their impact on prices.

In this framework, uninformed traders create random order flow, which helps informed traders hide their trades and prevents prices from adjusting immediately to private information. Black (1986) also highlights the importance of noise trading for market liquidity. Without it, informed traders would not be able to trade without revealing their informational advantage.

Easley et al. (1998) extend this framework by allowing informed traders to operate in both stock and option markets. Their model shows that informed trading influences not only prices but also trading volumes across markets, depending on where traders choose to trade. Informed traders are typically seen as more sophisticated participants, often institutional investors, who have better access to information or a stronger ability to process it (Shleifer & Vishny, 1986; Alangar et al., 1999). In contrast, uninformed traders trade continuously regardless of information events and do not consistently earn abnormal returns (Easley et al., 1996; Odean, 1999).

The ability of informed traders to choose between equity and option markets means that the distribution of trading activity across these markets may reflect private information, even when the direction of individual trades is not observed. This idea provides the basis for using aggregate volume measures, such as the option-to-stock volume ratio, to study return predictability in the following sections of this thesis.

2.2 Trading venue choice under asymmetric information

In markets with asymmetric information, informed traders are defined not only by the information they have but also by where they choose to trade. When multiple trading venues are available, such as equity and option markets, informed traders can allocate their trades across markets strategically (Easley et al., 1998). Therefore, the choice of trading venue is an important part of informed trading behaviour.

Theoretical models of informed trading show that different markets have their own advantages and constraints. Kyle (1985) demonstrates that informed traders act strategically to maximize profits while limiting their impact on prices. In the framework of Easley et al. (1998), the choice of where to trade depends on the characteristics of each market, such as liquidity, transaction costs, and the ability to express views about future firm value.

Option markets offer several features that can attract informed traders. Black (1975) argues that options allow traders to take leveraged positions with relatively low initial investment, which makes them suitable for using private information. In addition, options make it possible to benefit from both positive and negative expectations without trading the underlying stock. Because of these features, informed traders may prefer options when the expected gains from option trading are higher than those from trading stocks. The choice of trading venue affects not only prices but also trading volume. Easley et al. (1998) show that when informed traders move their activity from the stock market to the option market, it changes how trading volume is distributed across markets. As a result, observed volume patterns can reflect informed trading, even when the direction of individual trades is not known.

In most publicly available option datasets, it is not possible to determine whether trades are initiated by buyers or sellers. This information is usually available only to market makers or through proprietary trade and quote data (Johnson & So, 2012). As a result, the distribution of trading activity between markets becomes especially informative, because it reflects how informed traders respond to private information rather than the direction of individual trades.

The possibility that informed traders selectively choose where to trade implies that aggregate trading volume contains information beyond simple price changes. Therefore, changes in trading activity between equity and option markets may signal the presence of informed trading and help explain short-term return predictability. This idea motivates

the use of relative trading activity across markets, which is examined further in the next chapter.

2.2.3 Short-selling constraints

Short selling refers to selling a stock that the investor does not own by borrowing it from another party. The investor expects the price to decline and plans to buy the stock back later at a lower price to return it to the lender (Hull, 2022). A key contribution of Johnson and So (2012) is the incorporation of short-selling costs into a model of informed trading across markets. In practice, short selling involves borrowing fees, recall risk, and institutional constraints. All of these factors increase the cost of trading on negative information in equity markets. As a result, short-selling constraints can influence the choice of trading venue (Gene, 2002; Nagel, 2005).

Option markets offer an alternative way for traders to express negative views without shorting the underlying stock. An informed trader who expects a price decline can buy put options or sell call options, as both of them provide exposure to falling prices without the short selling costs in the equity market (Easley et al., 1998; Johnson & So, 2012). As a result, Johnson and So (2012) argue that informed traders are more likely to use options when trading on negative private information than when trading on positive information. This asymmetry indicates that informed trading is not evenly distributed across markets. Informed traders with positive information can trade directly in the equity market, while those with negative information are more likely to shift to the option market to avoid short-selling costs (Johnson & So, 2012). As a result, high relative option trading activity is associated with negative private information, whereas low relative option trading activity should reflect more positive information.

3 Options theory and efficient market hypothesis

Building on the theoretical framework of informed trading, this chapter introduces option markets and their role in financial markets. It begins by explaining the basic features and uses of options. Next, it presents the Black–Scholes model as a framework for option pricing. The chapter then discusses the Efficient Market Hypothesis and how information is reflected in stock prices. These concepts provide a basis for understanding how option trading activity may be linked to future stock returns.

3.1 Introduction to options

Derivatives are financial instruments whose value depends on another variable, referred to as the underlying asset. In practice, this underlying asset is most often the price of a traded financial security (Hull, 2022). For stock options, the value of the contract is directly linked to changes in the price of the underlying stock. Options give investors flexibility in how they take positions in financial markets. There are two main types of options: call options and put options. A call option allows the holder to buy the underlying asset at a predetermined price, while a put option gives the right to sell the asset under similar conditions (Hull, 2022). The predetermined price is known as the strike price, and the specified date is referred to as the expiration date.

Option contracts involve two parties. The buyer pays a premium to obtain the right to exercise the contract, while the writer receives the premium and takes on the obligation to fulfill the contract if exercised (Hull, 2022). As a result, the buyer's potential loss is limited to the premium, whereas the writer may face significantly larger losses. Options can also differ based on when they can be exercised. American options can be exercised at any time before expiration, while European options can only be exercised at maturity (Hull, 2022). Many pricing models, including the Black–Scholes model, are based on European-style options because they are easier to model.

Derivatives trading takes place both on organized exchanges and in over-the-counter (OTC) markets. Exchange-traded derivatives are standardized and support higher liquidity, while OTC contracts are privately negotiated and often involve larger individual transactions (Hull, 2022). Well-known options exchanges include the Chicago Board Options Exchange (CBOE) and EUREX.

Options are used for several purposes. Investors may use them for hedging to reduce risk, for speculation to gain leveraged exposure to price movements, or for arbitrage to exploit price differences between related assets. In efficient markets, arbitrage opportunities are typically short-lived as prices adjust quickly (Hull, 2022).

3.2 Black-Scholes model

The Black-Scholes model is based on the geometric Brownian motion assumption. To understand how option volume can affect stock prices, it is helpful to understand how the theoretical fair value of options is formed. The Black-Scholes option pricing model formed by Black and Scholes (1973) and continued by Merton (1973), was a breakthrough in pricing a European options contract (Hull, 2022). Developed in 1973, the fundamental model enabled a wide-spread option trading in derivative markets.

The core idea of the model is to calculate the probability that an option will be exercised at expiration, thus, it being in-the-money (ITM). Underlying stock's price, option's strike price and its time to maturity, volatility of the stock and risk-free interest rate, are variables required to the mathematical model to obtain an option's theoretical fair value (Black, 1975).

Only these variables are needed when simplified conditions in the market are assumed (Black, 1973):

- a) As described earlier, the stock price follows a lognormal distribution where μ and σ are constant.

- b) Security trading is assumed to be continuous.
- c) A market is expected to be frictionless and to not include any taxes.
- d) Short selling is possible.
- e) There are no riskless arbitrage opportunities.
- f) The underlying stock does not yield any dividends.
- g) The risk-free interest rate is constant.
- h) Investors can deposit and borrow money with risk-free interest rate.

Multiple assumptions included in the Black-Scholes model can cause discrepancy between the model and the real-world price. Researchers continue their efforts in refining the model to make it more realistic.

The BSM pricing formulas for call and put options are as follows (Hull, 2022):

$$c = S_0 N(d_1) - Ke^{-rT} N(d_2), \quad (1)$$

and,

$$p = Ke^{-rT} N(-d_2) - S_0 N(-d_1), \quad (2)$$

Where

$$d_1 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma \sqrt{T}}, \quad (3)$$

and,

$$d_2 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma \sqrt{T}} = d_1 - \sigma \sqrt{T}. \quad (4)$$

Where

S_0 = Price of the underlying asset

K = Option's strike price

T = Time to maturity

r = Risk-free interest rate

σ = Volatility

$N(x)$ = Cumulative probability distribution function

$N(x)$ represents the cumulative probability distribution function for a variable that follows a standard normal distribution $\phi(0,1)$. In other words, it is the probability that a variable following a standard normal distribution will have values less than x . (Hull, 2022).

The actual prices of options can differ from the values given by the Black-Scholes option pricing model. The model doesn't consider all factors that can affect the option price indirectly. For example, fundamental economic principles such as supply, and demand can cause the option price to differ from its theoretical price.

In the context of this thesis, the formerly introduced theories are relevant for several reasons. As mentioned earlier, if the market is efficient, option volume should be quickly incorporated into stock prices. Therefore, understanding whether and how option trading volume affects stock prices can provide insights into the efficiency of the market. Irregularities in price adjustments in response to changes in option volume could indicate market inefficiencies. Geometric Brownian motion can be used to simulate potential future stock price movements based on historical option volume data. Thus, it can be used to examine how the changes in option volume can affect the expected future equity prices. Finally, Black-Scholes model can be utilized to see if current option prices are in line with the model's predictions. By observing deviations between these two, it can suggest that other factors beyond the model influence option prices.

3.3 Efficient Market Hypothesis

The formation of Eugene Fama's theory of efficient markets was published in 1970 and since it has been declared as one of the most foundational theories in finance. According to the efficient market hypothesis (EMH), market is efficient when security prices reflect all publicly available information at any given time. Thus, the theory suggests that it is

impossible to beat the market because all information is already incorporated in equity prices. When new information appears in the market, investors adjust their investments accordingly which results to their new fair market value. Consequently, investors should not pick stocks in hope for a greater return but could utilize the average market returns through low-cost passive index investing.

Fama (1970) categorizes the efficient market in three forms based on the degree of which prices reflect information. The first one is the weak form, where the current asset prices reflect only the historical prices of assets and future price of assets are based on new information. Thus, technical analysis cannot be used, but with certain fundamental analysis average returns of the market could be outperformed. Second, the semi-strong form is when current asset prices reflect all publicly available, but not private, information. The semi-strong form argues that above average returns can't be generated either with fundamental or technical analysis. Fundamental analysis is ruled out because when new information appears in the semi-strong form, prices quickly adjust to new information. Only the possession of non-public information could enable the investor to gain superior returns. Finally, efficient market is in its strongest form when current asset prices reflect all information. So, additionally to public information, also private information is incorporated into asset prices. Thus, in the strong-form, even private information cannot be used to generate above average market returns.

Due to multiple assumptions included in the theory, the strongest form of market efficiency rarely holds. Fama (1970) states that in his theory, the market is assumed to be frictionless which does not represent a real market. Such frictionless market doesn't have any costs related to the transactions and information is free. In addition, the theory assumes market participants to have equal access to all information and use it to make same assumptions. Thus, EMH fails to take into consideration the trading behaviour of informed and uninformed market participants mentioned earlier. Trades of the uninformed can cause the price of the asset to differ from its fair value.

In theory, if markets would be efficient, option volume would not be able to predict future asset returns. Information indicated by option volume would be quickly incorporated into the stock price.

4 Option trading activity and stock return predictability

After discussing the theoretical background of efficient markets and options, attention can now be directed to the theory of how option trading activity relates to stock return predictability. The relationship between option and stock markets has been studied extensively in the financial literature. However, the results differ depending on the type of option data used and whether trade direction can be observed. This chapter reviews the relevant literature and explains why the O/S ratio is used as the main measure in this thesis.

4.1 Directional option volume and informational content

Early research on the informational role of option markets focuses on whether the direction of option trading activity convey information about future stock returns (Easley et al., 1998). The main idea is that some investors possess private information about a firm's future performance and try to exploit this information through trading before it is fully incorporated into stock prices. As discussed in the previous chapter, these investors are referred to as informed traders, meaning traders who act on information that is not yet publicly available (Easley et al., 1998). Option contracts are particularly attractive to informed traders because they offer embedded leverage, which allow traders to trade on the changes in the underlying stock price with a relatively small initial investment. For example, purchasing a call option requires paying only the option premium rather than the full stock price, although the option's value remains highly sensitive to changes in the underlying stock. As a result, this leverage increases the potential gains and lowers the amount of capital needed to enter a position (Black, 1975; Easley et al., 1998).

A key contribution to the directional option volume literature is Pan and Poteshman (2006), who study whether option trading volume contains information about future stock returns using detailed transaction data from the Chicago Board Options Exchange. Their dataset allows them to observe whether option trades are buyer- or seller-initiated

and whether they are opening and closing trades. This distinction is important, because opening trades are more likely to reflect new private information, while closing trades may be driven by profit-taking or portfolio adjustments rather than new beliefs about future stock prices (Pan and Poteshman, 2006).

Pan and Poteshman (2006) construct a put–call ratio based on buyer-initiated opening trades. The put–call ratio measures the relative trading volume of put options to call options. Pan and Poteshman (2006) show that the buyer-initiated put–call ratio strongly predicts future stock returns. Stocks with low put–call ratios subsequently earn higher returns, while stocks with high put–call ratios earn lower returns. The predictive power is strongest over short periods, especially over the next day and week, and weakens over time as information is incorporated into stock prices. These results suggest that option traders act on private information that is not immediately reflected in equity prices (Pan and Poteshman, 2006). The authors interpret their results as evidence that informed traders prefer to act on their directional views through option markets rather than through stock markets. In addition to embedded leverage, options allow traders to take positions without trading the underlying stock directly, which can reduce their impact on stock prices. By trading options instead of stocks, informed traders can exploit their information in a less visible way, especially when trading large positions (Pan and Poteshman, 2006).

Pan and Poteshman (2006) also find that opening trades contain more information than closing trades. This supports the idea that return predictability is linked to the arrival of new private information. In addition, they show that the predictive power of option volume is stronger for firms with high institutional ownership. This suggests that informed trading in option markets is more common for firms that are closely followed by sophisticated investors (Pan and Poteshman, 2006).

Overall, the literature on directional option volume provides strong evidence that option trading activity can predict future stock returns when the direction of trades is

observable. These findings suggest that informed traders use option markets to act on private information before it is reflected in stock prices. However, these measures rely on detailed transaction-level data, which is not always available. The limitations of these approaches are discussed in the next section.

4.2 Limitations of directional option volume

As research on option trading and stock return predictability develops, more attention has been given to the limitations of directional option volume measures. Directional option volume refers to trading activity classified based on whether trades are initiated by buyers or sellers (Pan & Poteshman, 2006). As discussed earlier, studies using this type of data provide evidence that option markets can reflect private information. However, these measures face important limitations. In particular, they rely on detailed data that is not always publicly available (Johnson & So, 2012). In addition, the interpretation of option volume can be unclear, which further limits their usefulness (Holowczak et al., 2014).

A primary limitation of directional option volume measures is that they rely on proprietary data. Measures based on directional data require information on whether option trades are buyer- or seller-initiated and whether they open or close positions. In most commonly available option datasets, only total trading volume can be observed, without details on trade direction or position type. This severely limits the ability to apply directional option volume measures outside specialized data environments and reduces their usefulness for empirical research and for market participants who rely on publicly available data (Johnson and So, 2012).

In addition, interpreting directional option volume is not straightforward when trade motives are unobserved. The informational content of call and put volume depends on whether options are bought or sold and on the purpose of the trade. Johnson and So (2012) emphasize that a high volume of call option trades may reflect bullish call buying

by informed traders, but it may also reflect call selling by traders with negative private information. Similarly, high put volume might not indicate only pessimism, as option trading may also be driven by hedging or volatility-based strategies rather than expectations about future stock prices (Ge et al., 2016). As a result, aggregate call and put volumes give an ambiguous signal about the investors' expectations, which makes it harder to use them as general predictors of returns.

Event-based studies further highlight both the strengths and the limitations of directional option volume measures. Amin and Lee (1997) document informed option trading prior to earnings announcements, while Cao et al. (2005) show that option volume increases ahead of takeover announcements and predicts abnormal stock returns. Although these findings demonstrate that option markets are actively used by informed traders in specific information events, their findings are difficult to apply when constructing continuous measures of informed trading across the market because these studies focus on particular events.

In addition to information-based explanations, the literature also considers alternative reasons why option trading activity may predict stock returns. One important explanation is based on investor disagreement combined with short-selling constraints (Miller, 1977). In this framework, pessimistic investors face restrictions that limit their ability to short sell, which prevents them from fully expressing negative views in the equity market. As a result, stock prices may mainly reflect the beliefs of optimistic investors, which can lead to temporary overvaluation and subsequent negative returns when disagreement diminishes (Miller, 1977). While option markets allow investors to express negative views more easily than equity markets, they do not completely remove short-selling constraints. This can imply that option trading activity may sometimes reflect differences in investor opinions rather than superior private information (Miller, 1977; Boehme et al., 2006).

Taken together, these issues highlight a broader difficulty faced by directional option volume measures. Without information on trade direction, investor identity, or trading motives, it is difficult to separate informed trading from other types of trading activity, such as that driven by investor disagreement. These limitations are particularly relevant in empirical studies that rely on publicly available data and aim to capture informed trading activity over time (Johnson and So, 2012). These constraints associated with directional option volume motivate the development of non-directional measures based on relative trading activity across markets. Rather than attempting to infer the sign of investors' information from individual option trades, the following research focuses on observable volume data that is more widely available.

4.3 Option-to-stock volume ratio (O/S)

Roll et al. (2010) introduce the option-to-stock volume ratio (O/S) as a non-directional measure of relative trading activity in option and equity markets. The O/S measures the allocation of trading activity in the option market compared to the underlying equity market using publicly observable data (Roll et al. 2010). Unlike directional option-based measures, O/S does not require information on whether option trades are buyer- or seller-initiated, nor does it rely on separating call and put volume, which is often not possible with standard datasets (Johnson and So, 2012). Instead, the ratio reflects investors' choice of trading venue, which may itself be informative under asymmetric information. Formally, the option-to-stock volume ratio is defined as:

$$O/S \text{ ratio} = \frac{\sum_{xc} \sum_{mc} \text{Call Volume}_{xc,mc} + \sum_{xp} \sum_{mp} \text{Put Volume}_{xp,mp}}{\text{Stock Volume}} \quad (5)$$

It measures the ratio of total option market volume to the total equity market volume by dividing the total listed options across all exercise prices and maturities by stock trading volume of the same period.

The interpretation of O/S follows from models of informed trading in multi-market settings. When traders possess private information about a firm's future value, they optimize and select the market where to trade based on expected profitability and market frictions (Kyle, 1985; Easley et al., 1998). In such environments, informed trading affects not only prices but also the allocation of trading volume across markets. This shows that relative trading activity can convey information even when individual trades cannot be identified as buys or sells (Easley et al., 1998). Roll et al. (2010) emphasize that variation in O/S can therefore be interpreted as a signal of informed trading intensity rather than just liquidity-driven trading.

A central mechanism linking O/S ratio to future stock returns is related to asymmetries in short-selling costs in equity markets. Trading on negative private information through short selling is often costly due to borrowing fees, recall risk, and institutional or regulatory constraints (Diamond and Verrecchia, 1987; D'Avolio, 2002). These frictions limit the ability of pessimistic informed traders to express negative views directly in equity markets (Nagel, 2005). In contrast, option markets allow traders to take bearish positions by buying put options or selling calls without shorting the underlying stock, which makes the option market a more attractive venue for trading on negative information (Easley et al., 1998).

Johnson and So (2012) formalize this idea and show that short-selling frictions lead informed traders with negative private information to shift their trading activity toward the option market. In contrast, informed traders with positive information can more easily exploit their signals through stock purchases, which creates an asymmetric allocation of informed trading across markets. This asymmetry implies that high option trading volume relative to stock volume reflects the presence of negative private information, while low O/S is associated with relatively positive information being incorporated through equity trading (Johnson and So, 2012).

Importantly, this mechanism does not depend on observing the direction of option trades. As mentioned before, aggregate call and put volumes are individually ambiguous when trade direction is unobserved, as call volume may reflect either bullish purchases or bearish call writing, and the same issue applies to put volume (Easley et al., 1998). By aggregating option volume across contracts and scaling it by equity volume, the O/S ratio captures the overall shift of informed trading activity across markets rather than the sign of individual trades (Roll et al., 2010). Empirical evidence provide support for this interpretation. Johnson and So (2012) construct the O/S ratio using separate measures of option and stock trading volume based on publicly available data. Their dataset includes 611,173 firm-week observations covering the period from 1996 to 2010. To determine how O/S affects future firm value, they sort firms by O/S at the end of each week and compare it to the average returns of a portfolio consisting of a short position in stocks with high O/S and a long position in stocks with low O/S from the same period.

Johnson and So (2012) document a strong negative relation between O/S and subsequent stock returns, with firms in the highest O/S deciles significantly underperforming firms in the lowest deciles over short horizons. More specifically, the difference in returns between the lowest and highest O/S deciles is about 0.34% per week, which corresponds to roughly 19.3% on an annual basis. In other words, if a firm has low O/S the firm outperforms the market and if a firm has a high O/S the firm underperforms the market (Johnson & So, 2012). This study supports the theory that when option trades are lower than the equity trades, the firm outperforms the market and when option trades are higher than equity trades, the firm underperforms the market.

This suggests that option volume totals predict future returns of the underlying asset and that outside observers can also utilize option volumes in price discovery. However, they discover that O/S's ability to predict future returns is relatively short lived. The predictability associated with O/S dissipates within weeks, which is consistent with the view that information is gradually incorporated into stock prices rather than reflecting compensation for risk.

Johnson and So (2012) also find results that are consistent with Pan and Poteshman (2006) regarding the role of informed traders in explaining the predictive power of option volume. They find that the predicting power of option volume to future equity value is caused by informed traders trading with their negative information in option markets to avoid short selling costs. They find that more informed traders with negative information switch from equity markets to option markets when short selling costs are high. This results in stronger negative relation between O/S and future returns. In contrast, less traders with negative information switch from equity market to option markets when bid-ask spreads increase, which weakens the negative relation of O/S to future returns. So, it seems that when informed traders possess negative information, they preferably establish their positions through options to avoid short selling costs and it negatively impacts the firm's future returns.

Ge et al. (2016) show that leverage is an important reason why option trading can predict stock returns. They also find that even when option volume is aggregated, the negative relationship between the O/S ratio and future returns remains. This supports the use of the O/S ratio as a practical measure when trade direction is not observable.

Woo and Kim (2021) examine whether option trading volume ratios have predictive power for future stock returns and find that both the call to put ratio and the option to stock volume ratio contain significant information about future returns. However, their results show that the predictive power of the O/S ratio is more robust compared to the call to put ratio. When both measures are included in the same regression model, the call to put ratio loses its statistical significance, while the O/S ratio remains significant. This suggests that the O/S ratio captures the information content of option trading activity more effectively than directional measures. These findings are consistent with earlier research, such as Blau et al. (2014), which also shows that the O/S ratio has stronger predictive power than the put call ratio, especially at weekly and monthly frequencies.

Option-to-stock volume ratio captures an economically important aspect of informed trading behaviour, namely how trading activity is distributed across markets under asymmetric information and market frictions. By focusing on trading venue choice rather than trade direction, O/S provides a theory-based and empirically tractable measure of informed trading that can be constructed using publicly available data. Whether the economic mechanisms documented primarily in U.S. markets extend to a European setting such as the DAX remains an open question that this thesis examines. The next chapter addresses this question by constructing the O/S ratio for DAX firms and examining its ability to predict future stock returns.

5 Data and methodology

This chapter describes the data and methodology used in the empirical analysis. It first presents the data, including the sample selection and variable construction. It then explains the methodology used to examine the relationship between the option-to-stock volume ratio and future stock returns.

5.1 Data

This study examines the predictive power of the O/S ratio for future stock returns using firms included in the DAX index during the period 2020–2025. The DAX index consists of 40 of the largest and most liquid companies listed on the Frankfurt Stock Exchange, which provides a suitable setting for analyzing the interaction between option and equity markets in a European context. However, not all DAX constituents have sufficiently active option markets. Of the 40 firms, 36 exhibit observable option trading activity on EUREX. In addition, firms with extremely low or near-zero option trading volume are excluded, as the O/S ratio becomes uninformative and may introduce distortions in the empirical analysis. Scout24, Volkswagen, and Fresenius Medical Care are excluded due to insufficient option trading activity. Additionally, Heidelberg Materials, Mercedes-Benz, Münchener Rück, and Vonovia are excluded due to the absence of observable option trading volume during the sample period. The empirical analysis is conducted at the daily firm level. Using daily data, the thesis aims to capture return predictability more precisely, as the predictive power is strongest over short horizons and gradually decreases when information gets factored into stock prices (Pan & Poteshman, 2006). The final sample therefore consists of 32 firms and a total of 47,296 firm-day observations.

The sample includes the firms that were in the DAX index at any point during the sample period. Each firm is included in the research only during their actual index membership period, resulting in an unbalanced panel. This approach helps reduce survivorship bias, which could otherwise arise if only firms that remain in the index throughout the entire

period were considered (Brown et al., 1992). Excluding firms that exit the index would remove companies undergoing structural changes, mergers, or financial distress, even though such conditions are often associated with elevated information asymmetry and informative option trading activity (Easley et al., 1998).

Daily option trading data are obtained from the EUREX exchange for all chosen DAX firms with single-stock options and sufficient option volume during the sample period. Option trading volume includes both call and put contracts across all available strike prices and maturities. For each firm and trading day, total option volume is constructed by aggregating trading volume across all listed option contracts.

Daily stock data are obtained for the corresponding firms and include stock trading volume, daily closing prices, market capitalization, and historical volatility. Stock trading volume is measured as the number of shares traded per day. To ensure comparability between option and stock trading activity, stock trading volume is converted into round-lot equivalents by dividing the number of shares traded by 100, as one standard equity option contract typically represents 100 shares of the underlying stock. This adjustment is incorporated into the construction of the *O/S* ratio.

Daily stock returns are computed using closing prices as the percentage change between consecutive trading days. The dependent variable in the empirical analysis is the next-day stock return. It is done by matching the return on day $t + 1$ with the *O/S* ratio measured on day t . This approach ensures that the analysis remains predictive, as all explanatory variables are measured before the returns are realized.

The key explanatory variable in this study is the option-to-stock volume ratio (*O/S*), which is formally introduced in the previous chapter. *O/S* measures the relative level of trading activity in the option market compared to the underlying stock market. The *O/S* ratio measures the relative intensity of option trading compared to equity trading for a

given firm-day. Higher values of O/S indicate that a larger share of trading activity occurs in the option market relative to the stock market.

Descriptive statistics are presented in Table 1. In the table, option volume and stock volume are daily measures and stock volume is transferred in round lots as explained before. Trading activity varies considerably across firms and over time. Option trading volume is strongly right-skewed (skewness = 3.66) and exhibits high kurtosis (23.15), indicating that a large proportion of option trading activity is concentrated in a relatively small number of firm-day observations. This pattern is consistent with earlier findings, where option trading tends to be clustered among the most actively traded firms and periods of heightened market activity. Stock trading volume shows similar but even more pronounced distributional properties. The distribution is highly right-skewed (skewness = 4.91) and extremely leptokurtic (kurtosis = 45.65), suggesting that trading activity is heavily concentrated in a few large and liquid firms. This is consistent with the structure of the DAX index, which consists of large-cap companies that dominate overall market liquidity.

The O/S trading intensity is measured using the natural logarithm of the O/S ratio, $\ln(O/S + 1)$, which can be seen in the table below. This transformation is used to ensure that highly skewed trading variables do not dominate empirical results. The transformed variable has a mean of 4.25 and a standard deviation of 1.89. Compared to the raw trading volume variables, the distribution is more balanced, although it remains slightly left-skewed (skewness = -0.72). The kurtosis of -0.16 indicates that extreme observations are substantially reduced after the transformation. This is important, as it suggests that the logarithmic specification mitigates the influence of extreme values and produces a measure that is more suitable for regression analysis.

Future stock returns have a mean close to zero (0.04 percent) and a standard deviation of approximately 2.02 percent. The distribution exhibits slight positive skewness (0.03) and high kurtosis (10.42), indicating the presence of occasional large return realizations.

This is consistent with the well-documented fat-tailed nature of equity return distributions. The mean return being close to zero aligns with expectations for short-horizon returns, where predictable components are typically small.

Table 1 Descriptive statistics.

	<i>Stock volume</i>	<i>Option volume</i>	<i>Ln(O/S+1)</i>	<i>Return (t+1)</i>	<i>ln(MV)</i>	<i>Volatility</i>
Mean	1978,76	24193,75	0,008693	0,0004	10,2376	0,3012
Standard Error	13,36	407,17	4,647966	0,0001	0,0041	0,0004
Median	803,60	5000,50	0	0,0005	10,2012	0,2896
Standard Deviation	3232,63	41932,51	1,891169	0,0202	0,9005	0,0761
Variance	10449903,12	1758335284,13	3,576522	0,0004	0,8110	0,0058
Kurtosis	45,65	23,15	-0,15974	10,4211	-0,5638	-0,5471
Skewness	4,91	3,66	-0,71746	0,0285	0,0965	0,3612
Range	88041,90	585753,00	9,981846	0,4921	5,1807	0,3491
Minimum	0,00	0,00	0	-0,2194	7,5687	0,1505
Maximum	88041,90	585753,00	9,981846	0,2727	12,7494	0,4996
Sum	115791273,10	256598951,00	200966,8	18,6991	484197,45	14247,08
Count	47296	47296	47296	47296	47296	47296
Largest(1)	88041,90	585753,00	9,981846	0,2727	12,7494	0,4996
Smallest(1)	0,00	0,00	0	-0,2194	7,5687	0,1505
Confidence Level(95,0%)	26,19	798,13	0,017038	0,0002	0,0081	0,0007

Overall, the descriptive statistics indicate substantial variation in both option and stock trading activity across firms and over time. At the same time, the return distribution remains centered around zero, suggesting that any predictive relationship between trading activity and future returns is likely to be detected through cross-sectional analysis rather than simple average returns.

5.2 Methodology

This thesis examines whether option trading volume predicts future stock returns using an ordinary least squares (OLS) regression. It is used to estimate the relationship between the O/S ratio and future stock returns by regressing next period returns on the O/S ratio and control variables. The analysis focuses on the O/S ratio and its ability to forecast subsequent stock returns at the firm level. The empirical setting consists of selected firms included in the DAX index, which represents one of the largest and most liquid equity markets in Europe. The sample period spans from January 2020 to October 2025.

The central objective of the empirical analysis is to determine whether variation in the relative intensity of option trading, measured by the O/S ratio, is associated with future stock returns. In particular, the analysis investigates whether higher option-to-stock trading activity reflects informed trading and therefore contains predictive information about subsequent price movements.

The unit of observation is the firm-day. All variables are constructed at a daily frequency, and the dataset is organized as a panel of firm-level observations over time. This structure allows for both cross-sectional and time-series variation in the analysis.

Option trading volume is constructed by aggregating all option transactions for a given firm and day. This aggregation includes all call and put options, across all strike prices and maturities. The aggregation is necessary because the raw option data are available at the contract level, and a firm-level measure of total option activity must be constructed.

Stock trading volume is measured over the same period. Stock trading volume is measured as the total number of shares traded for a given firm and day. As mentioned earlier, stock volume is divided by 100 to ensure comparability between option contracts and stock transactions. This adjustment ensures that the O/S ratio reflects comparable units

of trading activity. The resulting O/S ratio captures the relative intensity of option trading compared to stock trading and serves as a proxy for the degree of information-based trading in the option market.

The raw O/S ratio is characterized by a highly skewed distribution and the presence of extreme values. These properties can distort regression estimates and complicate interpretation. To address these issues, the O/S ratio is modified by applying a logarithmic transformation:

$$\log(O/S_{i,t}) = \ln(1 + O/S_{i,t}) \quad (6)$$

The addition of one ensures that observations with zero option volume are retained in the sample and avoids undefined values.

Second, the log-transformed O/S ratio is standardized using the full sample mean and standard deviation:

$$\widetilde{O/S}_{i,t} = \frac{\log(O/S_{i,t}) - \mu}{\sigma} \quad (7)$$

where μ and σ denote the mean and standard deviation of the log-transformed O/S ratio across all firms and all days in the sample period. This standardization produces a variable with mean zero and unit variance, allowing for a consistent interpretation of regression coefficients in terms of standard deviation changes. The standardized O/S ratio is used as the main explanatory variable in both portfolio sorting and regression analysis.

Stock returns are constructed using daily price data. Specifically, for each firm i and day t , returns are calculated as the percentage change in the stock price:

$$R_{i,t} = \frac{P_{i,t} - P_{i,t-1}}{P_{i,t-1}} \quad (8)$$

where $P_{i,t}$ denotes the closing price of firm i on day t . This measure captures the daily capital gain component of returns.

To examine the predictive relationship between option trading activity and future stock returns, the explanatory variable is aligned with next-day returns. The return series is therefore shifted forward such that the return realized on day $t + 1$ is matched with the O/S volume ratio measured on day t :

$$R_{i,t+1} \tag{9}$$

In practical implementation, this is achieved by shifting the return series one period forward within each firm. As a result, the observation for each firm-day t contains the O/S ratio at time t and the corresponding stock return at time $t + 1$.

Observations corresponding to the final trading day for each firm are excluded from the analysis, as the subsequent return $R_{i,t+1}$ is not observable.

5.2.1 Portfolio sorting

As a first step in the empirical analysis, a non-parametric portfolio sorting approach is used to assess the predictive power of the O/S ratio. This method provides an intuitive way to examine whether firms with high option trading activity exhibit systematically different future returns compared to firms with low option trading activity.

For each trading day, firms are sorted cross-sectionally based on their standardized O/S ratio $\widetilde{O/S}_{i,t}$. The firms are then divided into five equally weighted quintiles. Quintile 1 contains firms with the lowest O/S values, and Quintile 5 contains firms with the highest O/S values. For each day and each quintile, the equal-weighted average of next-day

returns $R_{i,t+1}$ is computed. This results in a time series of daily portfolio returns for each quintile.

To assess the economic significance of the O/S ratio, a high-minus-low portfolio is constructed:

$$Q5 - Q1 \tag{10}$$

This portfolio represents the difference in average returns between firms with the highest and lowest levels of option trading activity. A positive value of this spread would indicate that high O/S firms outperform low O/S firms. This would align with the hypothesis of the study. While portfolio sorting provides a clear and intuitive test, it does not fully exploit the variation in the data. Therefore, it is complemented by a regression-based approach.

5.2.2 Regression framework

To formally evaluate the relationship between the O/S ratio and future stock returns, a pooled panel regression is estimated using ordinary least squares (OLS). The baseline specification is given by:

$$R_{i,t+1} = \alpha + \beta \widetilde{O/S}_{i,t} + \varepsilon_{i,t} \tag{11}$$

where $R_{i,t+1}$ denotes the future daily return of firm i , and $\widetilde{O/S}_{i,t}$ is the standardized O/S volume ratio. The coefficient β captures the marginal effect of option trading activity on subsequent stock returns. Since the O/S ratio is standardized, β can be interpreted as the change in next-day stock returns associated with a one standard deviation increase in the log-transformed O/S ratio. All explanatory variables are measured at time t , while the dependent variable is measured at time $t + 1$. This lag structure ensures that the

regression relies exclusively on information available prior to the realization of returns to preserve the predictive interpretation of the model.

5.2.3 Control variables

To examine whether the predictive power of the O/S ratio is robust to firm characteristics, additional control variables are incorporated into the regression framework. Consistent with the empirical asset pricing literature, firm size and stock return volatility are included as controls.

Firm size is measured using market capitalization. To reduce skewness and ensure comparability across firms, the natural logarithm of market capitalization is used:

$$\ln (MV_{i,t}) \quad (12)$$

Firm size is a well-known determinant of stock returns and is also closely related to trading activity in both stock and option markets. Including size as a control helps ensure that the estimated effect of the O/S ratio is not driven by differences between large and small firms.

Stock return volatility is proxied by historical volatility, which reflects the level of uncertainty in stock returns. Option trading activity is strongly related to volatility, as higher uncertainty increases both hedging demand and speculative trading. At the same time, volatility is associated with expected returns. Including this variable allows for a clearer separation between the informational content of option trading and general risk effects.

The extended regression specification is:

$$R_{i,t+1} = \alpha + \beta \widetilde{O/S}_{i,t} + \gamma_1 \ln (MV_{i,t}) + \gamma_2 Vol_{i,t} + \varepsilon_{i,t} \quad (13)$$

where $Vol_{i,t}$ denotes historical volatility. All control variables are measured at time t , consistent with the predictive framework of the analysis. The coefficient of primary interest is β , which captures whether variation in the O/S ratio is associated with future stock returns after controlling for firm size and volatility. A statistically significant estimate of β would indicate that option trading activity contains incremental information about subsequent stock returns beyond standard firm-level characteristics. This regression framework allows the study to test whether the O/S ratio contains predictive information about future stock returns. The results of the empirical analysis are presented in the next chapter.

6 Empirical results

This chapter presents the empirical results of the study. It examines whether the option-to-stock volume ratio predicts future stock returns. The results are first presented using portfolio sorting and then analyzed using regression models.

6.1 Portfolio sorting results

This section presents the results from the portfolio sorting approach used to examine the predictive power of the O/S ratio. As described in the methodology, firms are sorted daily into quintiles based on their standardized O/S values. Quintile 1 contains firms with the lowest relative option trading activity, while Quintile 5 contains firms with the highest.

For each quintile, the average next-day return is computed. The results are summarized in Table 2.

Table 2 Portfolio sorting results.

Quantile	Average return
1 (Low O/S)	0,043%
2	0,029%
3	0,034%
4	0,054%
5 (High O/S)	0,039%

The results do not exhibit a clear monotonic relationship between the O/S ratio and future stock returns. While the fourth quintile shows the highest average return, the pattern across quintiles is non-linear. In particular, the highest O/S portfolio (Quintile 5) does not yield the highest returns.

To assess the economic significance of the O/S ratio, a high-minus-low portfolio is constructed by taking the difference between the returns of Quintile 5 and Quintile 1:

$$Q5 - Q1 \tag{14}$$

The resulting spread is:

$$Q5 - Q1 = -0.00003648 \tag{15}$$

which corresponds to approximately -0.0036% per day. This negative spread indicates that, on average, firms with the highest option-to-stock trading activity slightly underperform firms with the lowest activity. However, the magnitude of this difference is economically insignificant.

The portfolio sorting results provide limited evidence in support of the hypothesis that option trading activity predicts future stock returns. In contrast to the theory where high O/S firms tend to outperform low O/S firms, the results in this study do not indicate a positive relationship.

It is important to note that the reported results are based on pooled average returns across all observations. While this approach provides an initial indication of the relationship between O/S and returns, it may not fully capture the dynamic behaviour of portfolio returns over time. Consequently, the portfolio results should be interpreted as preliminary evidence. To provide a more thorough assessment, the analysis proceeds to a regression-based framework, which allows for a more precise evaluation of the predictive power of the O/S ratio while controlling for firm characteristics.

6.2 Regression results

This section presents the results from the regression analysis used to examine the predictive power of the O/S ratio. As outlined in the methodology, a pooled ordinary least squares (OLS) regression is estimated, where next-day stock returns are regressed on the standardized O/S ratio.

Table 3 presents the results from the baseline regression. The estimated coefficient on the standardized O/S ratio is negative, with a value of -0.00017 . This indicates that higher option trading activity relative to stock trading is associated with slightly lower subsequent stock returns. In economic terms, a one standard deviation increase in the O/S ratio corresponds to a decrease of approximately 0.017% in next-day returns. However, the statistical significance of this relationship is limited. The associated p-value is 0.0636, which exceeds the conventional 5% significance threshold, although it is marginally significant at the 10% level. The corresponding t-statistic of -1.855 suggests that the evidence for a predictive relationship is weak.

The explanatory power of the model is extremely low, as reflected in the R^2 value of 0.00007. This indicates that variation in the O/S ratio explains only a negligible fraction of the variation in stock returns.

Table 3 Regression results.

Panel A: Coefficient Estimates			
Variable	Coefficient	t-Statistic	p-value
O/S ratio (standardized)	-0.00017	-1.855	0.0636
Constant	0.00040	4.259	< 0.001

Panel B: Model Statistics	
Statistic	Value
Observations	47,296
R^2	0.00007
Adjusted R^2	0.00005
F-statistic	3.442

Prob(F-statistic) 0.0636

The regression results are broadly consistent with the findings from the portfolio sorting analysis. Both approaches therefore suggest that the O/S ratio does not exhibit strong predictive power for future stock returns in the DAX market over the sample period. This finding provides only limited support for the study's hypothesis, as the estimated relationship is weak and lacks statistical significance at conventional levels.

6.3 Regression with controls

To assess whether the predictive power of the O/S ratio is robust to firm characteristics, the regression model is extended to include firm size and volatility as control variables. The results of this extended model are reported in Table 4.

Table 4 Regression results with control variables.

Panel A: Coefficient Estimates			
Variable	Coefficient	t-Statistic	p-value
O/S ratio (standardized)	-0.00020	-2.098	0.0359
ln(MV)	-0.00008	-0.713	0.4757
Volatility	0.00327	2.606	0.0092
Constant	0.00018	0.151	0.8800

Panel B: Model Statistics	
Statistic	Value
Observations	47,296
R ²	0.00025
Adjusted R ²	0.00018
F-statistic	3.909
Prob(F-statistic)	0.0084

The coefficient on the standardized O/S ratio remains negative but becomes statistically significant at the 5% level, with an estimated value of -0.00020 and a p-value of 0.036. This indicates that higher option trading activity relative to stock trading is associated with lower subsequent stock returns. In economic terms, a one standard deviation increase in the O/S ratio corresponds to a decrease of approximately 0.020% in next-day returns.

Compared to the baseline regression, the inclusion of control variables strengthens both the magnitude and statistical significance of the O/S coefficient. While the baseline model produced only weak evidence at the 10% level, the controlled specification provides stronger support for a negative relationship between option trading activity and future returns.

Among the control variables, volatility is positively related to future returns and statistically significant at the 1% level. This finding is consistent with the risk-return trade-off, as higher volatility is associated with higher expected returns. In contrast, firm size, measured as the logarithm of market capitalization, is not statistically significant. This finding suggests that size does not play a major role in explaining return variation in this specification. The overall explanatory power of the model remains low, as indicated by the R^2 value of approximately 0.00025. However, this is typical in empirical asset pricing studies using daily data. Importantly, the F-statistic indicates that the model is jointly significant.

Despite these findings, the overall explanatory power of the regression models remains low, as reflected in the small R^2 values. Taken together, the results of this study suggest that the O/S ratio does not exhibit strong or economically meaningful predictive power for future stock returns in the DAX market over the sample period. While the regression results with controls provide some evidence of a statistically significant relationship, the effect is weak and opposite in sign to that documented in prior studies. This finding contrasts with the previous literature conducted in the U.S. equity markets.

6.4 Discussion of results

Although the empirical results presented in the previous sections are not statistically significant, their interpretation remains important. The absence of a significant relationship between the O/S ratio and future stock returns provides valuable insight, particularly in light of earlier studies that document strong predictive effects. This section therefore examines the economic relevance of the findings, compares them with prior literature, and discusses possible explanations grounded in the theoretical framework of the study.

When comparing the results of this study to earlier research, a clear contrast emerges. Johnson and So (2012) document a strong negative relationship between the O/S ratio and future stock returns, showing that firms in the lowest O/S decile outperform those in the highest decile by approximately 0.34 percent per week. This finding implies that high option trading activity relative to stock trading reflects negative private information and predicts lower subsequent returns (Johnson & So, 2012). In contrast, the results obtained from the DAX sample do not exhibit a comparable pattern. The return spread between high and low O/S portfolios is economically negligible and statistically insignificant, and the regression estimates do not indicate any meaningful relationship between the O/S ratio and future returns. These findings suggest that the predictive power of the O/S ratio is not universal and may depend on market-specific conditions.

A central explanation for this result relates to the role of informed trading, which constitutes the theoretical foundation of the O/S measure. The predictive power of the O/S ratio relies on the assumption that option markets are actively used by informed traders who possess private information about future stock prices (Easley et al., 1998; Johnson & So, 2012). However, as discussed in the theoretical framework, option trading activity may also be driven by uninformed traders engaging in hedging, liquidity-motivated trading, or speculative strategies unrelated to private information (Black, 1986; Easley et al.,

1996). If option trading in the DAX market is dominated by such non-informational motives, the O/S ratio may primarily capture noise rather than informed trading activity. In this case, the signal becomes diluted, and its ability to predict future returns weakens or disappears entirely. This interpretation is consistent with the observed lack of statistical significance.

In addition to the composition of traders, the mechanism through which option trading conveys information may differ across markets. The theoretical explanation proposed by Johnson and So (2012) emphasizes the role of short-selling constraints in the equity market. When short selling is costly or restricted, informed traders with negative private information prefer to trade in the option market, leading to a higher O/S ratio and lower subsequent returns (Diamond & Verrecchia, 1987; Johnson & So, 2012). While this mechanism is well supported in U.S. markets, its relevance in the DAX context may be more limited. If short-selling constraints are less binding, or if alternative mechanisms for expressing negative views are readily available, informed traders may not systematically shift their activity to the option market. Consequently, the O/S ratio would no longer reflect negative private information in the same way, weakening its predictive power.

At the same time, more recent literature suggests that the predictive ability of option trading activity may not be driven solely by short-selling constraints. Ge et al. (2016) argue that embedded leverage is a key factor attracting informed traders to option markets, as options allow investors to take large positions with relatively small capital (Black, 1975; Ge et al., 2016). From this perspective, option markets are preferred not only for expressing negative information but also for exploiting informational advantages more efficiently. If the use of leverage differs across markets, this may also explain the absence of predictability in the DAX sample. In particular, if investors in the DAX market do not utilize options primarily for leverage-based information trading, the O/S ratio may fail to capture informed trading activity.

Market liquidity may further contribute to the observed results. Compared to the U.S., the European single-stock option market is generally less liquid, and trading activity is more concentrated among a smaller set of firms. Lower liquidity increases transaction costs and may discourage informed traders from using option markets (Easley et al., 1998). If informed traders prefer to trade directly in the stock market instead of options, the informational content of option trading volume diminishes. In such an environment, the O/S ratio may not accurately reflect informed trading behaviour, which weakens its predictive ability.

The choice of the sample period may also play a role. The period from 2020 to 2025 is characterized by exceptional market conditions, including the COVID-19 pandemic, heightened uncertainty, and increased participation by retail investors. Prior research suggests that increased retail trading activity may introduce noise into trading volume and weaken the link between trading activity and private information (Odean, 1999; Barber et al., 2009). Consequently, the relationship between option trading activity and future returns may be less stable during this period compared to earlier samples examined in the literature.

Another potential explanation relates to the timing of return predictability. Prior research shows that the predictive power of the O/S ratio is short-lived and dissipates relatively quickly as information becomes incorporated into stock prices (Johnson & So, 2012; Pan & Poteshman, 2006). If the adjustment process in the DAX market occurs either more rapidly or more gradually than in U.S. markets, the use of next-day returns may not fully capture the relevant return horizon. This mismatch between the timing of the signal and the realized returns may contribute to the lack of statistically significant results.

Finally, it is possible that the predictive relationship is present only for certain groups of firms rather than across all firms. Previous research suggests that informed trading is more common in firms with high information asymmetry, high institutional ownership,

or strong short-selling constraints (Pan & Poteshman, 2006; Nagel, 2005). When the analysis is conducted using a pooled regression, these differences across firms may be averaged out, which can hide potential predictability within specific subsets of firms.

In addition to these explanations, the findings may also be interpreted in the context of market efficiency. According to the efficient market hypothesis, publicly observable information should be rapidly incorporated into stock prices (Fama, 1970). Since the O/S ratio is constructed from publicly available trading volume data, its predictive power may be limited in markets where information is quickly reflected in prices. The absence of return predictability in the DAX market may therefore indicate a relatively high degree of informational efficiency, where option market signals are incorporated into stock prices without delay.

In summary, several factors may explain why this study does not find evidence that the O/S ratio predicts future stock returns in the DAX market. These include differences in market structure, the dominance of uninformed trading in option markets, measurement limitations of the O/S ratio, lower market liquidity, and the specific characteristics of the sample period. Together, these findings suggest that the predictive power of option trading activity is not universal but depends on the underlying market environment and the extent to which option markets are used by informed traders.

7 Conclusion

In this concluding chapter, the main findings of this thesis are summarized and interpreted in relation to the research hypotheses. In addition, the implications of the results are discussed, followed by an assessment of the study's limitations and suggestions for future research.

7.2. Summary of findings

This thesis examines whether the option-to-stock volume ratio (O/S) contains predictive information about future stock returns in the DAX index during the period 2020–2025. The motivation for this research comes from earlier literature which suggests that option trading activity reflects informed traders' behaviour and may therefore provide signals about future equity price movements.

The empirical analysis is conducted using daily firm-level data and is conducted through portfolio sorting and OLS regression. In contrast to earlier findings, particularly those documented by Johnson and So (2012) in the U.S. markets, the results of this study do not provide statistically significant evidence that the O/S ratio predicts future stock returns in the DAX market. The portfolio sorting results do not exhibit a clear monotonic pattern across O/S quintiles, and the return spread between high and low O/S portfolios is small and statistically insignificant. Similarly, the regression analysis indicates that the estimated coefficient on the O/S ratio is close to zero and lacks statistical significance.

The hypotheses of the study were:

H_1 : The option-to-stock volume ratio contains predictive information about subsequent stock returns.

H_2 : Stocks with lower option-to-stock volume ratios earn higher future returns than stocks with higher option-to-stock volume ratios.

The empirical results do not support the first hypothesis (H1). The O/S ratio does not exhibit statistically significant predictive power for future stock returns in the DAX index. This suggests that, in this market setting, aggregate option trading activity does not reliably reflect private information that would be incorporated into subsequent stock price movements.

Similarly, the second hypothesis (H2) is not supported by the findings. The portfolio sorting results do not indicate that stocks with low O/S ratios systematically outperform those with high O/S ratios. The return spread between the lowest and highest O/S portfolios is both economically small and statistically insignificant. Overall, the results suggest that the O/S ratio does not provide meaningful predictive information for short-horizon stock returns in the DAX market during the sample period.

7.3. Contribution to literature

These findings contribute to the literature by providing evidence from a European market context, where the informational role of option trading may differ from that observed in U.S. markets. While prior research argues that high O/S reflects negative private information due to short-selling constraints in equity markets, the absence of a significant relationship in this study suggests that the underlying economic mechanisms may not generalize across all markets. One possible explanation relates to differences in market microstructure and liquidity. Compared to the U.S., the European single-stock options market is less developed, which may limit the extent to which informed traders utilize options as their primary trading venue. As a result, option trading volume may contain less informative signals regarding future stock price movements.

From a theoretical perspective, the findings of this thesis offer a more detailed view of the role of option markets in price discovery. The informed trading hypothesis suggests that option markets may lead stock markets due to leverage and lower costs of trading on negative information. However, the empirical results indicate that this effect may depend on specific market conditions. In particular, the movement of informed traders to the option market may be weaker when option liquidity is low or when other trading strategies are more attractive. As a result, where informed traders choose to trade is important for understanding the interpretation of the O/S ratio.

7.4. Limitations of the study

Although focusing on overall option volume has several advantages, it is important to recognize the limitations of this study. The analysis is based on aggregate option trading volume and does not distinguish between buyer- and seller-initiated trades or between opening and closing positions. As a result, the O/S ratio captures overall trading activity but does not provide information about the direction of trades.

In addition, the sample is limited to firms in the DAX index, which may reduce the ability to generalize the results to other European markets or to smaller firms with different trading characteristics. Finally, the empirical analysis focuses on short-term return predictability and does not examine longer-term effects or alternative model specifications that could reveal different patterns.

7.5. Recommendations for future research

There are several directions for future research. First, future studies could examine the predictive power of the O/S ratio over different time horizons, such as weekly or monthly returns, to see whether the informational content of option trading appears over longer periods. Second, using more detailed option data, for example information on investor

types, could provide a better understanding of the mechanisms behind the relationship between option trading and stock returns. Third, extending the analysis to other European indices or conducting cross-country comparisons could help determine whether the results are specific to the DAX or reflect broader differences between European and U.S. markets.

In conclusion, this thesis does not find evidence that the option-to-stock volume ratio predicts stock returns in the DAX index during the period 2020–2025. Although this result differs from earlier findings in the literature, it highlights the role of market structure and institutional factors in shaping the informational content of option trading. Rather than contradicting existing theories, the results suggest that the relationship between option trading activity and stock returns depends on the specific market environment and may vary across markets and time periods.

References

- Alangar, S., Bathala, C. T., & Rao, R. P. (1999). The effect of Institutional Interest on the Information Content of Dividend-Change Announcements. *The Journal of financial Research*, 22 (4), 429–448. <https://doi.org/10.1111/j.1475-6803.1999.tb00704.x>
- Amin, K. I., & Lee, C. M. C. (1997). Option Trading, Price Discovery, and Earnings News Dissemination. *Contemporary accounting research*, 14(2), 153-192. <https://doi.org/10.1111/j.1911-3846.1997.tb00531.x>
- Bank for International Settlements. (2021). *OTC derivatives statistics at end-December 2020*. <https://www.bis.org/statistics/derstats.htm>
- Barber, B. M., Odean, T., & Zhu, N. (2009). Systematic noise. *Journal of financial markets (Amsterdam, Netherlands)*, 12(4), 547-569. <https://doi.org/10.1016/j.finmar.2009.03.003>
- Black, F., & Scholes, M. (1973). The Pricing of Options and Corporate Liabilities. *The Journal of political economy*, 81(3), 637-654. <https://doi.org/10.1086/260062>
- Black, F. (1975). Fact and Fantasy In the Use of Options. *Financial analysts journal*, 31 (4), 36-72. <https://doi.org/10.2469/faj.v31.n4.36>
- Black, F. (1986). Noise. *The Journal of finance (New York)*, 41(3), 529-543. <https://doi.org/10.2307/2328481>
- Blau, B. M., Nguyen, N., & Whitby, R. J. (2014). The information content of option ratios. *Journal of banking & finance*, 43, 179-187. <https://doi.org/10.1016/j.jbankfin.2014.03.023>
- Boehme, R. D., Danielsen, B. R., & Sorescu, S. M. (2006). Short-Sale Constraints, Differences of Opinion, and Overvaluation. *Journal of financial and quantitative analysis*, 41(2), 455-487. <https://doi.org/10.1017/S0022109000002143>
- Brown, S. J., Goetzmann, W., Ibbotson, R. G., & Ross, S. A. (1992). Survivorship Bias in Performance Studies. *The Review of financial studies*, 5(4), 553-580. <https://doi.org/10.1093/rfs/5.4.553>

- Cao, C., Chen, Z., & Griffin, J. (2005). Informational Content of Option Volume Prior to Takeovers. *The Journal of business (Chicago, Ill.)*, 78(3), 1073–1109. <https://doi.org/10.1086/429654>
- Chan, K., Chung, Y. P., & Johnson, H. (1993). Why Option Prices Lag Stock Prices: A Trading-based Explanation. *The Journal of finance (New York)*, 48(5), 1957–1967. <https://doi.org/10.1111/j.1540-6261.1993.tb05136.x>
- Diamond, D. W., & Verrecchia, R. E. (1987). Constraints on short-selling and asset price adjustment to private information. *Journal of financial economics*, 18(2), 277-311. [https://doi.org/10.1016/0304-405X\(87\)90042-0](https://doi.org/10.1016/0304-405X(87)90042-0)
- Easley, D., O'Hara, M., & Srinivas, P. (1998). Option Volume and Stock Prices: Evidence on Where Informed Traders Trade. *The Journal of finance (New York)*, 53(2), 431–465. <https://doi.org/10.1111/0022-1082.194060>
- European Securities and Markets Authority (ESMA). (2020). Market impacts of the 2020 short selling bans. <https://www.esma.europa.eu/>
- Fama, E. F. (1970). Efficient Capital Markets: A Review of Theory and Empirical Work. *The Journal of finance (New York)*, 25(2), 383. <https://doi.org/10.2307/2325486>
- Fama, E. F., & MacBeth, J. D. (1973). Risk, Return, and Equilibrium: Empirical Tests. *The Journal of political economy*, 81(3), 607-636. <https://doi.org/10.1086/260061>
- Fama, E. F., & French, K. R. (1998). Value versus growth: The international evidence. *The Journal of Finance*, 53(6), 1975–1999. <https://doi.org/10.1111/0022-1082.00080>
- Fung, S., & Loveland, R. (2020). When do informed traders acquire and trade on informational advantage? Evidence from Federal Reserve stress tests. *The journal of futures markets*, 40(10), 1459–1485. <https://doi.org/10.1002/fut.22149>
- Ge L., Lin T. & Pearson N. D. (2016). Why does the option to stock volume ratio predict stock returns? *Journal of financial economics*, 120 (3), 601-622. <https://doi-org.proxy.uwasa.fi/10.1016/j.jfineco.2015.08.019>
- Gene, D. (2002). The market for borrowing stock. *Journal of financial economics*, 66(2-3), 271-306. [https://doi.org/10.1016/S0304-405X\(02\)00206-4](https://doi.org/10.1016/S0304-405X(02)00206-4)

- Holowczak, R., Hu, J., & Wu, L. (2014). Aggregating Information in Option Transactions. *The Journal of derivatives*, 21(3), 9–23. <https://doi.org/10.3905/jod.2014.21.3.009>
- Hu, J. (2014). Does option trading convey stock price information? *Journal of financial economics*, 111(3), 625-645. <https://doi.org/10.1016/j.jfineco.2013.12.004>
- Hull, J. (2022). *Options, futures, and other derivatives* (Eleventh edition. Global edition.). Pearson Education.
- Jensen, M. C., & Meckling, W. H. (1976). Theory of the firm: Managerial behavior, agency costs and ownership structure. *Journal of Financial Economics*, 3(4), 305–360. [https://doi.org/10.1016/0304-405X\(76\)90026-X](https://doi.org/10.1016/0304-405X(76)90026-X)
- Johnson, T. L., & So, E. C. (2012) The option to stock volume ratio and future returns. *Journal of financial economics*, 106(2), 262–286. <https://doi.org.proxy.uwasa.fi/10.1016/j.jfineco.2012.05.008>
- Kyle, A. S. (1985). Continuous Auctions and Insider Trading. *Econometrica*, 53(6), 1315–1335. <https://doi.org/10.2307/1913210>
- Leland, H. E., & Pyle, D. H. (1977). Informational Asymmetries, Financial Structure, and Financial Intermediation. *The Journal of finance (New York)*, 32(2), 371. <https://doi.org/10.2307/2326770>
- Merton, R. C. (1973). Theory of Rational Option Pricing. *Bell Journal of Economics and Management Science*, 4(1), 141-183. <https://doi.org/10.2307/3003143>
- Miller, E. M. (1977). Risk, Uncertainty, and divergence of opinion. *The Journal of finance (New York)*, 32(4), 1151-1168. <https://doi.org/10.1111/j.1540-6261.1977.tb03317.x>
- Muravyev, D., Pearson, N. D., & Paul Broussard, J. (2013). Is there price discovery in equity options? *Journal of financial economics*, 107(2), 259–283. <https://doi.org/10.1016/j.jfineco.2012.09.003>
- Nagel, S. (2005). Short sales, institutional investors and the cross-section of stock returns. *Journal of financial economics*, 78(2), 277-309. <https://doi.org/10.1016/j.jfineco.2004.08.008>

- Odean, T. (1999). Do Investors Trade Too Much? *The American economic review*, 89(5), 1279–1298. <https://doi.org/10.1257/aer.89.5.1279>
- Pan, J., & Poteshman, A. M. (2006). The Information in Option Volume fo Future Stock Prices. *The Review of financial studies*, 19 (3), 871-908. <https://doi.org/10.1093/rfs/hhj024>
- Roll, R., Schwartz, E., & Subrahmanyam, A. (2009). Options trading activity and firm valuation. *Journal of Financial Economics*, 94(3), 345–360. <https://doi.org/10.1016/j.jfineco.2008.02.002>
- Roll, R., Schwartz, E & Subramanyam, A. (2010). O/S: the relative trading activity in options and stock. *Journal of Financial Economics*, 96(1), 1–17. <https://doi.org.proxy.uwasa.fi/10.1016/j.jfineco.2009.11.004>
- Shleifer, A., & Vishny R. W. (1986). Large shareholders and corporate control. *Journal of Political Economy*, 94 (3), 461–488. <https://doi.org/10.1086/261385>
- Stephan, J. A., & Whaley, R. E. (1990). Intraday Price Change and Trading Volume Relations in the Stock and Stock Option Markets. *The Journal of finance (New York)*, 45(1), 191–220. <https://doi.org/10.1111/j.1540-6261.1990.tb05087.x>
- Woo, M., & Kim, M. A. (2021). Option volume and stock returns: Evidence from single stock options on the Korea Exchange. *Seonmul yeongu (Online)*, 29(4), 280-300. <https://doi.org/10.1108/JDQS-06-2021-0012>

Artificial intelligence tools (such as ChatGPT) were used to assist in language editing and improving the clarity and structure of the text.