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Option Expiration Day Impact on Underlying Stock Return

A study on the Swedish Option Market

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Sammanfattning

Examensarbetets titel: Option-förfallodagens inverkan på underliggande aktiens avkastning: en studie på den svenska optionsmarknaden

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Fem nyckelord: Optionsmarknad, Öppna optionskontrakt, avkastning, delta-hedging, Förfallodag

Forskningsfrågor: Är det statistiskt signifikant att det finns en förändringar i aktieavkastning på optionens förfallodag i den underliggande aktien? har de öppna options kontrakten en påverkan på aktieavkastningen på optionens förfallodag?

Syfte: Syftet med examensarbetet är att undersöka om det finns en signifikant skillnad i aktieavkastningen vid optionens förfallodag i relation till de öppna options kontrakten i de underliggande aktierna inom OMXS30-indexet.

Metod: En kvantitativ studie som använder en deduktiv ansats för att statistiskt beskriva relationen mellan den dagliga aktieavkastningen med open interest och handlad volym.

Teoretiska perspektiv: Det teoretiska ramverket består av optionsteori och empirisk forskning om förfallodagens påverkan på handlad volym och aktieavkastning, samt relationen mellan aktieavkastning under förfalloveckan och optionsvolymen.

Resultat: Regressionsresultaten visar att månader med hög net open interest visade statistiskt signifikanta resultat. November, som hade låg netto open interest, visade ingen statistisk signifikans. Nollhypotesen kunde förkastas. T-testet visade också att den dagliga avkastningen på förfallodagen skiljer sig signifikant från den genomsnittliga dagliga avkastningen under månader förutom November.

Slutsats: Eftersom regressionsresultatet visar en R-squared över 0.1 kan vi dra slutsatsen att det finns en statistisk signifikans för att en större volym av öppna optionskontrakt ger en starkare korrelation. Vi ser också motsatsen i November, då en låg net open interest visade låg korrelation. Korrelationen visar dock att handlad volym och antalet öppna kontrakt inte är tillräckliga variabler för att prognostisera framtida avkastning på egen hand.

Abstract

Title: Option expiration day impact on underlying stock return: a study on the swedish option market

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Authors: Penkina, Alisa; Karaduman Sorsenger, Alan; Kakai, Sirwan

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Key words: Option Market, Open Interest, Stock Return, Delta Hedging, Option Expiration Day

Research questions: Is there significant change in the stock return on option expiration dates in the underlying stock? Does the net open interest have an effect on the return of the underlying stock on option expiration day?

Purpose: The purpose of the bachelor's thesis is to study whether there is a significant difference in the stock returns on option expiration dates in relation to the net open interest of the underlying stocks within the OMXS30 index.

Methodology: A quantitative study using a deductive approach to statistically describe the relationship between the daily stock return with open interest and traded volume.

Theoretical perspective: The theoretical framework consists of option theory and empirical research on the impact of option expiration on traded volume and stock return, together with the relationship between stock returns during the expiration week and the option volume.

Result: Regression results show that months with high net open interest showed statistically significant results. November, which had low net open interest, showed no statistical significance. The null hypothesis could be rejected. The T-test also showed that the daily return on expiration day differs significantly from the average daily return during months except November.

Conclusions: Since the regression results show an R-squared above 0.1, we can conclude that there is statistical significance that a larger volume of open option contracts corresponds to a stronger correlation. We also saw the opposite in November, when a low net open interest showed low correlation. However, the correlation shows that traded volume and number of open contracts are not sufficient variables on their own to predict future returns.

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9th of January 2023

Alisa Penkina   Alan Karaduman Sorsenger   Sirwan Kakai

Terminology

Expiration day - The last day on which an option contract can be exercised, often falls on the third Friday of the month.

Open Interest - Total number of outstanding contracts that have not yet been closed out. Represents the number of options that have been bought but not yet sold or exercised.

Delta hedging - Strategy to hedge the risk associated with price movements in an underlying stock. Taking Position in an option and in the underlying stock. Often used by market makers to manage their risk.

Market Maker - Financial firm that provides liquidity to the market by buying and selling securities.

Traded Volume - Number of shares or option contracts in a stock that have been traded over a specific period.

Hedge rebalancing trade - Adjusting a delta-hedged position by executing trades in the underlying stock or in the option.

Statistically significant - A statistical result is said to be statistically significant if it is very unlikely to have occurred by chance. More specifically, statistical significance is determined, if nothing else is stated, by default with a p-value of less than 0.05.

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1. Introduction

1.1 Background

Option exchanges have introduced several key innovations, including standardizing certain contractual terms and creating a central clearing corporation to act as issuer and obligor for each option contract, breaking the link between a specific option writer and buyer. These innovations have made it easier to trade existing call and put options in the secondary market, providing increased liquidity, continuous public reporting of prices, better information on trading volume and open positions, and reduced transaction costs. The volume of options traded on these exchanges has significantly exceeded the composite trading volume of the underlying securities, demonstrating the success of these markets. On the other hand, the success of option exchanges has raised important questions about the potential impact of options trading on other segments of the capital markets, including the new issues market, the market for low-priced stocks, and the market for the underlying common stocks. Specifically, these questions relate to how options trading may affect the prices and liquidity of these markets, as well as the overall functioning of these markets (Klemkosky, 1978).

Option trading can cause significant movements in the underlying stock. The price increase of GameStop in early January 2021 has probably not gone unnoticed, based on the significant amount of media attention in late January and early February of 2021 due to the surge in the stock price and trading activity involving the company's shares.

On January 27th, 2021, the price of GameStop stock had gone up to $347, while it had previously been trading for $31 on January 13, 2021. The striking surge in the stock price was caused by an increase in trading by non-professional retail investors using the Robinhood financial platform, a platform where retail option trading is a significant part of its business. Organized via the WallStreetBets chat forum on Reddit, a large portion of the positions were attributed to retail investors covering previous GameStop short positions or initiating new long positions. Prior to the price increase, GameStop Corp. had become one of the most shorted companies in the U.S. 140% of the shares available for trading had been sold short and had not been covered to close out the positions. A large portion of the short positions were taken by long-short hedge funds (Malz, 2021).

A large volume of the positions in GameStop Corp were conveyed through options, which contributed to volatility in the stock through hedging. The volume of call and put options rose during the period from January 13th to January 27th, 2021, which was attributed to retail investors as well as professional investors who covered short positions or established new long positions. The hedging was done by option dealers, who commonly sell call and put options in large volumes to earn a volatility premium. By way of buying the underlying stock when the price is rising and selling when the price is falling, option dealers are hedging themselves. Whenever there is a large change in the underlying price, the option dealer has to buy or sell in a bad market condition, which exposes the dealer to massive losses. Notably, GameStop's increasing price forced the option dealer to sell call and put options to mitigate losses and maintain a hedged position (Malz, 2021).

1.2 Problematization

Different studies have shown that option trading affects the underlying stock price. This concern has been a subject of discussion ever since options began trading in 1973, though only in more recent times has convincing evidence been developed to support this thesis (Ni, Pearson, Poteshman & White, 2021).

The study by Chiang (2014) explores the impact of option expiration on stock market trading activity and the resulting effect on the distribution of the underlying stock price. Specifically, it was found that stocks with large numbers of deep In the Money call options tend to have significantly lower returns on option expiration dates, even when no new information has been released to the market. On these dates, the average daily returns drop by 0.8% per day, and this decrease remains significant even after adjusting for systematic risk. Additionally, observations show that less liquid stocks experience a stronger average price decline on option expiration dates.

The findings suggest that the large-scale negative price movement observed on option expiration dates is a result of selling pressure, as predicted by the price-pressure hypothesis (PPH). Chiang also observed a full price reversal following the low expiration-date returns, further supporting the PPH. On option expiration dates, investors with long positions in the option market may choose to exercise their deeply In the Money call options and sell the acquired shares in the stock market. This demand for immediate sales can lead to selling pressure in the stock market. Many option writers are also hedged by writing covered calls, which may not provide enough buying pressure to offset the selling pressure created by the option holders. As a result, the non-synchronization between buying and selling activity in the underlying stocks can cause net selling pressure on the expiration date and result in a decline in stock returns (Chiang, 2014).

A study published in 2005 (Ni, Pearson & Poteshman) presented notable evidence that option trading changes the price of the underlying stock by showing that the closing price of stocks clusters around the option strike prices on expiration dates. It is evident that the hedge rebalancing done by option market makers contributes to the clustering. The data used was taken from 1996 through 2002 on the daily trading volume of every call and put option on the stocks traded on any U.S. exchange. Different explanations for the expiration date clustering were investigated, including delta-hedge rebalancing by investors who had net-purchased option positions and also stock price manipulation by investors who sold options in the week leading up to the expiration date. The estimations made suggest that the returns of optionable stocks are affected by an average of at least 16.5 basis points per expiration date, and that at least 2% of optionable stocks have their returns changed on a typical expiration date. Given the number of optionable stocks on any given expiration date, this implies that the associated change in the market capitalization of optionable stocks is roughly $9.1 billion per expiration date, regardless of the percentage of stocks impacted.

The study by Ni, Pearson, Poteshman and White (2021) questioned whether option trading affects the underlying stock prices and, if so, to what extent. By examining the effect of delta-hedging, the study presented evidence that hedge rebalancing done by option market makers affects the volatility of stock returns. Data was used that included daily net open interest of investors to determine net open positions of delta hedgers for each underlying stock between the period of 1990 through 2001 on the Chicago Board Options Exchange, which investigated whether the net gamma of delta-hedging investors is negatively correlated to the volatility of the underlying stock. Secondly, data on signed volumes of different investors was used to estimate positions of likely delta hedgers during the period 2002-2012. The negative relation between stock return volatility and the net gammas of the option positions was found to be significant. The results of the study revealed that around 10.5% of the daily absolute return of optioned stocks was attributed to option market participants who rebalanced the stock hedges of their option positions. In addition, hedge rebalancing is estimated to change the daily absolute stock return by 5% during the period of 1990-2001, and by 13% between 2002-2012. Further findings in the study were that the negative relation was found in both liquid and illiquid stocks, regardless of the capitalization size of the firm.

Previous studies show that delta hedging has an effect on the underlying stock price. As mentioned in the study by Ni, Pearson, Poteshman & White (2021), dynamic trading strategies associated with a delta-hedge position require buying or selling the underlying stock as the delta of the option changes. However, if the underlying stock is not traded in a perfectly liquid market, the rebalancing trade will change the price of the underlying stock. The trading will also affect the volatility, depending on whether the gamma is negative or positive of the hedged option position.

Given that price changes in underlying stocks are due to liquidity in the market, it is important to investigate this matter on the Swedish Option Market because the Swedish market has much smaller liquidity compared to the Chicago Board Options Exchange, where the previous study was conducted, which is the largest exchange in the world for trading stock options (Hull, 2022). However, there are no earlier studies on the Swedish Option Market that examine whether option trading affects the underlying stock price. As shown in the study by Chiang (2014), the expiration date of options is typically a day with high levels of trading activity. Evidence from the options market indicates that the total open interest of options tends to remain stable during the expiration week. This suggests that many investors wait until the last day of the expiration period to close their positions, resulting in a significant volume of trades in the options market. A similar study will be applied to the Swedish Option Market to investigate if there is a significant change in stock on option expiration dates and if the effect is attributed to a large net open interest in the underlying stocks.

1.3 Purpose

The purpose of the bachelor's thesis is to study whether there is a significant difference in the stock returns on option expiration dates in relation to the net open interest of the underlying stocks within the OMXS30 index.

1.4 Question Statement

1. Is there significant change in the stock return on option expiration dates in the underlying stock?
2. Does the net open interest have an effect on the return of the underlying stock on option expiration day?

1.5 Scope

Based on the available data, it was not possible to separate the option positions of market makers from those of retail investors to investigate how delta hedging specifically affects the underlying stock price on the option expiration day on the Swedish market, as one of the previous studies had done on the U.S. option market. This thesis is limited to examining the correlation between net open interest on In the Money options, trading volume, and daily returns of the stocks on the option expiration date to determine if the total number of outstanding contracts affects the underlying stock return. Net open interest is an indicator of trading activity in the market and the number of contracts that are actively open and not settled. An increase in activity can lead to higher stock volume, as more trades are being executed. The open interest may affect the underlying stock because an increase can indicate that there is more demand for action, depending on the type of option, which could potentially put upward or downward pressure on the underlying stock price.

1.6 Contribution to research

This study adds to the existing research by examining the Swedish Option Market, where there has been no previous investigation into the impact of option expiration days on underlying stock prices. We believe that this research, because of the size differences between the US and Swedish markets, has the potential to improve our understanding of derivative markets and inform more effective portfolio decision-making. To the best of our knowledge, this is the first study to address this topic in the Swedish market.

1.7 Disposition

The following section presents the foundational theories. The hypotheses that we will test in order to fulfill the purpose of this paper are outlined in Chapter 2. The method for achieving this purpose is described in Chapter 3. Chapter 4 includes details on data collection, data processing, and tests that will be conducted to support our hypotheses. In Chapter 5, the results of these tests are presented and analyzed in relation to the purpose of the study, as well as the theories and previous research outlined in Chapter 1 and 2. In the final section, we draw conclusions, address the purpose of the study, and discuss the broader implications of the study, as well as suggesting areas for further research.

2. Theory

2.1 Options

There are two different types of options. A call option gives the holder the right to buy the underlying stock for a determined price, known as the exercise or strike price, by a certain date, known as the expiration date or maturity. A put option gives the holder the right to sell the underlying stock for a determined price by a certain date. Options which can be exercised at any time up to the expiration date are American options, while European options can only be exercised on the expiration date. Options can be traded both on exchanges and in the over-the-counter market, most of the options traded on the exchange are American options. The contract is usually an agreement to buy or sell 100 shares of a stock (Hull, 2022).

The expiration date is the third Friday of the expiration month. As the time to maturity increases, the value of the call and put options also increases because it gives more exercise opportunities (Hull, 2022).

2.2 Open Interest and Trading Volume

The open interest is the total number of outstanding contracts in a particular market or security. It is the opposite of the volume, which is the number of contracts that have been traded during a specific period of time (Hull, 2022).

The open interest is the total number of outstanding contracts in a particular market or security. It is the opposite of volume, which is the number of contracts that have been traded during a specific period of time (Hull, 2022). The open interest can increase when new contracts are initiated and it can decrease when existing contracts are settled or closed. The open interest is a useful indicator because it can show the overall demand for a particular contract or market based on the level of activity or liquidity. Moreover, the open interest reflects the total number of contracts held by market participants in options, whether they are bought call or put options. The open interest is affected by the opening and closing of trades. When a market participant exercises an option or closes a trade, the open interest is reduced. It can be calculated by adding up all the open contracts and subtracting the closed contracts. Unlike volume, the open interest decreases when a contract is closed or settled. For example, if a market participant buys a security, the volume increases by one. ,If the same participant then sells the security, the volume increases by another one, resulting in a total volume of two. Open interest, on the other hand, decreases when the contract is closed or settled. Open interest can be seen as the cash flowing into the market. As the open interest increases, more money is moving into the contract. A decline in open interest means that money is flowing out of the contract (CME Group, n.d.)

2.3 Delta

One of the important parameters in pricing, hedging, and risk management for options is delta. Delta can be explained as the ratio of change in the price of a stock option to the change in the price of the underlying stock (Hull, 2022). Delta can also be defined as the number of units of the underlying stock that must be held in a portfolio to replicate, for example, a long position in the option at a given time. It is worth noting that as information changes, delta will also change (Sundaram & Das, 2016).

The delta of a call option is positive, while it is negative for a put option. Additionally, the delta of a call option falls between 0 and 1, and between -1 and 1 for put options. This means that if the underlying stock increases/decreases by $1, the holder of the call/put option will gain/lose $1. The delta of an option depends on whether it is In the Money. A delta of 1 indicates that the option is likely to end In the Money, while options that are deeply Out of the Money are closer to a delta of 0. As the option moves more into-the-money, its delta increases (Sundaram & Das, 2016).

2.4 Gamma

The gamma is the rate of change of the option's delta in relation to the change in the price of the underlying asset (Hull, 2022). Gamma, which shows how sensitive delta is to changes in the price of the underlying stock, is valuable to a trader who delta-hedges a portfolio of options. When gamma has a high value, it indicates that delta will change significantly even with a small change in the price of the underlying stock, meaning the portfolio needs to be rebalanced more frequently to remain delta-hedged. On the other hand, when the value of gamma is small, the portfolio does not need to be rebalanced as often (Sundaram & Das, 2016).

The gamma of an option is always positive. When an investor is "long gamma" (as cited in Sundaram & Das, 2016), they are a holder of an option. The counterpart, or writer of the option, is "short gamma" and has a negative gamma position. The net gamma is the sum of all call gammas minus the sum of all put gammas (Spotgamma, n.d.).

2.5 Moneyness of Options

The moneyness of an option determines whether it is profitable for the holder to exercise the option. If the strike price of a call option is below the current market price of the underlying asset, the option allows the holder to buy the asset at a lower price than it is currently worth, so it is considered "In the Money." Similarly, a put option with a strike price above the current market price of the underlying asset gives the holder the right to sell the asset at a higher price, so it is also "In the Money." On the other hand, options with strike prices above the current market price for calls and below the current market price for puts are "Out of the Money," as the holder would not make a profit by exercising the option (Hull, 2022).

2.6 Market Maker

The role of an option market maker is to add liquidity to the market, allowing trading in the option exchange to facilitate the execution of buy and sell orders without delays. The market maker, who is an individual, will quote both a bid and an ask price on an option. The bid is the price at which the market maker is willing to buy the option, and the ask is the price at which the market maker is willing to sell the option. The ask is always higher than the bid, and the bid-ask spread is the amount by which the ask exceeds the bid. The exchange on which the options are traded sets an upper limit for the bid-ask spread. The option market maker makes a profit from the bid-ask spread and uses methods such as delta hedging to manage risk (Hull, 2022).

In Sweden, the institutions that act as market makers are Swedbank AB, Svenska Handelsbanken AB, Skandinaviska Enskilda Banken AB, Pareto Securities AB, Carnegie Investment Bank, Aktieinvest Fondkommission AB, and ABG Sundal Collier ASA (ESMA, 2022).

2.7 Delta-Hedging

Delta can be used in three different ways: in replication, in delta-hedging, and as a sensitivity measure. Option positions can be hedged using the underlying stock, which is known as delta-hedging (Sundaram & Das, 2016). For example, if a call option has a delta of 0.6, the price of the option will change by 60% with a small change in the underlying stock (John C. Hull, 2022). To hedge a position, an investor can buy 0.6 units of the underlying stock if they have sold call options, which give the buyer the right but not the obligation to buy a certain number of shares in a stock. The gain from the stock position would offset the loss in the option position and vice versa. In the same way, the delta of the stock position offsets the delta of the option position.

As mentioned by Ni, Pearson, Poteshman, and White (2016), for an option market maker to maintain a delta-neutral position after writing options, the market maker needs to buy the underlying stock after its price has increased due to a decrease in the delta of the written option. The market maker will then sell the stock when the price has decreased, since the delta of the written option has increased. Since the option position consists of written option contracts, the gamma is negative. To maintain delta-neutrality, the underlying stock is bought by the market maker so that the delta of the combined positions of options and underlying stock equals zero. Similarly, to delta-hedge a positive-gamma option position, the underlying stock must be sold after a price increase and bought after the price has decreased.

The delta-hedging investor will maintain a stock position that is opposite to the delta of the option position they hold. The investor trades in the underlying stock when the delta of the existing portfolio of options changes in order to keep the option and stock position delta-neutral.

2.8 Rebalancing Trades

A delta-neutral position is a position with a delta of 0. However, since the delta of an option does not remain constant, the position needs to be rebalanced in order to remain delta-hedged. This hedge can be adjusted periodically, known as dynamic hedging, or it can be static, meaning that the position is never adjusted after it has been set up initially (Hull, 2022). Rebalancing more often provides a good hedge, but the investor will incur high transaction costs. If the gamma is high, the portfolio needs to be rebalanced more frequently, so it is preferable to create a portfolio that is both gamma- and delta-neutral (Björk, 2019).

Ni, Pearson, Poteshman, and White (2016) predict that dynamic delta hedgers who manage negative gamma option positions will buy stocks after a price increase and sell after the price decreases. As a result, the pressure from demand can drive prices to higher or lower levels than can be justified by fundamental data. Therefore, stock prices are more likely to reverse when the gamma is negative for delta hedgers than when the gamma is positive or close to zero. Even so, volatility changes are related to the sign of the net gamma of delta hedgers.

2.9 Volatility Changes Due to Hedge Rebalancing

If the gamma of the aggregate position of delta-hedgers is negative, as previously mentioned, the hedge rebalancing trade of buying the stock if the price increases and selling if the price decreases will lead to increased volatility of the underlying stock. On the other hand, if the gamma of the aggregate position of delta-hedgers is positive, the volatility of the underlying stock will be reduced. This suggests that there is a negative correlation between the volatility of the underlying stock and the gamma of the aggregate option position of delta hedgers (Ni, Pearson, Poteshman, and White, 2016).

2.10 OMXS30 Index

The OMXS30 is an index that consists of the 30 most actively traded stocks listed on the Nasdaq Stockholm stock exchange. The stocks included in the index are reviewed and potentially updated on the first trading day of January and July each year. The stocks that are included in the index are determined based on their trading volume over a six-month period starting seven months before these dates. There is a rule in place to ensure that the index is not heavily impacted by changes to its constituents, meaning that a stock must be among the 15 most traded in order to be added to the index, and a stock must fall outside the top 45 in terms of trading volume in order to be removed from the index. The OMXS30 is a market-weighted index, meaning that the value of the index is influenced by the stocks it includes in proportion to their market capitalization. The index is based on closing prices, meaning that changes to the index are only triggered by actual trades in the included stocks (Nasdaqomxnordic, n.d.).

2.11 Previous empirical research

2.11.1 Index options open interest and stock market returns

The study by Seo, Byun, and Kim (2020) investigates the behavior of informed traders and hedgers in the option market. The central hypothesis is that the expansion of options open interest can provide insight into future stock price movements. The authors believe that hedgers use options to reduce the variance in their profits from their underlying positions and hedging activities. Informed traders are also thought to possess information about future economic conditions before uninformed investors. The model in the study implies that hedgers in the options market will buy In the Money or Out of the Money options based on their expectations for future stock returns. The empirical results show that the growth of OTM options open interest on the S&P 500 index significantly predicts the subsequent monthly excess returns of the S&P 500 index. The findings also provide empirical evidence that the information conveyed by the open interest of options is distinct from that provided by the trading volume of options, indicating that the growth of options open interest brings information about future stock market returns beyond that of the trading volume of the option. The results also suggest that hedgers play a significant role in the index option market.

2.11.2 The Impact of Option Expiration on Underlying Stocks: The UK Evidence

Pope and Yadav (1992) investigate the relationship between option expiration and the trading volume and returns distribution of the underlying stock using data from the UK option market. The study examines the effect of option expiration on the trading volume and the return of the underlying stock. The results show that there is a downward price pressure immediately prior to option expiration. There is also an increase in trading volume immediately before and a decrease in trading volume immediately after the option expiration day, which could be due to liquidity trading and the unwinding of arbitrage positions. However, the results are based on a relatively small number of events and may be partially influenced by weakly significant abnormal volume residuals in the studied period. The findings in this study support the idea that option expiration does not bring new information to the market and is not accompanied by any systematic change in stock volatility. There is no reason to expect corresponding price pressure, as the statistical significance is relatively small and the size of the option expiry-related residual return is on average only -0.5 percent.

2.11.3 The Impact of Option Expiration on Underlying Stock Prices and The Determinants of The Size of The Impact

In Hess's (1982) study, the aim was to examine daily returns of underlying stocks during the period around the option expiration day. The findings show that there is a build-up of activity during the expiration week that reaches its peak in the final two days before the expiration day of the option. This is because all option holders must make a decision about their options before the end of the week, and the profitability of their choice becomes clearer as the option value becomes solely dependent on its intrinsic value. As a result, position unwinding and exercising tend to occur late in the expiration week. On the other hand, the positive abnormal return found on Tuesday through Friday may be due to a reaction to the selling pressures of the preceding six days. The upward pressure found during the following week was thought to be caused by new stock and option positions. The results provide evidence of a significant relationship between expiration week underlying stock returns and option volume.

2.12 Hypothesis

After outlining the theoretical framework and previous research for this study, we can build hypotheses based on the given information. These hypotheses aim to examine mechanisms that influence underlying stock returns on the Swedish market, using previous research as a guide to identify the most relevant and important aspects to study. The hypotheses provide a roadmap for testing and evaluating the theories and concepts presented in the theoretical framework. They will be tested using empirical data and statistical analysis to determine their validity and reliability.

The purpose of this study suggests that there may be a relationship between the option expiration date and the daily returns of the underlying stock. There are a few potential reasons for this relationship. One possibility is that as the option expiration date approaches, there may be an increase in activity in the options market. This could be because more investors are interested in buying or selling options as the expiration date gets closer, leading to an increase in traded volume and open interest. This increased activity in the options market could, in turn, affect the price of the underlying stock, leading to changes in its daily returns.

Another possibility is that the option expiration date may affect the supply and demand for the underlying stock. As the expiration date approaches, the demand for the underlying stock may increase as investors who hold options on the stock exercise their contracts and buy or sell the underlying stock. This increase in demand could drive up the price of the underlying stock, leading to an increase in its daily returns. It is important to note that these are just a few potential reasons, in addition to delta-hedging and rebalancing trades mentioned earlier, for the relationship between the option expiration date and the daily returns of the underlying stock.

The null hypothesis for this situation can be formulated as: H_0 = *There is no relationship between daily return and traded volume and open interest at the expiration date of the option*. This would imply that the multiple linear regression analysis would return an R-squared value of 0.1 or less (for more details regarding R-squared value guidelines, see Section 4.5.2).

An alternative hypothesis for this situation is: H_{1a} = *There is a significant relationship between daily return and traded volume and open interest at the expiration date of the option*. This would imply that the multiple linear regression analysis would return an R-squared value of greater than 0.1, indicating that the model is able to explain a significant portion of the variance in the data.

A second hypothesis is generated that depends on whether the regression H_{1a} is true or not. If it is true, the second hypothesis would be stated as H_{1b} = *The daily return on the expiration date is significantly different from the mean daily return within the range of the standard deviation*. The hypothesis will be tested and evaluated using different methods, both applied to the same dataset that has been acquired for this study.

3. Data

In order to complete the analysis, a significant amount of reliable data was required. The primary sources of data collection were Bloomberg and Factset. The decision to use Bloomberg as the database and platform was based on its accessibility and the fact that its offerings closely aligned with the intended scope of the examination. Additionally, Bloomberg is the most widely used platform in the financial markets. Factset is a financial data and analytics platform that offers a range of benefits to its users. One key advantage is the platform's wide range of data sources, which include company filings, news articles, and market data. This allows users to get a comprehensive view of the financial landscape. The data from Bloomberg were used to determine the characteristics of the options listed on each stock, and the Factset data was used to obtain the main result of stock return recorded on a daily basis.

The equity data was obtained from Bloomberg, specifically from the stocks in the OMXS30 Index. The OMXS30 Index is a stock market index of Nasdaq Stockholm in Sweden that consists of the 30 most actively traded companies listed on Nasdaq Stockholm. It is a widely followed index in Sweden and is seen as a good indicator of the overall performance of the Swedish stock market. For the underlying securities, we utilized data on daily returns, daily price, and daily traded volume.

The option data that was used was also obtained from Bloomberg. For the single stock options on the underlying securities, the data included the type of option, strike price, expiration date, open interest, traded volume, and option prices. The use of this data allowed us to examine the relationships between the underlying securities and the single stock option expiration dates in order to develop the methodology introduced in Chapter 4. Additionally, the inclusion of market-wide returns provided us with a benchmark against which to compare the performance of the underlying securities on option expiration dates. Overall, this diverse dataset allowed us to thoroughly analyze the factors that influence the value of these financial instruments and to develop robust models to describe the correlation.

3.1 Time Period

The study is based on a four-month period between August 22, 2022, and December 16, 2022. This choice of time period was made due to the limited data available in Bloomberg and FactSet, which was limited to analyzing a 120-day period on a rolling basis. This means that our analysis was confined to examining the most recent four months of data, with each day being added as it becomes available and the oldest day being removed. While this can be a challenging constraint, it also allows the study to stay up-to-date with the most recent market trends. While we would have preferred to examine a longer time period to get a more comprehensive view of the market, the data constraints unfortunately necessitated a shorter time frame. Options trading is not as prevalent in Sweden as it is in the United States, which means that the availability of data for analysis is more limited. This can be a limiting factor when it comes to the comprehensiveness of our analysis. However, it is important to remember that the Swedish market is much smaller in size compared to the U.S. market, so the limited data we do have can still provide valuable insights into the specific characteristics of the Swedish options trading scene and the effects it might have on the underlying securities. Despite this limitation, we remain confident that the four-month period we have chosen still offers valuable results for this study and that it can provide unique insights due to the data constraints, which can be a useful tool for understanding the Swedish market.

4. Method

4.1 Data Processing

The data processing method began by collecting information about the underlying assets from Factset, including details such as the stock price and volume traded. Next, information about options for each underlying asset was collected from Bloomberg, including the expiration date, strike price, and open interest for each option.

To narrow the focus, only In the Money call and put options were considered. The moneyness of each option was determined by comparing the strike price to the stock price at expiration date. Specifically, call options with a strike price less than the stock price at expiration date were considered In the Money, and put options with a strike price greater than the stock price at expiration date were considered In the Money. This allowed for a clear distinction between options that were in- or Out of the Money, and ensured that only relevant options were included in the analysis, as Out of the Money options will not be exercised and expire worthless.

The final steps of the data structuring included summing the open interest of all In the Money call options for each underlying asset as well as the open interest of all In the Money put options for each underlying asset. Then, the net open interest of these In the Money put and call options for each underlying asset was calculated. The traded volume for each underlying stock at the expiration date was gathered. As for the dependent variable, the relative daily return of the stock at the expiration date was gathered and the effect of OMXS30 was disregarded to obtain the real daily return of the stock. All of this information was then listed in an Excel sheet, with the following columns in the stated order: the expiration date, price change of the stock, price change of OMXS30, price change of the stock without considering OMXS30, total call open interest of the stock, total put open interest of the stock, traded volume of the stock, and net open interest of the stock. This allowed for a clear and organized representation of the data and facilitated the calculation of the correlation matrix and the creation of a multiple regression model accordingly.

4.2 Python Programming

Python is a programming language that can be used, for example, as a tool for data analysis and machine learning, with a wealth of libraries and functions at your disposal. In this report, we used Python to compute correlation matrices and build multiple regression models using data from

Excel files. The results of these Python functions were displayed in the terminal or in a separate window, including a heatmap representation of the correlation matrix (explained in Section 4.3). Overall, Python proved to be an effective and efficient choice for these tasks.

We chose to use Python for the correlation matrices and multiple regression models for several reasons. Python is a versatile programming language, meaning that it can be used for a wide range of tasks beyond statistical analysis. Python's large collection of libraries and frameworks also provides many options for visualization and machine learning, which can be useful in addition to statistical analysis. If there is any future research wanting to expand on the code, there are opportunities to go beyond the scope of statistical analysis.

4.2.1 Imported Libraries

In order to carry out the necessary computations and analyses in Python, we imported several libraries that provided the necessary functions and capabilities. These included Matplotlib, Pandas, Seaborn, and Statsmodels. Matplotlib is used for creating static, animated, and interactive visualizations in Python. It allows us to create a wide range of charts, plots, and other graphics that can be useful in understanding and interpreting data. Pandas is a powerful tool for working with data in Python. It provides data structures and data analysis tools for handling and manipulating large and complex datasets with ease. For this report, Pandas was used specifically to read Excel file sheets as well as manipulate and prepare the scanned data before building the multiple regression model. Seaborn is built on top of Matplotlib and provides a higher-level interface for creating visually appealing statistical graphics. It is particularly useful for quickly generating publication-quality plots and charts. In this report, Seaborn and Matplotlib were combined to create a correlation matrix as a heatmap. Lastly, Statsmodels provides a variety of statistical models, statistical tests, and other tools for statistical analysis in Python. It is particularly useful for fitting and evaluating regression models and performing hypothesis tests.

4.3 Correlation Matrix

Before conducting the multiple linear regression described in Section 4.5, a correlation matrix was generated to examine the correlation coefficients for each pair of variables involved in the regression model, including both the stock's daily return at expiration date as the dependent variable and the stock's traded volume and the option's open interest as the independent variables. The correlation matrices computed covered three different calculations of the open interest of each option: the sum of open interests of all call options for each underlying asset, the sum of open interests of all put options for each underlying asset, and the net open interest of all call and put options for each underlying asset.

The correlation matrix provides information about the strength and direction of the relationship between the stock's daily return at expiration date and each independent variable, as well as the relationship between the independent variables themselves. The correlation coefficient for each variable pair can range from -1 to 1, where 0 indicates no relation between the two variables, while 1 and -1 indicate a complete correlation. A positive correlation coefficient means that an increase in one variable results in an increase in the other variable, and a negative correlation coefficient means that an increase in one variable results in a decrease in the other variable.

The correlation matrix thereby provides insight into the potential influence of each independent variable on the dependent variable, and it also helps identify the risk of multicollinearity (see Section 4.4) among the independent variables (Brooks, 2019).

Specifically, in this thesis, we used Python to compute and display the correlation matrix for our regression models, and the libraries used for this were Pandas, Seaborn, and Matplotlib (for more detail, see lines 24-28 in Appendix 1).

4.4 Multicollinearity

Multicollinearity refers to the situation in multiple regression models where there is a high correlation between two or more independent variables. When multicollinearity is present, the effects of the independent variables may be intermixed, making it difficult to isolate the specific contribution of each independent variable (Brooks, 2019). To avoid multicollinearity in a regression model, one has to identify which independent variables are correlated with each other and remove unwanted variables from the regression model.

The correlation matrix in Section 4.3 can identify any potential multicollinearity. However, to detect multicollinearity in a regression model, we calculated the variance inflation factor (VIF) for each independent variable. The VIF calculations involved three scenarios in which the stock's daily return at expiration date is the dependent variable, and the stock's traded volume, as well as either the sum of all open interests of call options, sum of all open interests of put options, or net open interest of both put and call options of each underlying asset, are the independent variables.

4.4.1 Variance Inflation Factor

The VIF measures how much the variance of the traded volume is influenced by its relation with the open interest and vice versa. A VIF value of 1 indicates that there is no multicollinearity in the model. On the other hand, a VIF between 1 and 5 suggests a low level of multicollinearity, while a VIF greater than 5 indicates a high level of multicollinearity.

The VIF was calculated with Python and utilized the libraries Statmodels and Pandas (see lines 40-46 in Appendix 1).

4.5 Multiple Linear Regression

The most relevant regression model for this thesis was the multiple linear regression, since we want to see if there is any arbitrary model that describes the linear relationship between the dependent variable stock's daily return at expiration date and the independent variables: stock's traded volume and either the sum of all open interests of call options, sum of all open interests of put options, or net open interest of both put and call options of each underlying asset. We have thereby formulated three multiple regression equations for each month that follow the structure below:

$$r_{daily} = \beta_{intercept} + \beta_{volume} x_{volume} + \beta_{openInterest} x_{openInterest} + \varepsilon$$

where r_{daily} is the dependent variable, x_{volume}, $x_{openInterest}$ are the independent variables, $\beta_{\text{intercept}}$ is the intercept term, β_{volume}, $\beta_{openInterest}$ are the regression coefficients for the independent variables, ε is the error term.

4.5.1 Ordinary Least Squares

In this thesis, we used the most commonly used method for fitting a linear regression model: ordinary least squares (OLS). The goal with OLS is to minimize the sum of the squared differences between the observed values of the daily return at expiration date and the predicted values of the daily return at expiration date, based on the values of the traded volume and open interest. We did so by finding the values of the regression coefficients that minimize the sum of the squared error.

$$SEE = \sum_{i=1}^{27} \left(r_{daily} - \hat{r}_{daily} \right)^2$$

where SEE is the sum of the squared errors, r_{daily} is the observed daily returns at expiration date and

$\hat{r}_{daily}$ is the predicted daily return at expiration date.

The multiple regression model using the OLS-method was computed in Python with the help of the library Statsmodels (see lines 50-56 in Appendix 1).

4.5.2 R-Squared

The coefficient of determination, also known as R-squared, measures how well the multiple linear regression is fitted based on the given data. The value of R-squared describes how much of the variation in the stock's daily return at expiration date can be described by the traded volume and open interest. The R-squared value ranges from 0 to 1. We used the following guidelines to determine how well fitted the multiple linear regression models turned out: a value of 0.1 or less indicates that a very small proportion of the stock's daily return at expiration date can be described, we will use this as an indication that traded volume and open interest cannot predict and describe the stock's daily return. A value between 0.1 and 0.3 indicates that a moderate proportion of the stock's daily return at expiration date can be described, meaning that the traded volume and open interest can sometimes predict and describe the stock's daily return. A value between 0.3 and 0.5 indicates that a medium-sized proportion of the stock's daily return at expiration date can be described, meaning that traded volume and open interest can be used to predict up to half of the stock's daily return. A value of 0.5 and over indicates that a large proportion of the stock's daily return can be described, meaning that traded volume and open interest can be used to give quite accurate predictions of the stock's daily return.

4.6 Heteroskedasticity

Heteroskedasticity means that the standard deviation of a variable is not constant over time. This can be problematic for statistical analysis because many statistical techniques assume that the errors are evenly distributed and have a constant variance. When this assumption is violated, the results of statistical tests may be incorrect and p-values may be invalid (Brooks, 2019).

To the opposite of heteroskedasticity, homoscedasticity refers to a situation in which the standard deviation of a variable is constant or nearly constant. Homoskedasticity is necessary to ensure that the statistical tests used in linear regression produce reliable results.

The Breusch-Pagan test was used to determine whether the linear regression model was heteroscedastic or homoscedastic. If the test indicated that the model was heteroskedastic, it was likely due to the presence of outliers in the data. Since this study only included 27 companies, it was not appropriate to remove any data points. Instead, we examined each underlying asset more closely during the months when the regression model was heteroskedastic.

4.6.1 Breusch-Pagan test

The Breusch-Pagan test was computed using Python with the help of the Statsmodels library (see lines 59-70 in Appendix 1). If the p-value of the Breusch-Pagan test is less than the regression model's significance level, then there is evidence of heteroskedasticity in the model.

4.7 Autocorrelation

Autocorrelation measures the relation between a variable at a given time and another value of itself at a previous time. When there is a high degree of autocorrelation, it indicates that the values of the variable are not independent, and that past values have an effect on current values (Brooks, 2019).

We did not perform tests for autocorrelation because our data is cross-sectional rather than serial, and autocorrelation tests are specifically relevant for serial data.

4.8 Mean Daily Return vs Expiration Date and One Sample T-Test

If you have the mean and standard deviation of a set of data, the interval of the first standard error refers to the range of values that are one standard deviation away from the mean. This interval can be expressed as the mean plus or minus one standard deviation. For example, if the mean of a set of data is 10 and the standard deviation is 1, the interval of the first standard error would be 9 to 11.

The methodology the study is using to analyze the data involves comparing the mean of previous dates to the daily return on the expiration date by calculating the mean of the previous dates and using this value as a reference point. We will then determine the standard deviation of the data set and use it to define an interval around the mean. This interval, which is often referred to as the "standard error", will be plus or minus one standard deviation from the mean. We will then compare the daily return on the expiration date to this interval. If the daily return falls within the interval, it will be considered typical or representative of the rest of the data set. If the daily return falls outside of the interval, it may be considered more extreme or unusual. This analysis will allow us to determine whether the daily return on the expiration date is typical or unusual compared to the mean of the previous dates.

In order to determine the statistical significance of our data, we will be using a one sample t-test method. This method allows us to compare the mean daily return of all the stocks with the one sample return on the expiration date and determine whether any observed differences between those values are likely to be due to chance or if they are likely to reflect a true underlying difference between the groups. By conducting a t-test, we will be able to make informed conclusions about the relationship between our variables and draw meaningful insights from the data.

We will begin to calculate the t-statistic, which represents the difference between the sample mean for each month and the expiration date return, divided by the standard error of the mean. Then use the t-statistic to calculate the p-value, which represents the probability of observing a difference as large or larger than the one observed in the sample. Lastly the p-value is compared with the significance level of 0.05, if the results are less than the significance level, the results are statistically significant. If the p-value is greater than the significance level, the results are not statistically significant.

The results of this one sample t-test should be able to provide an answer to the dependent hypothesis $H_{1b.}$

4.9 Reliability

The reliability of our study depends on the reliability of both the data and the results. To ensure the reliability of the data, we obtained it from two reputable sources: Bloomberg and FactSet. Subjective biases can also impact the categorization of empirical data and the drawing of conclusions (Bryman and Bell, 2017). To avoid this, we explained the assumptions underlying our selection of screening methods and our conclusions, which were based on previous research and established methodology. Another potential issue with the reliability of our results is that they may vary depending on the time period (Bryman and Bell, 2017). To address this, we conducted multiple separate regressions to ensure stability over that period and took into account any potential differences in conditions between the expiration dates of each month that was analyzed.

4.10 Validity

To ensure that our study is valid, it is important that our measures accurately assess the relationship between open interest on options and the performance of the underlying security. We based our model on financial theory, which provides a strong theoretical and empirical basis for the idea that options have an impact on the underlying security. Previous research has also examined the relationship between open interest on options and the daily return of underlying stocks, and this research was further used to study the Swedish market. To ensure the validity of our multiple regression model, we performed tests on multicollinearity, heteroskedasticity, and autocorrelation. We also analyzed the explanatory power of the independent variables using R-Squared, which is presented in Chapter 4 and reported in Chapter 5.

5. Result

5.1 Correlation Matrix for each Expiration Date

Figure 1-4 illustrates the correlation matrix between the stock's daily return at expiration date and all the independent variables used in the multiple linear regression models in Section 5.2. The diagonal of each correlation matrix (top left to bottom right) is all 1s because each variable is perfectly correlated with itself.

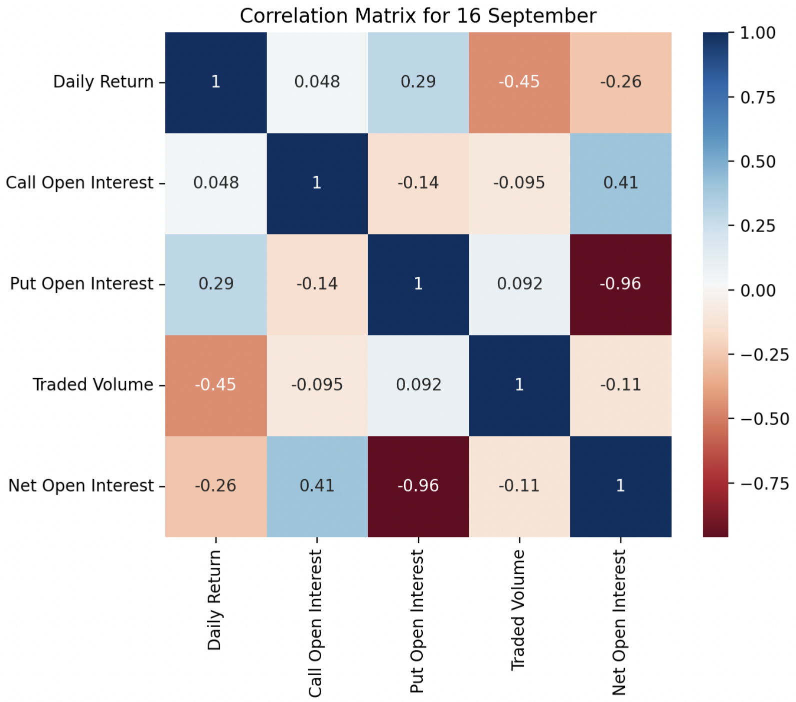

Figure 1: *A correlation matrix for the expiration date at 16 September of the dependent variable stock's daily return at expiration date and the independent variables sum of all call options' open interest, sum of all put options' open interest and the net open interest of all put and call options.*

Figure 1 shows the correlation matrix for the expiration date on September 16. We can see that the net open interest is strongly negatively correlated with the put open interest, with a value of -0.96, but not as strongly with the call open interest, with a value of 0.41, meaning that the put open interest is rather dominant in determining the change of the net open interest for the September expiration date.

The most important things to look at in the correlation matrix are the first column and all the values around 0.5 and above or all the values around -0.5 and below. The first column shows the individual correlation of all the independent variables with the stock's daily return. Call open interest has a very low correlation with the stock's daily return, while put open interest, traded volume, and net open interest show a moderate correlation with the daily return.

The only high correlation coefficient that is noteworthy apart from the first column is the red square that represents the correlation between the net open interest and put open interest. This indicates that if these two variables were to be included as independent variables in the same regression model, there might be a risk of multicollinearity.

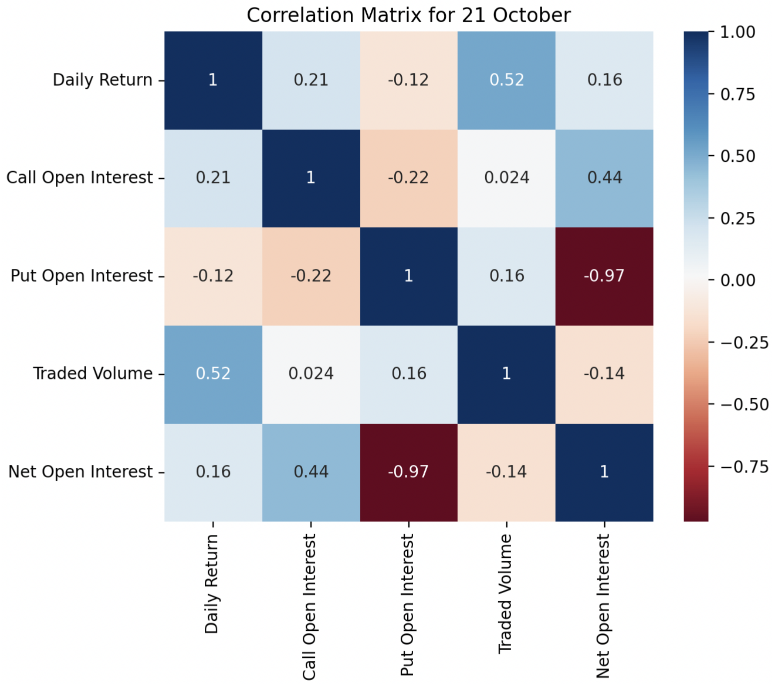

Figure 2: *A correlation matrix for the expiration date at 21 October of the dependent variable stock's daily return at expiration date and the independent variables sum of all call options' open interest, sum of all put options' open interest and the net open interest of all put and call options.*

Figure 2 shows the correlation matrix for the expiration date on October 21. Just as for the expiration date on September 16, this period shows a much stronger correlation between put open interest and net open interest than that of call open interest and net open interest. This means that put open interest is once again affecting net open interest more than call open interest does.

Compared to the previous period, traded volume has a positive correlation with the stock's daily return rather than a negative correlation. Also, call open interest has a significantly stronger correlation with the stock's daily return, with a value of 0.21. The correlation between call open interest and the stock's daily return is even stronger than the stock's daily return with put open interest and net open interest, respectively.

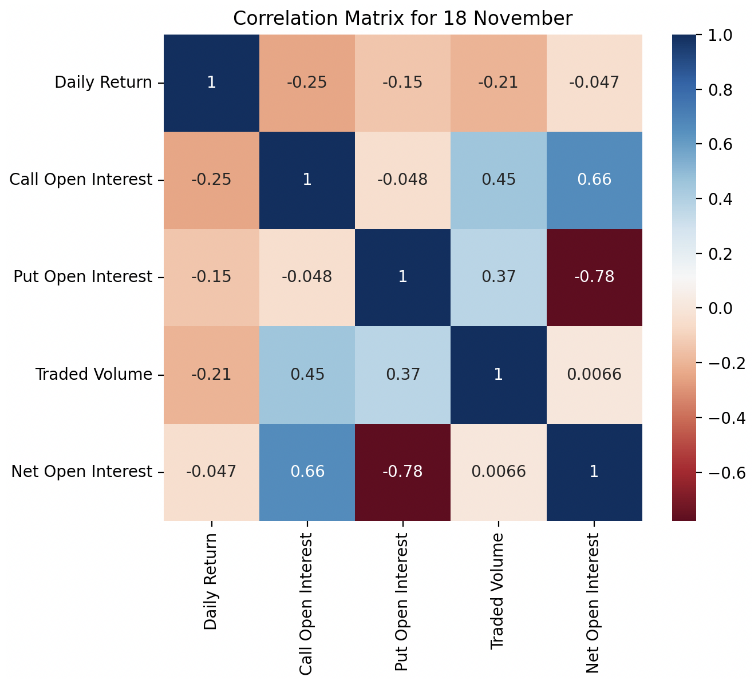

Figure 3: *A correlation matrix for the expiration date at 18 November of the dependent variable stock's daily return at expiration date and the independent variables sum of all call options' open interest, sum of all put options' open interest and the net open interest of all put and call options.*

Figure 3 shows the correlation matrix for the expiration date on November 18th. In this correlation matrix, we see a strong correlation between net open interest and put open interest, with a value of -0.78, as well as between net open interest and call open interest, with a value of 0.66. The difference is that put open interest gives a negative correlation with net open interest and call open interest gives a positive correlation.

As for the first column, we can see that net open interest has a very low correlation with the stock's daily return. Generally, each of the correlation coefficients between the stock's daily return and the independent variables show a value between -0.3 and 0, indicating a low negative correlation.

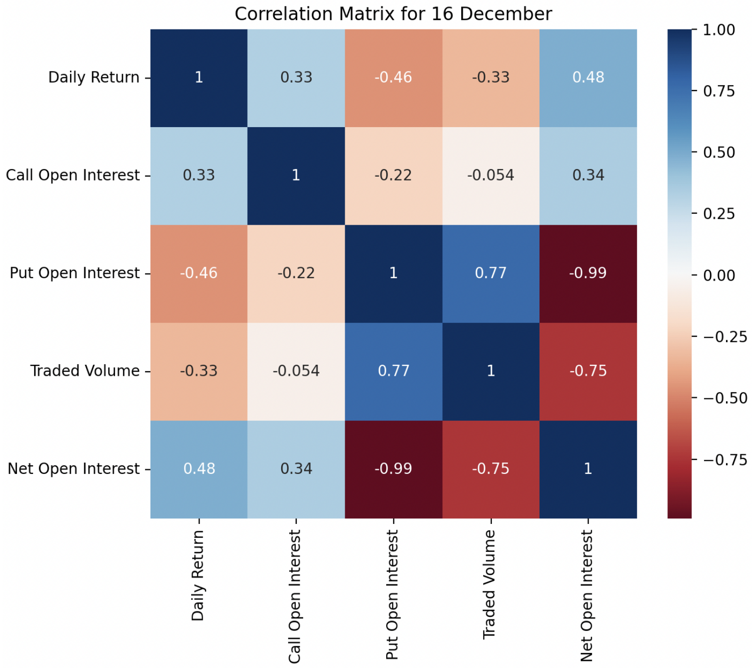

Figure 4: *A correlation matrix for the expiration date at 16 December of the dependent variable stock's daily return at expiration date and the independent variables sum of all call options' open interest, sum of all put options' open interest and the net open interest of all put and call options.*

Figure 4 shows the correlation matrix for the expiration date on December 16th. We can see at a glance that the colors on the correlation matrix are very concentrated, indicating strong correlations. None of these are in the first column, meaning that there might be potential for multicollinearity in this period. We see strong correlations between traded volume and put open interest, net open interest and put open interest, and traded volume and net open interest. This means that regression models for December 16th involving traded volume and put open interest or traded volume and net open interest might show multicollinearity tendencies.

Regarding the first column, we can see significantly stronger correlations between the stock's daily return and each independent variable.

5.2 Multiple Linear Regression Model for each Time Period

5.2.1 Results for Expiration Date at 16 September

Variables	***VIF-value***
Intercept	1.857332
Traded Volume	1.357183
Net Open Interest	1.153263

Table 1: *The variation inflation factors for every independent variable for the multiple linear regression model at expiration date 16 September.*

Table 1 shows the variation inflation factors for each independent variable used in the regression model. The intercept has the highest VIF-value: 1.857332. This indicates that there is moderate multicollinearity in the model, meaning that it is not high enough to significantly affect the results. The remaining independent variables have VIF-values that are lower, indicating a lesser degree of multicollinearity. Since there are no VIF-values above 5, nothing has to be removed when computing the regression model.

Appendix 4 shows the multiple linear regression model at the expiration date 16 September with the independent variables traded volume and the net open interest. Based on the p-values, it looks like the coefficient for the "Traded Volume" variable is statistically significant at the 0.05 level, while the coefficient for the "Net Open Interest" is statistically significant at the 0.1 level. The coefficient for the "Intercept" variable is not statistically significant at either the 0.05 or 0.1 level.

The R-squared value of 0.304 indicates that about 30.4% of the variance in the response variable is explained by the predictors in the model.

The F-statistic of 5.233 and the corresponding p-value of 0.013 indicate that the overall fit of the model is statistically significant at the 0.05 level.

The result from the Breush-Pagan test for heteroscedasticity is displayed in the table below.

Included independent variable	***p-value***
Traded Volume & Net Open Interest	0.5979

Table 2: *The Breusch-Pagan test for the multiple linear regression model on 16 September involving the independent variables traded volume and net open interest.*

The p-values from the Breusch-Pagan test is 0.5979 (see Table 2). This value is greater than 0.05, which means that there is not sufficient evidence to conclude that there is heteroscedasticity in the model.

5.2.2 Results for Expiration Date at 21 October

Variables	*VIF-value*
Intercept	1.321690
Traded Volume	1.470619
Net Open Interest	1.106551

Table 3: *The variation inflation factors for every independent variable for the multiple linear regression model at expiration date 21 October.*

Table 3 shows the variation inflation factors for each independent variable used in the regression model. All variables in Table 3 are very low, showing a moderate to almost no multicollinearity and will thereby not significantly impact the regression model. And since there are no VIF-values above 5, nothing has to be removed when computing the regression model.

According to appendix 7, the multiple linear regression model for the expiration date of October 21 showed that the coefficient for the "Traded Volume" variable was statistically significant at the 0.05 level, while the coefficients for the "Intercept" and "Net Open Interest" variables were not statistically significant.

The R-squared value of 0.324 indicates that the predictors in the model explain about 32.4% of the variance in the response variable.

Additionally, the F-statistic and corresponding p-value of 5.748 and 0.00913 respectively, suggest that the overall fit of the model is statistically significant at the 0.05 level.

The result from the Breush-Pagan test for heteroscedasticity is displayed in the table below.

Included independent variable	*p-value*
Traded Volume & Net Open Interest	3.1201×10^{-5}

Table 4: *The Breusch-Pagan test for the multiple linear regression model on 21 October involving the independent variables traded volume and net open interest.*

The p-values from the Breusch-Pagan test is 3.1201×10^{-5} (see Table 4). This value is less than 0.05, which means that there is sufficient evidence to conclude that there is heteroscedasticity in the model.

5.2.3 Results for Expiration Date at 18 November

Variables	***VIF-value***
Intercept	1.771641
Traded Volume	1.045324
Net Open Interest	1.002268

Table 5: *The variation inflation factors for every independent variable for the multiple linear regression model at expiration date 18 November.*

Table 5 shows the variation inflation factors for each independent variable used in the regression model. Both traded volume and net open interest show a VIF-value very close to 1, which indicates that there is almost no multicollinearity present in the model. Intercept those, however, have a higher VIF-value, indicating that there is a moderate multicollinearity. Although, since there are no VIF-values above 5, nothing has to be removed when computing the regression model.

In appendix 10, the multiple regression model yielded non-significant results, as indicated by the p-values of the coefficients. The R-squared value of 0.045 suggests that the predictors in the model only explain about 4.5% of the variance in the response variable. Additionally, the F-statistic and corresponding p-value of 0.5716 and 0.572 respectively, indicate that the model's overall fit is not statistically significant at the 0.05 level.

The result from the Breush-Pagan test for heteroscedasticity is displayed in the table below.

Included independent variable	***p-value***
Traded Volume & Net Open Interest	0.3215

Table 6: *The Breusch-Pagan test for the multiple linear regression model on 18 November involving the independent variables traded volume and net open interest.*

The p-values from the Breusch-Pagan test is 0.3215 (see Table 6). This value is greater than 0.05, which means that there is not sufficient evidence to conclude that there is heteroscedasticity in the model.

5.2.4 Results for Expiration Date at 16 December

Variables	***VIF-value***
Intercept	1.862041
Traded Volume	2.263339
Net Open Interest	2.625453

Table 7: *The variation inflation factors for every independent variable for the multiple linear regression model at expiration date 16 December.*

Table 7 shows the variation inflation factors for each independent variable used in the regression model. The VIF-values for all variables are much greater than that of the previous months. The VIF-value for net open interest of 2.625453 indicates that there is a considerable multicollinearity in the model. However, it does not exceed a VIF-value above 5, indicating that the multicollinearity is not great enough to harm the regression model. Since there are no VIF-values above 5, nothing has to be removed when computing the regression model.

Appendix 13 shows the p-values, only the "Net Open Interest" coefficient is marginally significant at the 0.05 level, while the other coefficients are not statistically significant at that level. The R-squared value of 0.236 suggests that the predictors in the model explain about 23.6% of the variance in the response variable. F-statistic and corresponding p-value of 3.697 and 0.0398 respectively, indicate that the overall fit of the model is statistically significant at the 0.05 level.

The result from the Breush-Pagan test for heteroscedasticity is displayed in the table below.

Included independent variable	***p-value***
Traded Volume & Net Open Interest	0.7574

Table 8: *The Breusch-Pagan test for the multiple linear regression model on 16 December involving the independent variables traded volume and net open interest.*

The p-values from the Breusch-Pagan test is 0.7574 (see Table 8). This value is greater than 0.05, which means that there is not sufficient evidence to conclude that there is heteroscedasticity in the model.

5.3 Mean Daily Return vs Expiration Date and One Sample T-Test

To see a deviation in the stock price's daily return on the expiration day, we have measured the mean and standard deviation of the daily return from the previous month after the expiration day to the day before the next month's expiration day and compared this to the daily return for the expiration day.

In the results of the multiple linear regression, we obtained a result in November with an R-squared that was statistically insignificant. This result made it easier to interpret the results of the mean daily returns and the return on the expiration date, as well as the supplementary One Sample T-test. The November results showed that, except for one stock, all stocks were within the range of the first standard deviation. The One Sample T-test also showed similar results, with the majority of the stocks not being statistically significant (see Appendix 14-17).

The results for the other three months showed varied results, which may indicate that the significance of expiration returns changes depending on the net open interest in those months compared to November.

Based on the clear results for November and the varied results for the other months, we conclude that our hypothesis H_{1b} is true, as the daily return on the expiration date is significantly different from the daily mean. Since this hypothesis was dependent on the results of the significance of the multiple regression model, we can compare the results for a non-significant month to those for a significant month.

6. Conclusion

The purpose of this study was to investigate the effect of option trading on the daily return of the underlying stock, specifically on the expiration date. To do this, we examined the statistical significance of the relationship between daily return and traded volume, as well as open interest for In the Money options.

With the results of our regression analysis, we can answer our first two hypotheses:

H_0 = *There is no relationship between daily return with traded volume and open interest at the expiration date of the option.*

H_{1a} = *There is a significant relationship between daily return with traded volume and open interest at the expiration date of the option.*

Since the regression results showed an R-squared above 0.1 for every month except November, we can conclude that we found statistical significance. Upon closer examination, we see that the low R-squared in November is due to a low net open interest compared to other months. We can therefore conclude that a higher net open interest leads to a higher R-squared. Based on these findings, we can reject the null hypothesis that "*There is no relationship between daily return with traded volume and open interest at the expiration date of the option*".

Through the clear results of November and the varied results of the other months, we establish that our hypothesis H_{1b} is true, as the daily return on the expiration date is significantly different compared to the daily mean. Since this hypothesis was dependent on the significance of the multiple regression model, we can compare the results of a non-significant month to those of a significant month and draw the conclusion that "*The daily return on the expiration date is significantly different from the mean daily return within the range of the standard deviation*.".

However, the R-squared shows that traded volume and open interest are not sufficient variables to make a prediction of the daily return. However, since there is statistical significance, it means that these variables do have an impact and should be included if one were to build a model to predict stock returns.

Our research shows that open interest may have a significant effect on the daily return of an option because it is an indicator of market sentiment and the level of activity in an option, which can lead to changes in the underlying stock. An increase in open interest, which indicates that new trades are entering the market, may be due to increased activity during the expiration week of options, as suggested by Hess (1982). According to Hess (1982), option holders must make a decision about their options before the end of the week, so traders tend to exercise their options late in the expiration week. The increase in activity during the following week may be due to the creation of new stock and option positions, potentially driven by delta hedging, which Ni, Pearson, Poteshman, and White (2016) found to be correlated with changes in the underlying stock price. As each option contract represents 100 units of the underlying stock and the open interest corresponds to the total number of outstanding option contracts, market makers' delta hedging activity, which involves buying or selling the underlying stock to maintain delta neutrality, may be one of the factors that has a significant impact on volume.

We found that, in 30% of the cases, the price movement of the underlying stock could be predicted by the amount of open interest and trading volume. This finding is similar to the results of Seo, Byun, and Kim (2020), who found that open interest provides information about future stock returns because it reflects the positions taken by delta hedgers.

Further Research

Since the scope of this study was focused on exploring the impact of option expiration on underlying stock returns, one possible area of further research to better determine the relationship between open interest and daily return on underlying stocks would be to compare the returns of optionable stocks with non-optionable stocks after risk adjustments to see if any differences can be explained by the amount of open interest that the optionable stocks have. As we found, open interest alone cannot explain the stock return of the underlying stock on the expiration day and, therefore, additional factors such as clearer data on option participants would be necessary to draw further conclusions.

Further investigation in this area could involve comparing the returns on the expiration Friday with returns on other Fridays with no expiration, if more data is available from earlier periods. This would allow us to see if there is any abnormal return that can be attributed to the options being exercised and the amount of open interest in the options. To more accurately determine whether any differences in returns can be attributed to expiration events or open interest, it would be useful to compare the stock itself to its returns on non-expiration Fridays, rather than comparing the stock to other optionable stocks that may be influenced by various other factors such as underlying fundamentals, market conditions, and investor sentiment. By examining the stock's own returns on expiration and non-expiration Fridays, we may be able to more clearly identify any impact that expiration events or open interest may have on the stock's returns.

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Appendix

Appendix 1. Python Code With Correlation Matrix And Multiple Regression Model Computation

```
from matplotlib import pyplot as plt
import pandas as pd
import seaborn as sns

import statsmodels.api as sm
from statsmodels.stats import diagnostic as diag
from statsmodels.stats.outliers_influence import variance_inflation_factor

# Load the data from the ExcelFile
# Does a regression for each sheet in the ExcelFile,
# for-loop to go through all sheets and facilitate any potential modifications
data = pd.ExcelFile('processed_data.xlsx')
sheet_list = ['Data_16sep', 'Data_21oct', 'Data_18nov', 'Data_16dec']
fridays = ['16 September', '21 October', '18 November', '16 December']
for i in range(len(sheet_list)):
    # Set new sheet as current expiration date to look at for the regression
    current_month = pd.read_excel(data, sheet_list[i])

    # Remove redundant data and set the data type to float
    current_month = current_month.drop(['Date', 'Daily Return of Stock', 'Daily Return of OMXS30'], axis = 1)
    current_month = current_month.astype(float)

    # Calculate and display the correlation matrix (values + heatmap using Seaborn and Matplotlib)
    corr = current_month.corr()
    sns.heatmap(corr, xticklabels = corr.columns, yticklabels = corr.columns, annot = True, cmap='RdBu')
    plt.title('Correlation Matrix for ' + fridays[i])
    plt.yticks(rotation=0)
    plt.show()

    current_month_call = current_month.drop(['Put Open Interest', 'Net Open Interest'], axis = 1)
    current_month_put = current_month.drop(['Call Open Interest', 'Net Open Interest'], axis = 1)
    current_month_net = current_month.drop(['Call Open Interest', 'Put Open Interest'], axis = 1)

    regressions = [current_month_call, current_month_put, current_month_net]
    oint_type = ['Call', 'Put', 'Net']

    for j in range(len(regressions)):

        # Adding constant to the data in order for the VFI to work, adds no value to the data otherwise
```

```
        X = sm.add_constant(regressions[j])

        # Creating the series with VFI values + printing it
        series = pd.Series([variance_inflation_factor(X.values, k) for k in range(X.shape[1])], index=X.columns)
        print('\n' + oint_type[j] + ': Variation Inflation Factor for ' + fridays[i])
        print('-'*50)
        print(series)

        print('Regression for ' + oint_type[j] + ' ' + fridays[i])
        # Set x- and y-values for the regression model, include a constant in the x-term to include y-intercept
        X = sm.add_constant(regressions[j].drop('Daily Return', axis = 1))
        Y = regressions[j]['Daily Return']
        # Computing the OLS regression on the data and print out a summary
        regression_model = sm.OLS(Y, X).fit()
        print(regression_model.summary())
        with open('output.txt', 'w') as fh:
            fh.write(regression_model.summary().as_text())

        # Run the Breusch-Pagan test
        _, pval, __, f_pval = diag.het_breuschpagan(regression_model.resid, regression_model.model.exog)

        # Print the results of the test
        if pval > 0.05:
            print("Breusch-Pagan's Test")
            print("p-value: ", pval)
            print("We fail to reject the null hypothesis, so there is no heteroscedasticity.\n")

        else:
            print("Breusch-Pagan's Test")
            print("p-value: ", pval)
            print("We reject the null hypothesis, so there is heteroscedasticity.\n")
```

Appendix 2. OLS Regression Results At 16 September For Stock's Daily Return Based On Call Open Interest

```
                            OLS Regression Results
==============================================================================
Dep. Variable:           Daily Return   R-squared:                       0.207
Model:                            OLS   Adj. R-squared:                  0.141
Method:                 Least Squares   F-statistic:                     3.132
Date:                Mon, 09 Jan 2023   Prob (F-statistic):             0.0619
Time:                        04:03:42   Log-Likelihood:                 74.625
No. Observations:                  27   AIC:                            -143.3
Df Residuals:                      24   BIC:                            -139.4
Df Model:                           2
Covariance Type:            nonrobust
======================================================================================
                         coef    std err          t      P>|t|      [0.025      0.975]
--------------------------------------------------------------------------------------
const                  0.0064      0.004      1.581      0.127      -0.002       0.015
Call Open Interest  3.609e-08   1.53e-06      0.024      0.981   -3.12e-06    3.19e-06
Traded Volume      -6.944e-10   2.79e-10     -2.489      0.020   -1.27e-09   -1.19e-10
==============================================================================
Omnibus:                        1.778   Durbin-Watson:                   1.823
Prob(Omnibus):                  0.411   Jarque-Bera (JB):                1.071
Skew:                          -0.094   Prob(JB):                        0.585
Kurtosis:                       2.043   Cond. No.                     1.73e+07
==============================================================================
```

Appendix 3. OLS Regression Results At 16 September For Stock's Daily Return Based On Put Open Interest

```
                            OLS Regression Results
==============================================================================
Dep. Variable:           Daily Return   R-squared:                       0.321
Model:                            OLS   Adj. R-squared:                  0.265
Method:                 Least Squares   F-statistic:                     5.677
Date:                Mon, 09 Jan 2023   Prob (F-statistic):            0.00958
Time:                        04:03:42   Log-Likelihood:                 76.724
No. Observations:                  27   AIC:                            -147.4
Df Residuals:                      24   BIC:                            -143.6
Df Model:                           2
Covariance Type:            nonrobust
=====================================================================================
                        coef    std err          t      P>|t|      [0.025      0.975]
-------------------------------------------------------------------------------------
const                 0.0015      0.004      0.362      0.720      -0.007       0.010
Put Open Interest  8.541e-07   4.25e-07      2.009      0.056   -2.33e-08    1.73e-06
Traded Volume     -7.429e-10   2.58e-10     -2.879      0.008   -1.28e-09    -2.1e-10
==============================================================================
Omnibus:                        0.361   Durbin-Watson:                   1.805
Prob(Omnibus):                  0.835   Jarque-Bera (JB):                0.517
Skew:                          -0.082   Prob(JB):                        0.772
Kurtosis:                       2.343   Cond. No.                     1.94e+07
==============================================================================
```

Appendix 4. OLS Regression Results At 16 September For Stock's Daily Return Based On Net Open Interest

```
                            OLS Regression Results
==============================================================================
Dep. Variable:          Daily Return   R-squared:                       0.304
Model:                           OLS   Adj. R-squared:                  0.246
Method:                Least Squares   F-statistic:                     5.233
Date:               Mon, 09 Jan 2023   Prob (F-statistic):             0.0130
Time:                       04:03:43   Log-Likelihood:                 76.381
No. Observations:                 27   AIC:                            -146.8
Df Residuals:                     24   BIC:                            -142.9
Df Model:                          2
Covariance Type:           nonrobust
=====================================================================================
                        coef    std err          t      P>|t|      [0.025      0.975]
-------------------------------------------------------------------------------------
const                 0.0030      0.004      0.774      0.446      -0.005       0.011
Traded Volume     -7.483e-10   2.62e-10     -2.858      0.009   -1.29e-09   -2.08e-10
Net Open Interest -7.263e-07   3.98e-07     -1.826      0.080   -1.55e-06    9.47e-08
==============================================================================
Omnibus:                        0.883   Durbin-Watson:                   1.690
Prob(Omnibus):                  0.643   Jarque-Bera (JB):                0.813
Skew:                          -0.174   Prob(JB):                        0.666
Kurtosis:                       2.224   Cond. No.                     1.79e+07
==============================================================================
```

Appendix 5. OLS Regression Results At 21 October For Stock's Daily Return Based On Call Open Interest

```
                            OLS Regression Results
==============================================================================
Dep. Variable:          Daily Return   R-squared:                       0.305
Model:                           OLS   Adj. R-squared:                  0.247
Method:                Least Squares   F-statistic:                     5.270
Date:               Mon, 09 Jan 2023   Prob (F-statistic):             0.0127
Time:                       04:03:43   Log-Likelihood:                 38.140
No. Observations:                 27   AIC:                            -70.28
Df Residuals:                     24   BIC:                            -66.39
Df Model:                          2
Covariance Type:           nonrobust
======================================================================================
                         coef    std err          t      P>|t|      [0.025      0.975]
--------------------------------------------------------------------------------------
const                 -0.0159      0.015     -1.095      0.284      -0.046       0.014
Call Open Interest  1.041e-05   9.09e-06      1.145      0.263   -8.35e-06    2.92e-05
Traded Volume       1.905e-09   6.33e-10      3.010      0.006    5.99e-10    3.21e-09
==============================================================================
Omnibus:                       20.305   Durbin-Watson:                   1.823
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               84.812
Skew:                          -0.871   Prob(JB):                     3.83e-19
Kurtosis:                      11.506   Cond. No.                     2.56e+07
==============================================================================
```

Appendix 6. OLS Regression Results At 21 October For Stock's Daily Return Based On Put Open Interest

OLS Regression Results

Dep. Variable:	Daily Return	R-squared:	0.311
Model:	OLS	Adj. R-squared:	0.253
Method:	Least Squares	F-statistic:	5.409
Date:	Mon, 09 Jan 2023	Prob (F-statistic):	0.0115
Time:	04:03:44	Log-Likelihood:	38.248
No. Observations:	27	AIC:	-70.50
Df Residuals:	24	BIC:	-66.61
Df Model:	2		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	-0.0029	0.014	-0.200	0.843	-0.032	0.027
Put Open Interest	-2.912e-06	2.37e-06	-1.231	0.230	-7.8e-06	1.97e-06
Traded Volume	2.049e-09	6.39e-10	3.209	0.004	7.31e-10	3.37e-09

Omnibus:	26.801	Durbin-Watson:	1.913
Prob(Omnibus):	0.000	Jarque-Bera (JB):	120.468
Skew:	-1.405	Prob(JB):	6.93e-27
Kurtosis:	12.959	Cond. No.	2.52e+07

Appendix 7. OLS Regression Results At 21 October For Stock's Daily Return Based On Net Open Interest

OLS Regression Results

Dep. Variable:	Daily Return	R-squared:	0.324
Model:	OLS	Adj. R-squared:	0.268
Method:	Least Squares	F-statistic:	5.748
Date:	Mon, 09 Jan 2023	Prob (F-statistic):	0.00913
Time:	04:03:44	Log-Likelihood:	38.508
No. Observations:	27	AIC:	-71.02
Df Residuals:	24	BIC:	-67.13
Df Model:	2		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	-0.0045	0.014	-0.331	0.744	-0.033	0.024
Traded Volume	2.05e-09	6.31e-10	3.251	0.003	7.49e-10	3.35e-09
Net Open Interest	3.048e-06	2.15e-06	1.418	0.169	-1.39e-06	7.48e-06

Omnibus:	26.933	Durbin-Watson:	1.907
Prob(Omnibus):	0.000	Jarque-Bera (JB):	120.290
Skew:	-1.421	Prob(JB):	7.57e-27
Kurtosis:	12.942	Cond. No.	2.42e+07

Appendix 8. OLS Regression Results At 18 November For Stock's Daily Return Based On Call Open Interest

```
                            OLS Regression Results
==============================================================================
Dep. Variable:           Daily Return   R-squared:                       0.073
Model:                            OLS   Adj. R-squared:                 -0.004
Method:                 Least Squares   F-statistic:                    0.9477
Date:                Mon, 09 Jan 2023   Prob (F-statistic):              0.402
Time:                        04:03:44   Log-Likelihood:                 93.131
No. Observations:                  27   AIC:                            -180.3
Df Residuals:                      24   BIC:                            -176.4
Df Model:                           2
Covariance Type:            nonrobust
=======================================================================================
                          coef    std err          t      P>|t|      [0.025      0.975]
---------------------------------------------------------------------------------------
const                  -0.0003      0.002     -0.145      0.886      -0.005       0.004
Call Open Interest -8.486e-07   9.65e-07     -0.879      0.388   -2.84e-06    1.14e-06
Traded Volume        -2.44e-10   4.45e-10     -0.548      0.589   -1.16e-09    6.75e-10
==============================================================================
Omnibus:                        2.632   Durbin-Watson:                   2.572
Prob(Omnibus):                  0.268   Jarque-Bera (JB):                1.669
Skew:                          -0.605   Prob(JB):                        0.434
Kurtosis:                       3.138   Cond. No.                     7.03e+06
==============================================================================
```

Appendix 9. OLS Regression Results At 18 November For Stock's Daily Return Based On Put Open Interest

```
                            OLS Regression Results
==============================================================================
Dep. Variable:           Daily Return   R-squared:                       0.049
Model:                            OLS   Adj. R-squared:                 -0.031
Method:                 Least Squares   F-statistic:                    0.6145
Date:                Mon, 09 Jan 2023   Prob (F-statistic):              0.549
Time:                        04:03:44   Log-Likelihood:                 92.779
No. Observations:                  27   AIC:                            -179.6
Df Residuals:                      24   BIC:                            -175.7
Df Model:                           2
Covariance Type:            nonrobust
======================================================================================
                         coef    std err          t      P>|t|      [0.025      0.975]
--------------------------------------------------------------------------------------
const                 -0.0005      0.002     -0.232      0.819      -0.005       0.004
Put Open Interest -2.908e-07    7.9e-07     -0.368      0.716   -1.92e-06    1.34e-06
Traded Volume     -3.616e-10   4.33e-10     -0.834      0.412   -1.26e-09    5.33e-10
==============================================================================
Omnibus:                        7.729   Durbin-Watson:                   2.435
Prob(Omnibus):                  0.021   Jarque-Bera (JB):                5.774
Skew:                          -0.974   Prob(JB):                       0.0558
Kurtosis:                       4.155   Cond. No.                     6.99e+06
==============================================================================
```

Appendix 10. OLS Regression Results At 18 November For Stock's Daily Return Based On Net Open Interest

```
                            OLS Regression Results
==============================================================================
Dep. Variable:           Daily Return   R-squared:                       0.045
Model:                            OLS   Adj. R-squared:                 -0.034
Method:                 Least Squares   F-statistic:                    0.5716
Date:                Mon, 09 Jan 2023   Prob (F-statistic):              0.572
Time:                        04:03:45   Log-Likelihood:                 92.733
No. Observations:                  27   AIC:                            -179.5
Df Residuals:                      24   BIC:                            -175.6
Df Model:                           2
Covariance Type:            nonrobust
=====================================================================================
                        coef    std err          t      P>|t|      [0.025      0.975]
-------------------------------------------------------------------------------------
const                -0.0005      0.002     -0.249      0.805      -0.005       0.004
Traded Volume     -4.202e-10   4.03e-10     -1.042      0.308   -1.25e-09    4.12e-10
Net Open Interest  -1.27e-07    5.5e-07     -0.231      0.819   -1.26e-06    1.01e-06
==============================================================================
Omnibus:                        6.098   Durbin-Watson:                   2.507
Prob(Omnibus):                  0.047   Jarque-Bera (JB):                4.325
Skew:                          -0.924   Prob(JB):                        0.115
Kurtosis:                       3.653   Cond. No.                     6.98e+06
==============================================================================
```

Appendix 11. OLS Regression Results At 16 December For Stock's Daily Return Based On Call Open Interest

```
                            OLS Regression Results
==============================================================================
Dep. Variable:           Daily Return   R-squared:                       0.207
Model:                            OLS   Adj. R-squared:                  0.141
Method:                 Least Squares   F-statistic:                     3.134
Date:                Mon, 09 Jan 2023   Prob (F-statistic):             0.0617
Time:                        04:03:45   Log-Likelihood:                 73.254
No. Observations:                  27   AIC:                            -140.5
Df Residuals:                      24   BIC:                            -136.6
Df Model:                           2
Covariance Type:            nonrobust
=======================================================================================
                         coef    std err          t      P>|t|      [0.025      0.975]
---------------------------------------------------------------------------------------
const                 -0.0018      0.005     -0.369      0.715      -0.012       0.008
Call Open Interest  1.126e-06   6.61e-07      1.703      0.101   -2.38e-07    2.49e-06
Traded Volume       -6.93e-10   3.98e-10     -1.740      0.095   -1.52e-09    1.29e-10
==============================================================================
Omnibus:                        4.997   Durbin-Watson:                   2.072
Prob(Omnibus):                  0.082   Jarque-Bera (JB):                3.368
Skew:                          -0.824   Prob(JB):                        0.186
Kurtosis:                       3.526   Cond. No.                     1.60e+07
==============================================================================
```

Appendix 12. OLS Regression Results At 16 December For Stock's Daily Return Based On Put Open Interest

```
                            OLS Regression Results
==============================================================================
Dep. Variable:           Daily Return   R-squared:                       0.210
Model:                            OLS   Adj. R-squared:                  0.144
Method:                 Least Squares   F-statistic:                     3.183
Date:                Mon, 09 Jan 2023   Prob (F-statistic):             0.0594
Time:                        04:03:45   Log-Likelihood:                 73.297
No. Observations:                  27   AIC:                            -140.6
Df Residuals:                      24   BIC:                            -136.7
Df Model:                           2
Covariance Type:            nonrobust
=====================================================================================
                        coef    std err          t      P>|t|      [0.025      0.975]
-------------------------------------------------------------------------------------
const                 0.0007      0.004      0.156      0.877      -0.008       0.010
Put Open Interest -2.464e-07   1.43e-07     -1.729      0.097     -5.4e-07    4.78e-08
Traded Volume      9.335e-11    6.2e-10      0.151      0.882    -1.19e-09    1.37e-09
==============================================================================
Omnibus:                        9.054   Durbin-Watson:                   2.446
Prob(Omnibus):                  0.011   Jarque-Bera (JB):                7.709
Skew:                          -0.934   Prob(JB):                       0.0212
Kurtosis:                       4.834   Cond. No.                     1.42e+07
==============================================================================
```

Appendix 13. OLS Regression Results At 16 December For Stock's Daily Return Based On Net Open Interest

```
                            OLS Regression Results
==============================================================================
Dep. Variable:           Daily Return   R-squared:                       0.236
Model:                            OLS   Adj. R-squared:                  0.172
Method:                 Least Squares   F-statistic:                     3.697
Date:                Mon, 09 Jan 2023   Prob (F-statistic):             0.0398
Time:                        04:03:46   Log-Likelihood:                 73.746
No. Observations:                  27   AIC:                            -141.5
Df Residuals:                      24   BIC:                            -137.6
Df Model:                           2
Covariance Type:            nonrobust
=====================================================================================
                        coef    std err          t      P>|t|      [0.025      0.975]
-------------------------------------------------------------------------------------
const                -0.0004      0.004     -0.081      0.936      -0.009       0.009
Traded Volume      1.355e-10   5.87e-10      0.231      0.819    -1.08e-09    1.35e-09
Net Open Interest  2.564e-07    1.3e-07      1.975      0.060    -1.15e-08    5.24e-07
==============================================================================
Omnibus:                        9.227   Durbin-Watson:                   2.382
Prob(Omnibus):                  0.010   Jarque-Bera (JB):                8.205
Skew:                          -0.905   Prob(JB):                       0.0165
Kurtosis:                       5.003   Cond. No.                     1.45e+07
==============================================================================
```

Appendix 14. 1st SD And One Sample T-Test For 16 September

September	Mean	SD	ExpDate	1st SD	SEM	T-Statistic	P-Value	Significancy
ABB SS Equity	-0.08	1.31	-2.86	Not in interval	0.31	9.01	0.00000007	Significant
ALFA SS Equity	-0.27	1.62	-3.62	Not in interval	0.38	8.78	0.00000010	Significant
ASSAB SS Equity	-0.28	1.81	-4.16	Not in interval	0.43	9.09	0.00000006	Significant
ATCOA SS Equity	-0.18	1.93	-2.78	Not in interval	0.46	5.71	0.00002556	Significant
AZN SS Equity	-0.77	1.29	-0.64	In interval	0.30	-0.44	0.66799823	Not significant
BOL SS Equity	-0.16	2.42	-1.99	In interval	0.57	3.20	0.00529561	Significant
ELUXB SS Equity	-0.82	2.08	0.03	In interval	0.49	-1.75	0.09846373	Not significant
ERICB SS Equity	-0.42	1.83	-0.32	In interval	0.43	-0.24	0.81234229	Not significant
ESSITYB SS Equity	-0.69	1.59	0.52	In interval	0.37	-3.23	0.00490713	Significant
EVO SS Equity	-0.31	2.18	-0.34	In interval	0.51	0.05	0.95957325	Not significant
GETIB SS Equity	-0.64	2.35	-1.26	In interval	0.55	1.10	0.28544610	Not significant
HEXAB SS Equity	-0.11	1.99	-3.03	Not in interval	0.47	6.21	0.00000942	Significant
HMB SS Equity	-0.70	2.65	0.63	In interval	0.62	-2.13	0.04821212	Significant
INVEB SS Equity	-0.23	1.59	-1.52	In interval	0.37	3.43	0.00317276	Significant
KINVB SS Equity	-0.45	2.60	-0.83	In interval	0.61	0.62	0.54189327	Not significant
NDA SS Equity	0.17	1.26	-3.57	Not in interval	0.30	12.56	0.00000000	Significant
SAND SS Equity	-0.55	2.57	-1.71	In interval	0.60	1.92	0.07210909	Not significant
SBBB SS Equity	-0.64	2.68	-6.38	Not in interval	0.63	9.10	0.00000006	Significant
SCAB SS Equity	-0.33	1.81	0.76	In interval	0.43	-2.57	0.01987265	Significant
SEBA SS Equity	0.15	1.28	-0.85	In interval	0.30	3.33	0.00393390	Significant
SHBA SS Equity	0.28	1.30	-0.73	In interval	0.31	3.30	0.00425970	Significant
SINCH SS Equity	-0.96	3.30	-0.29	In interval	0.78	-0.86	0.40352482	Not significant
SKFB SS Equity	-0.25	2.13	-1.27	In interval	0.50	2.03	0.05836053	Not significant
SWEDA SS Equity	0.59	1.45	-1.01	Not in interval	0.34	4.69	0.00021070	Significant
TEL2B SS Equity	-0.69	1.99	0.63	In interval	0.47	-2.81	0.01217503	Significant
TELIA SS Equity	-0.56	1.04	0.60	Not in interval	0.24	-4.72	0.00019729	Significant
VOLVB SS Equity	-0.07	1.60	-2.85	Not in interval	0.38	7.39	0.00000106	Significant

Appendix 15. 1st SD And One Sample T-Test For 21 October

October	Mean	SD	ExpDate	1st SD	SEM	T-Statistic	P-Value	Significancy
ABB SS Equity	0.28	1.96	1.30	In interval	0.40	-2.54	0.01832788	Significant
ALFA SS Equity	0.13	2.10	-1.24	In interval	0.43	3.21	0.00392388	Significant
ASSAB SS Equity	0.03	1.78	-0.80	In interval	0.36	2.29	0.03156801	Significant
ATCOA SS Equity	0.16	2.37	0.15	In interval	0.48	0.03	0.97412307	Not significant
AZN SS Equity	-0.09	0.93	0.70	In interval	0.19	-4.13	0.00040790	Significant
BOL SS Equity	-0.11	2.67	-1.95	In interval	0.55	3.37	0.00267162	Significant
ELUXB SS Equity	0.00	2.16	-0.18	In interval	0.44	0.41	0.68750187	Not significant
ERICB SS Equity	-0.63	3.34	-0.60	In interval	0.68	-0.05	0.96146617	Not significant
ESSITYB SS Equity	-0.25	1.21	1.41	Not in interval	0.25	-6.73	0.00000072	Significant
EVO SS Equity	0.45	2.99	0.40	In interval	0.61	0.07	0.94348450	Not significant
GETIB SS Equity	0.52	2.67	0.72	In interval	0.55	-0.37	0.71252729	Not significant
HEXAB SS Equity	-0.08	2.28	-1.42	In interval	0.47	2.86	0.00878191	Significant
HMB SS Equity	0.25	2.82	-2.92	Not in interval	0.58	5.52	0.00001306	Significant
INVEB SS Equity	0.05	1.94	-0.04	In interval	0.40	0.22	0.83157362	Not significant
KINVB SS Equity	-0.12	4.23	-2.75	In interval	0.86	3.05	0.00564613	Significant
NDA SS Equity	0.19	1.62	1.12	In interval	0.33	-2.80	0.01019119	Significant
SAND SS Equity	0.38	2.46	0.95	In interval	0.50	-1.13	0.26896281	Not significant
SBBB SS Equity	-0.74	4.40	-0.04	In interval	0.90	-0.77	0.44749158	Not significant
SCAB SS Equity	-0.25	1.81	-3.23	Not in interval	0.37	8.06	0.00000004	Significant
SEBA SS Equity	0.20	1.87	0.56	In interval	0.38	-0.94	0.35521637	Not significant
SHBA SS Equity	0.40	2.06	1.72	In interval	0.42	-3.13	0.00465419	Significant
SINCH SS Equity	1.14	5.38	34.01	Not in interval	1.10	-29.94	0.00000000	Significant
SKFB SS Equity	0.54	1.83	0.33	In interval	0.37	0.55	0.58494723	Not significant
SWEDA SS Equity	0.18	1.74	0.63	In interval	0.36	-1.27	0.21593032	Not significant
TEL2B SS Equity	-0.64	1.81	-1.76	In interval	0.37	3.03	0.00594640	Significant
TELIA SS Equity	-0.38	1.26	-12.29	Not in interval	0.26	46.47	0.00000000	Significant
VOLVB SS Equity	0.09	1.89	1.46	In interval	0.39	-3.54	0.00174174	Significant

Appendix 16. 1st SD And One Sample T-Test For 18 November

November	Mean	SD	ExpDate	1st SD	SEM	T-Statistic	P-Value	Significancy
ABB SS Equity	0.33	0.84	0.77	In interval	0.19	-2.28	0.03505464	Significant
ALFA SS Equity	0.32	3.18	1.51	In interval	0.73	-1.63	0.11972854	Not significant
ASSAB SS Equity	0.65	2.13	0.80	In interval	0.49	-0.31	0.76255354	Not significant
ATCOA SS Equity	0.87	2.35	0.94	In interval	0.54	-0.12	0.90347503	Not significant
AZN SS Equity	0.54	2.04	1.62	In interval	0.47	-2.30	0.03358910	Significant
BOL SS Equity	0.71	2.74	1.02	In interval	0.63	-0.50	0.62199477	Not significant
ELUXB SS Equity	0.85	2.45	0.38	In interval	0.56	0.83	0.41820928	Not significant
ERICB SS Equity	0.26	1.23	1.25	In interval	0.28	-3.51	0.00250338	Significant
ESSITYB SS Equity	0.51	1.40	1.39	In interval	0.32	-2.74	0.01358977	Significant
EVO SS Equity	0.28	1.72	0.37	In interval	0.39	-0.24	0.81650126	Not significant
GETIB SS Equity	0.69	1.86	-0.63	In interval	0.43	3.11	0.00609466	Significant
HEXAB SS Equity	0.76	3.06	1.30	In interval	0.70	-0.77	0.45131138	Not significant
HMB SS Equity	0.24	2.45	2.01	In interval	0.56	-3.16	0.00546380	Significant
INVEB SS Equity	0.55	1.58	1.02	In interval	0.36	-1.30	0.21012302	Not significant
KINVB SS Equity	0.75	3.43	0.03	In interval	0.79	0.91	0.37305993	Not significant
NDA SS Equity	0.13	0.77	0.65	In interval	0.18	-2.91	0.00924668	Significant
SAND SS Equity	0.55	1.80	1.27	In interval	0.41	-1.74	0.09923118	Not significant
SBBB SS Equity	2.41	7.03	1.38	In interval	1.61	0.64	0.53170302	Not significant
SCAB SS Equity	0.06	1.84	-0.36	In interval	0.42	1.00	0.33046025	Not significant
SEBA SS Equity	0.08	1.46	0.51	In interval	0.34	-1.28	0.21607106	Not significant
SHBA SS Equity	0.10	0.86	0.76	In interval	0.20	-3.32	0.00377858	Significant
SINCH SS Equity	1.54	10.71	-1.74	In interval	2.46	1.33	0.19939580	Not significant
SKFB SS Equity	0.11	2.64	1.67	In interval	0.61	-2.58	0.01898283	Significant
SWEDA SS Equity	0.22	1.38	0.27	In interval	0.32	-0.16	0.87284619	Not significant
TEL2B SS Equity	0.31	0.87	0.89	In interval	0.20	-2.89	0.00968677	Significant
TELIA SS Equity	0.17	1.50	0.27	In interval	0.34	-0.29	0.77426097	Not significant
VOLVB SS Equity	0.52	1.04	1.75	Not in interval	0.24	-5.12	0.00007131	Significant

Appendix 17. 1st SD And One Sample T-Test For 16 December

December	Mean	SD	ExpDate	1st SD	SEM	T-Statistic	P-Value	Significancy
ABB SS Equity	-0.17	0.96	-1.04	In interval	0.22	3.97	0.00090020	Significant
ALFA SS Equity	0.20	1.43	-2.47	Not in interval	0.33	8.12	0.00000020	Significant
ASSAB SS Equity	-0.24	1.34	0.13	In interval	0.31	-1.21	0.24261676	Not significant
ATCOA SS Equity	-0.01	1.59	-1.85	Not in interval	0.36	5.05	0.00008390	Significant
AZN SS Equity	0.20	0.68	-1.64	Not in interval	0.16	11.87	0.00000000	Significant
BOL SS Equity	0.37	1.85	-0.86	In interval	0.42	2.91	0.00933112	Significant
ELUXB SS Equity	0.10	1.88	-2.78	Not in interval	0.43	6.65	0.00000304	Significant
ERICB SS Equity	-0.05	1.55	-6.92	Not in interval	0.35	19.36	0.00000000	Significant
ESSITYB SS Equity	0.48	1.29	0.59	In interval	0.30	-0.36	0.72011436	Not significant
EVO SS Equity	0.11	1.58	-1.24	In interval	0.36	3.72	0.00158117	Significant
GETIB SS Equity	-0.27	2.42	-2.65	In interval	0.55	4.29	0.00043888	Significant
HEXAB SS Equity	-0.24	1.46	-1.86	Not in interval	0.33	4.86	0.00012606	Significant
HMB SS Equity	-0.27	2.47	0.18	In interval	0.57	-0.79	0.44160075	Not significant
INVEB SS Equity	0.04	1.07	-1.87	Not in interval	0.25	7.77	0.00000037	Significant
KINVB SS Equity	-0.23	3.27	-3.66	Not in interval	0.75	4.58	0.00023369	Significant
NDA SS Equity	-0.06	0.94	0.07	In interval	0.21	-0.61	0.55004151	Not significant
SAND SS Equity	-0.03	1.32	-0.95	In interval	0.30	3.03	0.00721925	Significant
SBBB SS Equity	0.39	4.92	-0.92	In interval	1.13	1.16	0.26152434	Not significant
SCAB SS Equity	-0.14	1.29	-0.67	In interval	0.30	1.79	0.09035074	Not significant
SEBA SS Equity	0.06	0.86	-1.67	Not in interval	0.20	8.85	0.00000006	Significant
SHBA SS Equity	-0.12	0.95	-0.63	In interval	0.22	2.34	0.03069662	Significant
SINCH SS Equity	1.13	3.20	-4.34	Not in interval	0.73	7.44	0.00000068	Significant
SKFB SS Equity	-0.38	1.74	-0.72	In interval	0.40	0.84	0.41187232	Not significant
SWEDA SS Equity	0.26	0.87	-1.81	Not in interval	0.20	10.37	0.00000001	Significant
TEL2B SS Equity	-0.04	0.88	-6.47	Not in interval	0.20	31.90	0.00000000	Significant
TELIA SS Equity	-0.28	0.84	-3.43	Not in interval	0.19	16.35	0.00000000	Significant
VOLVB SS Equity	-0.02	1.20	-0.73	In interval	0.28	2.60	0.01794094	Significant

Appendix 18. The Variation Inflation Factors For Traded Volume And Either Call Or Put Open Interest At Expiration Date 16 September

Variables	*VIF-value*
Intercept	1.863462
Traded Volume	1.269619
Call Open Interest	1.009148

Variables	*VIF-value*
Intercept	2.138346
Traded Volume	1.356925
Put Open Interest	1.178253

Appendix 19. The Variation Inflation Factors For Traded Volume And Either Call Or Put Open Interest At Expiration Date 21 October

Variables	*VIF-value*
Intercept	1.539442
Traded Volume	1.378314
Call Open Interest	1.055238

Variables	*VIF-value*
Intercept	1.427775
Traded Volume	1.467562
Put Open Interest	1.091744

Appendix 20. The Variation Inflation Factors For Traded Volume And Either Call Or Put Open Interest At Expiration Date 18 November

Variables	*VIF-value*
Intercept	1.796848
Traded Volume	1.272241
Call Open Interest	1.296981

Variables	*VIF-value*
Intercept	1.777151
Traded Volume	1.193506
Put Open Interest	1.166398

Appendix 21. The Variation Inflation Factors For Traded Volume And Either Call Or Put Open Interest At Expiration Date 16 December

Variables	*VIF-value*
Intercept	2.258279
Traded Volume	1.129440
Call Open Interest	1.124223

Variables	*VIF-value*
Intercept	1.767529
Traded Volume	2.440407
Put Open Interest	2.741696

Appendix 22. The Breush-Pagan Test Results For The Regression Models Involving Traded Volume And Either Call Or Put Open Interest At Expiration Date 16 September

Included independent variable	*p-value*
Call Open Interest	0.3565
Put Open Interest	0.4011

Appendix 23. The Breush-Pagan Test Results For The Regression Models Involving Traded Volume And Either Call Or Put Open Interest At Expiration Date 21 October

Included independent variable	***p-value***
Call Open Interest	1.5305×10^{-5}
Put Open Interest	2.6768×10^{-5}

Appendix 24. The Breush-Pagan Test Results For The Regression Models Involving Traded Volume And Either Call Or Put Open Interest At Expiration Date 18 November

Included independent variable	***p-value***
Call Open Interest	0.0267
Put Open Interest	0.4767

Appendix 25. The Breush-Pagan Test Results For The Regression Models Involving Traded Volume And Either Call Or Put Open Interest At Expiration Date 16 December

Included independent variable	***p-value***
Call Open Interest	0.1286
Put Open Interest	0.7611