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MARKET MICROSTRUCTURE AND ITS EFFECT UPON PRICE DETERMINATION EFFICIENCY

PhD Thesis

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STATEMENT OF ORIGINALITY

This is to certify that to the best of my knowledge, the content of this thesis is my own work. This thesis has not been submitted previously for a higher degree or qualification at any other university or institute of higher learning. I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis, and sources used have been acknowledged.

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Finally, I would like to dedicate this thesis to my parents as well as my wife Gianna Stamati. Besides being a source of constant encouragement, they are an inspiration to me.

PREFACE

Some findings of Chapter 4 and 5 were presented as a working paper co-authored with Assoc. Prof. Alexakis at a seminar, organized by Consob and the Catholic University of the Sacred Heart, Department of Economic Sciences and Business Management in April 2019. Some findings of chapter 5 have been included in a paper co-authored with Assoc. Prof. Alexakis and Senior Lecturer V. Pappas titled "Market abuse under different closing price estimation methods: A European case." SSRN (code 3481323). The paper has been submitted in the International Review of Financial Analysis (ABS3), for evaluation.

Some findings from Chapter 4 have also been presented at the 18th Annual Conference "Hellenic Finance and Accounting Association (HFAA)" as paper co-authored with Associate Professor C. Kottaridi and Senior Lecturer V. Pappas titled "Intraday stock returns patterns revisited. A day of the week and market trend approach." SSRN (code 3482450). The paper has been submitted in the Research in International Business and Finance (ABS2), for evaluation.

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1. Introduction

1.1 Thesis Motivation

The financial market is the place where buyers and sellers gather to trade securities. Traders can meet on a physical trading floor, or they can communicate through an electronic trading platform. Trades can be arranged by financial intermediaries, such as dealers and brokers, or transacted directly through the interaction of buyers and sellers without the involvement of intermediaries.

According to O'Hara (1995), whatever the setting, there are rules either explicit or implicit that govern the trading mechanisms and define the market structure. This organizational structure of trading determines traders' behaviour – what, when, where, and how they can trade – and is the origin of market liquidity and price formation. Market microstructure is thus defined as "the study of the process and outcomes of exchanging assets under the explicit trading structures used for financial securities" (O'Hara, 1995). Madhavan (2000) also describes market microstructure as the process by which investors' appetite is ultimately converted into prices and volumes. As a consequence, market microstructure is formed by market structure and trading rules.

Stock exchanges perform a range of activities with the most essential being, the trading function, i.e. providing the facility to traders to buy or sell financial instruments quickly, and the price formation, which is the process of determining the price of a financial instrument in the market. These functions play an essential role for investors because they allow them to reallocate their asset holdings and to manage their financial risks according to their personal preferences, at acceptable cost levels.

Stock exchanges conduct a range of activities that support these core functions, including (a) liquidity services—operating physical (or, nowadays, electronic) and legal infrastructure that facilitates the meeting of demand and supply; and (b) trading rules—providing a set of rules under which orders are conveyed and matched, and trades executed. These rules define and protect the property rights of market participants, provide predictability, constrain fraud and market manipulation, foster liquidity and ensure that stock exchange members—through whom trades must be executed—are sufficiently creditworthy; see O'Hara (2003).

Price formation is the procedure under which information assessment is consolidated into stock prices and is vital for the financial practitioners when they form investment portfolios and monitor transactions. When prices reflect all available information, it is said that prices are "efficient." An efficient price can be seen as expecting the true price of an instrument. When prices are efficient, nobody trading with publicly known information can make abnormal profits. This is central to the 'efficient market hypothesis' (EMH) introduced by economist Eugene Fama in 1970.

Opposite to the prediction of the EMH, many studies document calendar-related micro-structural irregularities in the movements of stock prices. These calendar anomalies can be found when stock returns form calendar patterns for certain days of the year, weeks, months, or events in the case of intraday data during different periods in a trading session. Similar patterns are also observed for the return volatility, which is not random but exhibits temporal patterns. A vast amount of studies sustained that according to the day of the week effect stock returns tend to be lower when the markets open on Mondays, and higher at the close on Fridays and that average stock price returns of Monday was higher than all other weekdays price returns (French 1980, Keim and Stambaugh 1984, Harris 1986, Agrawal and Tandon 1994, Mills and Coutts 1995). The intraday data allows exploiting the information which cannot be tracked using the data of lower frequency and allow a better approach to the financial markets' behaviour. Some well-documented empirical findings are the so-called U-shaped, reverse J-shaped, or L-shaped patterns in the intraday behaviour for stock returns. That is, returns appear to be positive, statistically significant, and the highest at the opening of the market, decline during the trading day when trading activity is lower, and rise again towards the market closure. The same intraday movements have been noticed in return volatility, accordingly. A vast number of explanations for the existence of the periodicities in the financial markets has emerged in the last years.

In this thesis, we examine for any possible statistical relationships based on intraday stock returns. According to the EMH stock returns, even intraday stock returns should not be time-dependent. The possible existence of the day of the week irregularity provides an abnormal return on a particular day of the week. Day of the week abnormality means a systematic and continuous pattern in stock market return specifying that average price returns and consequently price returns volatility of all days are different from each other. Our purpose is to provide a thorough analysis of possible intraday seasonality by examining the behaviour of intraday returns and return volatility of the General index of Athens Stock Exchange (ASE) for an extended period, and different days of the week by discriminating between "bull" and "bear" markets. Analytically, we apply a time-dependent model in a bull, bear market, and examine for possible different stock price behaviour in these two periods for every single trading day of the week.

Trying to identify the reasoning behind the U-shape in stock price returns and volatility, especially the peak at the closing price formation phase, we investigate whether the closing prices are influenced by large investors or not. Notably, the formation of the closing price is crucial, since it is used by most technical analysts for their reports and forecasts as well as by mutual funds in order to calculate the value of their units. The closing price, in particular, is a significant signal as it is used in most technical analyst reports and forecasts, as well as by institutional investors like open-end mutual funds in order to calculate the value of their units. Moreover, closing prices are used by a wide range of information users for a diverse range of purposes, e.g., third-party data vendors, index providers, listed companies, and market regulators. Therefore, the determination of closing prices is of paramount importance.

The closing price mechanism that is used by almost all major securities exchanges in the world is the closing call auction mechanism. Closing auctions aim at determining a unique and representative closing price specifically because they concentrate liquidity over a limited period of time (few minutes only). The more participants in closing auctions, the higher the liquidity, the more efficient the price and the lower the risk of manipulation. Closing auctions are well-established and widely understood mechanisms in the financial markets industry. Closing auctions benefit the market by concentrating on liquidity, reducing cost, and safeguarding the price formation process. These auctions have a fixed schedule defined by trading venues, and processes are transparent as the theoretical auction price is continuously published. Closing auctions have become focal coordination venues for liquidity seekers (Admati and Pfleiderer (1988), Spiegel and Subrahmaniam (1995))[1], they also lower execution cost and sharpen price determination (see Pagano and Schwartz (2003) on the Paris Bourse and Comerton-Forde et al. (2007) on the Singapore Stock Exchange)[2]. Studies also find that the introduction of call auctions significantly reduced day-end returns' skewness and kurtosis, suggesting less manipulation.

Thus, it is extensively considered that call auctions improve price efficiency and provide grounds for prevention of price manipulation since it produces a harmonised price imitating the interaction of buyers and sellers, and importantly permits the execution of orders at the closing price. Over the last few years, the turnover in the closing auction in the EU has increased as a percentage of the total turnover traded over the trading day. Closing auctions volumes across Europe's major trading venues have on average reached the 20% of daily average volumes in the first half of 2019, and touching a 23% in June 2019, according to Reuters[3]. Regulated Markets are also required as per MiFID II Article 48 to "have in place effective systems, procedures, and arrangements to ensure their systems are resilient" and can "ensure orderly trading under conditions of severe market stress". Regulated Markets must

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[1] Admati A., and P. Pfleiderer, 1991, *Sunshine trading and financial market equilibrium*, Review of Financial Studies, Vol. 4, pp. 443-481; Spiegel M. and A. Subrahmanyam, 1995, *On intraday risk premia*, Journal of Finance, Vol. Issue1, pp. 319-339.
[2] Pagano M. S. and R.A. Schwartz, 2003, *A closing call's impact on market quality at Euronext Paris*, Journal of Financial Economics, Vol. 68, pp. 439 – 484; Comerton-Forde C. and T.J. Putniņš, 2011, *Measuring closing price manipulation*, Journal of Financial Intermediation, vol. 20, pp. 135-158.
[3] See Reuters – "The final five minutes of trading have become the busiest time of day for stock market traders in Europe". AUGUST 18, 2019

also have arrangements in place for in the case of any failure of their trading systems.

Given the belief of the effectiveness of closing auction against manipulation, this thesis deals with that belief and whether closing auction aids closing price efficiency. According to the Market Abuse Regulation No 596/2014, two of the signals that may indicate abusive behaviour and possible market manipulation are defined as: signal "5. Orders to trade given or transactions undertaken which represent a significant proportion of the daily volume of transactions in the relevant financial instrument on the trading venue concerned, in particular when these activities lead to a significant change in the price of the financial instruments" and signal "10. Buying or selling of a financial instrument at the reference time of the trading session (e.g. opening, closing, settlement) in an effort to increase, to decrease or to maintain the reference price (e.g. opening price, closing price, settlement price) at a specific level – (usually known as marking the close)." The focus of the present thesis is upon the conjunction of these two manipulative behaviours: Transactions that represent a significant proportion of the daily volume of transactions in the most liquid financial instruments of Athens Stock Exchange (ASE) for a given period, together with the marking the close of those instruments. We use the signals mentioned above as a proxy for closing price efficiency based on the model developed by Felixson and Pelli (1999) to test possible effort from investors to determine closing prices in ASE.

1.2 Objectives, contribution and Thesis structure

This thesis tries to take a closer look at the effect of the microstructure on closing price formation mechanism. It provides evidence on how the patterns of intraday trading especially during the end of trading day, can be explained by closing price formation process. The results can be useful to national regulators, exchanges, and researchers when they structure a stock market trading interface and a compelling closing price mechanism.

In chapter 2, the analysis starts with providing the theoretical framework of market microstructure applied in this thesis and its effect both on EMH and market manipulation.

In chapter 3, a thorough analysis of the trading characteristics of the Greek Exchange is presented, in order to explain special features like the trading system, stock market indices, settlement rules, and market microstructure. To help readers better understand how the Greek stock market handles market manipulation, an extensive description of possible manipulation types and procedures is offered.

In chapter 4, the methodology design is considered, in order to reach the relevant conclusions of the statistical investigation of the intraday behavior of the General index of the Athens Stock Exchange in order to discover possible intraday patterns that can be used for trading and regulatory purposes. Such a finding should be in contrast to the prediction of the Efficient Market Hypothesis EMH, i.e., stock prices fluctuate randomly, reflecting random news arriving in the market. We expand our investigation for intraday pattern during a “bull” and a “bear” period trying to identify whether investors’ sentiment plays a role in a possible pattern formation. In addition, we examine the possibility for patterns during the different days of the week since microstructure characteristics like market making, closing call auction method or clearing and settlement of transactions may influence possible price patterns. The statistical results indicate specific return patterns. We obtained statistical evidence for a U shape pattern for stock returns and a measure of return volatility. Stock returns tend to be positive with the opening and the closing of a trading session, and this pattern is statistically stronger for specific days of the week. The return pattern formation is different for a “bull” market that follows an upward trend as compared to a “bear” market characterized by a downward trend.

The intraday pattern is an anomaly based on the documented evidence that market microstructure characteristics like information asymmetry between investors, the participation of market makers to the price formation or clearing and settlement procedures and investors’ sentiment, which is different during different market phases or financial crises, may influence trading behavior accordingly. This is one of the major outcomes of the work done in the frame of this Thesis. Several studies have examined stock market seasonality and intraday data. Nevertheless, according to our knowledge, there is not such a study that examines possible differences in patterns in different market phases or days of the week combined with investors’ sentiment. The design of this thesis is such that it can capture patterns based on investors’ sentiment (bull and bear phases) as well as microstructure characteristics (information asymmetry during the different market phases each day of the week, market-making participation, clearing-settlement schedule, short-selling restrictions).

As closing price formation and the effort of dominant investors to determine closing price can give answers on the seasonality patterns that were identified, in chapter 5 we investigate whether closing prices under different estimated methods can be affected by large investors or not. Closing prices are used as benchmarks to make effective investment decisions, as well as to advise, monitor, and validate transactions. Our research is based upon two of the signals that may indicate abusive behavior during the formation of the stock closing price as they are defined in the Market Abuse Regulation. Specifically, we examine the conjunction of transactions that represent a significant proportion of the daily volume of transactions in the most liquid stocks of the Athens Stock Exchange, together with the marking the close of those stocks. We investigate further whether the change of the closing method at the Athens Stock Exchange (ASE) had an effect on the deterrence of this behavior. Indeed, in order to achieve a more efficient price formation at closing, the Athens Stock Exchange implemented a closing call auction method. This thesis tests the effect of closing call auction method on the effort of the dominant investors to determine the closing price and how well-designed call auction matching algorithms can reduce those efforts. Then, analysis is extended in order to check how dominant's investors' trading behavior during closing auctions is affected by features like randomization of closing times and volatility interrupters. The results reveal a possible successful closing price determination by dominant investors before the implementation of the closing call auction method, which is persistent after the implementation of the closing call auction method. We obtained strong statistical evidence that even a well-designed call auction-matching algorithm with features like dissemination of projected closing price, volatility extensions, non-synchronous closing times, and a price tolerance deviation method does not prevent entirely large investors from influencing practices regarding closing price. Taking a step further, we recognize the profound effect that dominant investors may have on the "reference price" just before the Auction method commences, because this price “drives” the closing auction at the desired level.

Chapter 6 concludes by emphasizing how regulators, trading venues, or researchers in understanding the trading patterns and closing price determination strategies under various market structures can use the elements presented. Trading venues have introduced a number of mechanisms by vigorous enforcement of the law and trading rules, which include direct supervision, inspection, reporting, product design requirements, position limits settlement price rules, market halts, and closing auction methods in order to sustain stock price manipulation. The reason why most of the EU’s stock exchanges use call auction mechanism for determining closing prices of listed companies is because closing auctions theoretically contribute to making listed companies more visible and traceable at large quantities of shares, with a high degree of execution probability and reliable prices. According to findings of this thesis, a call auction mechanism should be a dynamic process and should be redesigned at relatively short periods of time, not giving time to possible manipulators to adapt and take advantage of the weaknesses of a current auction system.

2. Background on price formation process and Interaction with Market Manipulation

This chapter provides the fundamentals of the economic framework to assess the impact of stock exchange structure on the functioning of equity markets. Market microstructure literature points out the vital role that stock exchanges play in the price formation process. By contributing to better price formation, stock exchanges render to more efficient markets. This is the central idea and the key objective behind the introduction of the European Markets in Financial Instruments Directive (MiFID I) in 2007 and its revisions in 2018 by MiFID II and accompanying regulation (MiFIR), that financial markets need to improve market transparency and consequently the price formation process. According to Bailey (2005)[4], security Markets are places where traders meet to trade securities. Trading is a search process in which price, quantity, and time of the trade are key factors. Bidders and sellers try to find a counter-party to trade, and security markets are designed to reduce this counterparty search cost. The important elements that make markets work efficiently are: trading rules and the legal and institutional framework together with communication and trading technology; market efficiency as defined through asymmetric information between informed and uninformed traders; trustworthiness and creditworthiness;

In that aspect, due to the fact that there is a vast number of financial literature on market microstructure in that area, this analysis covers the price formation process and how the microstructure features affect stock return and its volatility. Then, in order to explain and understand better the results of this

[4] Roy E. Bailey (2005) The Economics of Financial Markets Cambridge University Press SECURITY MARKETS

affection, we try to identify the effect of changes on the market design like the design of closing call auction to the trustworthiness and creditworthiness of the market.

2.1 Price formation process and Market Microstructure Importance

Market microstructure is defined as the theory under which the trading of financial instruments is performed through clearly defined rules classifying the trading structure. Thus, the organizational structure of trading and the mechanisms under which trading is performed is governed by specific rules. This structure defines traders' actions meaning that their trading behavior is determined by the time, the place, and how they are going to trade, and this is actually the foundation of price formation and market liquidity, O'Hara, (1995). Madhavan (2000) defines market microstructure as "the area of finance that studies the process by which investors' latent demands are ultimately translated into prices and volumes" and exploits the role of explicitly defined market structure to illustrate how different trading algorithms affect price formation, and why prices move through a particular pattern.

Several market microstructure features affect the price formation rules, like the architectural configuration of a market, the time of news announcements, investors' sentiment and behavior, and the intraday trading patterns of major institutional investors. The securities market is the place where bidders and sellers come across to trade financial instruments. The place where traders are gathered can be either at a trading floor or through an electronic trading system. Trades can be performed through the participation of brokers and dealers or can be arranged directly by investors through the mechanisms of direct electronic access (DEA/DMA) without the intervention of dealers. According to Francioni et al. (2008), the key features that characterize markets are trading rules and the legal and institutional framework, information transparency, principal-agent issues, and correspondingly asymmetric information between informed and uninformed traders and trustworthiness and creditworthiness.

Thus, microstructure analysis has four extensive applications, all of which are a key focus of this thesis. First, it explains the importance of market structure progression. Security Markets are places where investors, brokers, and dealers gather to trade securities (e.g., Trading venues, Multilateral trading facilities - MTF's, Organized Trading Facilities-OTF's, etc.). Trading is a continuous process, under which investors try to trade with another counterparty. In this process, the time, the volume, and the price of the orders are key factors.

Secondly, information dissemination and transparency are vital for the market integrity as participants value the importance of the price formation according to the access they have upon the full information of the market.

Thirdly, access and dissemination of price information from dealers and brokers are crucial as they play an important role throughout the trading process because they trade either for their own account or for the investors' accounts. Specifically, dealers (market makers are an example) quote a bid, and an ask price simultaneously trying to profit from the spread, or get their clients' positions and then trade for them at a profit. Brokers (known as agents) insert orders under explicit instructions from their clients and trade with other counter-parties and get paid by commissions. Security markets are structured to reduce counterparty search costs. As specified by O'Hara (2003), the ability of the trading structures to match the trading needs of bidders and sellers is very crucial in identifying the competency of markets.

Fourthly, the structure of trading is very crucial for investors, company owners, and regulators since fair pricing encourages confidence and attracts market participants to trade stocks that are reasonably priced; enhance shareholder wealth, and advance liquidity and transparency eliminating market manipulation cases.

2.1.1 Architectural configuration of a stock market

The choice of the trading mechanism (e.g., a continuous limit order book market, a quote driven market, a periodic call auction, a block trading facility, or combinations of the above) is essential in order to attract the attention of institutional brokers/asset managers and broker/dealer participants to trade and provide confidence to the market. Three main characteristics describe the architectural configuration of a financial market[5]:

a. trading mechanism and corresponding systems,

b. trading algorithms under which trading is taking place, and

c. information dissemination system (pre-and-post trade transparency).

Those characteristics can be analyzed as follows:

a. Trading venues can be categorized according to their trading systems (the processes under which bid and ask orders are matched). The most common methods used by stock exchanges are quote-driven and order-

[5] For a thorough analysis of trading systems, see Harris (2003), Foucault, et al. (2013), and Armour et al. (2016).

driven systems. Both systems have a mechanism for determining prices in a way that mirrors the demand and supply for a given financial instrument. The quote driven is facilitated by dealers, which are financial intermediaries having an obligation to provide liquidity to the market by entering bid and ask orders (known as quotes) and being the counterparty to all transactions. The dealers will trade from their own inventory, or they can trade with other dealers, as well. In quote driven markets, in order for a broker to trade for better prices and larger volumes, (s) he must negotiate with a dealer and eventually will choose which dealer they will trade with. In the order-driven systems, buyers and sellers trade directly with each other. This is the prevailing system in European stock exchanges and follows specific trading rules regarding the matching process and the prices under which the buyers and sellers can trade. The fact that trading is performed unanimously and traders cannot choose their counterparty, order-driven markets involve clearinghouses; however, some exchanges use a mixture of order-driven systems called mixed or hybrid systems in which certain specialist dealers have the duty to provide liquidity and execute particular orders.

b. Trading algorithms (format) differ across different types of markets. There are two types of trading algorithms: i) Continuous markets under which trading is performed through a central limit order book arranging trades continuously as orders arrive and, ii) Call markets (periodic auctions markets) in which orders are collected for batch processing. This thesis will focus upon the continuous market platform, which is the most prevailing one to most exchanges and actually offers the opportunity for outstanding buy and sell orders to be organized based on priority and matched according to trading rules. Under both systems, order processing and trading is performed under specific rules imposed by the trading venues. Different types of orders can be used, affecting market liquidity and trade price. The limit and market orders are the most elementary types of orders that participants can route to a trading system. Upon the entrance of market orders the participant specifies the quantity to trade instantaneously at the best prevailing price in the order book; if the quantity at the best price cannot satisfy the market order completely, then the remaining quantity is executed at the next available best price in the market. Market orders are aggressive orders and considered as liquidity takers because they are executed immediately with prevailing limit orders on the other side of the order book. When a buy market order is entered into the system, the order is executed with the best available (lowest offer price) limit order on the other side of the order book. The trade is executed at the ask price, and the limit order (if the whole quantity is matched) is removed from the order book. Since the limit order has been removed from the order book, the new higher offer price is revealed as the best offer price. In continuous systems, this process happens in a near endlessly driven by algorithmic trading strategies. The best bid, best ask, are continually updating as orders are matched on the order book.

On the contrary, limit orders behave differently. Upon entrance of a limit order, the participant needs to specify the volume to trade at the best available price by setting a threshold (the limit price) at which the participant can trade. Limit orders are passive orders meaning that they supply liquidity to the market because this order is summed up to the order book since there is not a counterparty against which the order can be executed. Brokers that enter limit orders on both sides of the market (known as quotes) are called market makers. By entering quotes, market makers make a profit from their bid-ask spread. This spread is actually their reward for providing liquidity in the market. Some markets have 'designated market makers' who have the task to enter quotes on a regular basis, especially during times of extreme liquidity;

Apart from the types of orders that are specified under with the price characteristic (limit or market), a different type of conditions can also be linked to an order like:

- stop orders which are activated upon the satisfaction of the condition that the stop price reaches a specific threshold;
- Validity instructions indicating how long the order remains in the order book (Day-valid for a day only; Good-till-cancel-valid until cancellation by the broker; Good until Day- valid until an expiration date; Immediate-or-cancel- execute immediately and cancel what is left from the quantity; fill-or-kill and All- or None to be executed completely or not at all)
- At the close orders - to be traded exclusively at the closing price;
- At the open orders are traded on open prices- to be traded exclusively at the opening price)

c. Another important aspect of the trading mechanism is how the trading information is disseminated to the participants. Information systems gather, form, store, and disseminate information concerning trades, quotes, and orders. Electronic trading systems disseminate and manage existing orders. The information shaping as a result of the submission of orders and the execution of trades on a trading venue is crucial under the EU regime, and especially in MiFID II, known as pre-and post-trade transparency. Pre-trade transparency includes orders and quotes accompanied by their quantities, while post-trade transparency comprises executed prices and quantities. An important characteristic of the continuous market order book system is the level of which market participants have access to the existing orders in the order book. The continuous order book gives details about the prevailing prices and quantities of the limit orders. Market users are most interested in the limit orders defining the highest buy, and the lowest sell one, known as the best bid and offer (BBO). The difference between the best buy and sell order is the famous bid-ask spread. In EU, according to MiFID II, trading venues need to be fully transparent and have to disseminate pre- and post-trade transparency data to the public within 15 minutes of the occurrence of a transaction. In that aspect, market operators and investment firms that manage a trading venue fall under the provision of a price and volume transparency since they have to publish bid and offer prices and the depth of orders at those prices.

2.1.2 Information Transparency

Information transparency leads us to the second attribute of the importance of market microstructure, which states that a market is transparent when all information about orders, quotes, and trades is reported immediately to the public, Francioni et al. (2008). Consequently, a market is liquid when traders are able to perform transactions whenever they like without a major influence on price. Traders use orders to make public their trading appetite. As illustrated earlier in section 2, price formation is the process by which information is fused into prices, and the efficient market comes on the surface when all the information is mirrored to the securities price. However, in practice, there are costs and complications to obtaining and acting on information, so there is a trade-off between the benefit of informational efficiency and the costs of getting the information to reach that efficiency. Trading complications include adverse selection costs, portfolio holding fees, and order handling fees. These costs are tolerated by market makers and other liquidity providers, who expect a reward through their bid-ask spread and the orders provided by liquidity providers. If the costs and risks are high enough, the spread offered is extensive, and orders reflect the depth they offer. This process makes the price formation important. Therefore, price formation is the process that moves one efficient price to the next, as new information is incorporated by participants into the new price. This dynamic process makes the market move from one efficient price to the next, and the movement speed is the crucial factor of determining price formation. As the price formation process gets better, the value of its information (both pre-trade and post-trade) will increase because participants become more assured of the value of the information.

2.1.3 Efficient Market Hypothesis (EMH)

The significance of information symmetry leads us to the third feature of the importance of microstructure analysis, which is market efficiency. As depicted by the Efficient Markets Hypothesis (EMH), a market is informationally efficient if traders cannot realize extra returns by just dealing with accessible information. The EMH is related to the idea of a "random walk," which describes a price time series where all consequently price changes signify random departures from prior prices. The idea behind the random walk is that if the flow of information is unrestrained and information is instantaneously passed into the securities prices, then future prices will mirror only future's news and will not be affected by the present price changes. However, since the news is unpredictable, price changes must be random as well. Consequently, prices are fully adjusted to the existing information, and investors by acquiring a set of securities from the market will gain returns as high as those achieved by the experts, Malkiel, (2003).

According to Mulherin et al. (1991), stock exchanges should be characterized by accurate information, as reflected in the prices of the instruments traded on the exchange. When prices reflect all the available information, it is said that prices are 'efficient,' so nobody trading with publicly known information can make profits more than the fair compensation of the accompanying risk. This is central to the 'efficient market hypothesis' introduced by economist Fama in 1970 and expanded after that due to the work of Malkiel (1973), Beja (1977), Grossman and Stiglitz (1980), Lo and MacKinlay (1988), Lehmann (1990), etc. According to Fama (1970), in order for the efficiency to be achieved, the following conditions should hold:

- There are no transaction costs in trading financial instruments;
- Information is costless and available to all market participants;
- There is a consent between the market participants on the implications of available information on the financial instruments prices and their future distribution.

Fama (1970) sustains that while these conditions are sufficient, they are not necessary because market inefficiency does not automatically come from the violation of one or more of these conditions. In an efficient market, the prices of securities move randomly since they reflect the rational use of all relevant and available information.

Consistent with Le Roy (1989, 1990), in an Efficient Market, the Fair Game model holds for stock price changes:

$$E\left[P_t - \left(\frac{\overline{P_t}}{I_{t-1}}\right)\right] = 0 \text{ or } E\left(\frac{R_t}{I_{t-1}}\right) = 0 \quad (2.1)$$

where I_{t-1} is the information established as defined at time t-1, P_t is the real price at time t, $\overline{P_t}$ is the anticipated price which is based on the information established I_{t-1}, and P_t- $\overline{P_t}$ is the prediction error which is uncorrelated with variables in the information established at I_{t-1}. As Samuelson (1965) stated, all agents should earn the same expected rate of return, equal to the equilibrium return assuming a non-zero equilibrium return and that agents are risk-neutral and have constant time preferences and common probabilities. Fama (1970) suggested the following characterization of market efficiency, actually rejecting the suggestion that returns are a Fair Game, thus making the EMH a joint hypothesis:

$$X_t = \left(R_t - \left(\frac{R_t}{I_{t-1}}\right)\right) \qquad (2.2)$$

where

$$\text{E}(x_t) = \text{E}\left[R_t - \text{E}\left(\frac{R_t}{I_{t-1}}\right)\right] = 0 \quad (2.3)$$

Where x_t is the excess return at time t with respect to the equilibrium expected return projected at time t, as defined by the information I_{t-1}. Under the assumption that the equilibrium return is constant through time is crucial for empirical tests to define that returns are uncorrelated with variables identified under information I_{t-1}because, like Leroy (1989) noted, "On Fama's definition any capital market is efficient, and no empirical evidence can possibly bear the question of market efficiency."

In an informationally efficient market satisfying the above conditions, prices fully mirror all the available information. Nevertheless, in the real world, it is hard to find a market in which all the conditions, as mentioned earlier, hold concurrently; that is why the violation of them is of extensive attention to researchers of market efficiency.

2.1.3.1 Classification of EMH

As stated by Roberts (1967) and later by Fama (1970), market efficiency is classified into three forms based on the nature and absorption of the information mirrored in the stock prices. These forms can be categorized into weak, semi-strong, and strong forms of market efficiency.

1. Weak form efficiency indicates that all historical information in the markets is entirely mirrored in the stock prices, and analysis of former information is immaterial concerning the prediction of future price fluctuations. Thus, weak-form market efficiency presumes that prevailing financial instrument prices fully mirror all instruments market information, including the historical fluctuation of prices and other market-specific information like trading characteristics of exchange specialist, or trading block trading and abnormal volume records.

2. Semi-strong market efficiency expands the weak form by stating that financial instruments prices reflect all information that can is available to be

reached by everyone. It actually broadens the approach that forming of prices takes account of both currently prevailing information and previous information, meaning that this theory encompasses that the stock prices project past information and instantly adjust to the news arriving in the market. In this way, the semi-strong form EMH emphasizes the fact that security prices adjust instantaneously to the publication of all public information, and that prevailing financial instruments' prices fully reflect all available public information, which might be incorporated by the financial statements of the companies and their balance sheet structure, the quality of corporate governance, earnings projections, etc.

3. Strong form market efficiency is the extensive form of EMH covering both the weak and semi-strong form. It asserts that both private and public information is mirrored into the prices of the financial instruments. Taking under consideration this theory, the securities prices totally reflect all information, either public or private, meaning that all investors have full access to all information related to the forming of prices.

The Efficient Market Hypothesis has significant effects on firms and investors that purchase their stocks. In an efficient securities market, when information arrives, the consequent news spread so rapidly that is instantaneously mirrored into the securities prices. Thus, gaining access to that information will not help investors to earn abnormal returns. The efficient market hypothesis deals with traders that profit from knowledge acquired by gathering and processing information relevant to stock prices before other people have access to it. These informed investors try to predict consistently future returns based on a data set available to the market and gain from these predictions contrary to what the Efficient Market hypothesis has anticipated.

Therefore, price formation is the process that describes the movement from one efficient price to the next, while new information is received by traders and transferred accordingly to the stock prices. This process is dynamic, and the speed with which prices change to new values is a critical component of understanding price formation.

2.1.3.2 Anomalies on Prediction of EMH

The theory of Efficient Markets is under discussion, causing a dispute between researchers for many years now. Some researchers gave proof of strong evidence concerning EMH, and some others did not. Other researchers suggested different models to explain price behavior deviation from what the Efficient Market Hypothesis implies, like Bagehot (1971), Kyle (1985), Glosten and Milgrom (1985), Easley and O'Hara (1987), Admati and Pfleiderer (1988), Holden and Subrahmanyam (1992), Glosten (1994), and Easley et al. (1996).

However, anomalies attributed to a kind of pattern to the movement of prices, their returns thereof, and volumes that contradict the efficient market hypothesis, is evident. It is generally documented that securities markets show inefficiency at some point in time caused by price or volume anomalies, which actually lead to an expectable movement pattern in the market. These anomalies have been categorized by researchers as fundamental, technical, and calendar anomalies, depending on the theory that they are linked to, Kumar and Java (2017).

Fundamental anomalies are associated to semi-strong market efficiency since they are related to the valuation of financial information and how investors estimate them based on those evaluations. An example of this is the book-to-market ratio and how low ratios companies outpaced the companies with high book to market ratio, or the predictive power of price-earnings (P/E) under which investors earn higher returns when purchasing stocks with low price/earnings ratios, or the dividend yield of the market, and how investors receive higher rates of return from the stock market when they acquired a basket of equities with higher dividend yield and low future rates when stocks at the moment they were purchased they had low dividend yields .

Conversely, technical, and calendar anomalies can be attributed to the weak form of market efficiency. Technical analysis is the study of previous financial instruments prices and volumes in order to predict future prices and earn abnormal returns on those instruments. Consequently, an investor could foresee future price fluctuations simply by studying historical information. A well-known technical analysis technique is the one that uses a moving average or a signal like “double bottoms” in order to predict future prices and earn above-normal returns and outperform the market. Opposite to the prediction of the EMH many studies document calendar-related irregularities in the movements of stock prices. These calendar anomalies can be found when stock returns form calendar patterns for certain days of the year, weeks, months, or events in the case of intraday data during different periods in a trading session conflicting the market efficiency hypothesis. In that sense, daily investors can adjust their trading strategies in order to gain abnormal returns based on the inferred previous patterns, Harris (2003). For example, if the previous securities returns illustrate the so-called ‘weekend effect’, investors could adjust their trading strategy of selling securities on Fridays and purchasing on Mondays to take advantage of the specific pattern. Therefore, the existence of securities anomalies provides evidence for deviating from the EMH and opens the prospect of gaining abnormal returns by taking advantage of the prevailing information.

These anomalies are observed in the distribution of stock returns and the return volatility, which is not random but exhibits temporal patterns. A well-documented empirical finding and an essential scope of this thesis is the so-called U-shape pattern for intraday returns. This pattern describes the fact that mean returns exhibit distinct intraday patterns, with overall high returns and return volatilities at the beginning and the end of the trading day, and has been verified empirically for numerous periods and different markets. There also appear to be a number of day-of-the-week effects that relate to the significant variation of returns for different days of the week, also called a Monday effect. This particular effect is going to be examined later for the Greek market, and a vast number of researchers document it. For example, French (1980) documents significantly higher Monday returns and Plimsoll, et al., (2013) found that stock returns and volatilities behave differently on different days of the week. The weekend effect is indicative of the fact that returns on Friday are positive and highest while on Monday are the smallest and sometimes negative, compared to returns on other days of the week. Other calendar effects can be described as:

- Turn-of-the-month and intra-month effects: There also seem to exist patterns in returns around the turn of the month where the securities prices increase on the last trading day of the month and the first days of the following month, Lakonishok and Smidt, (1988) and Khan et al.

(2014) whereas the intra-month effect give high positive returns in the first half of the month in comparison to the second half, Vasileiou & Samitas, (2015).

- Turn-of-the-year effect/ January effect: A vast number of academics have shown that January's stock market returns show a very unusual behavior meaning that trading volumes and returns tend to be unusually high during the last week of December and the first two weeks of the year. Haugen and Lakonishok (1988), Floros (2008), Moller and Zilca (2008), and Kumar & Pathak, (2016) recognized the high January returns.

Taking into consideration the aforementioned anomalies, EMH is challenged by the existence of intraday regularities, and potentially intraday patterns that are primarily explained by the microstructure effects like specifics of information flow (i.e., information asymmetries between traders), trading mechanisms like trading and clearing mechanisms use and investors sentiments.

The literature that tries to explain these anomalies is enormous, and the next sections will try to give the more representative of it regarding the impact of microstructure effects on intraday patterns.

2.1.3.3. Seasonality explained by Information Asymmetries.

Kyle (1985) was the first one that demonstrated the importance of asymmetry information between investors. Based on Kyle model, Admati and Pfleiderer (1988), Foster and Viswanathan (1990, 1993a,b, 1994, 1996), Back and Pedersen (1998) and Wang (1998) provided the theory behind the behavior of the U-shaped patterns based on the interaction of informed, liquidity traders like institutional traders (discretionary or not) and market makers and the timing of their trading. According to the theory of asymmetric information, return, and volatility patterns arise from the access of the traders to private, public, or noise trading information regarding the assets that are invested. Liquidity traders receive overnight information about the assets and trade actively during the open of the market, while informed traders as they get access to the market during the trading process and acquire information, are more active while the closing as the market approaches to it. Their theory ended up that trading volume and return volatility follow a U shape pattern.

The presence of intraday patterns in stock returns and the related reasoning behind it, has been documented in several studies for various markets and using different sampling frequencies for the US stock market behavior to be the most prevalent one. French and Roll, (1986) and Lockwood and Linn, (1990) supported the existence of a U-shaped pattern in the intraday stock price movement in US stock markets while McInish, Wood, and Ord, (1985) using 15-minute return NYSE, found that intraday returns broadly follow a U-shaped pattern as return and return volatility are higher at the open and close of trading and lower in the middle of the day. Harris (1986), reported significant positive returns at the opening and closing of NYSE for all days except Mondays, and Terry (1986) reported a significant last hour return of the Dow Jones 30, which is more apparent on Friday. Jain and Joh (1988) also found a U-shaped intraday return and return volatility pattern on the NYSE stock trading. Ozenbas, Schwartz, and Wood (2002) have examined stock price volatility for five markets: the NYSE, Euronext Paris, Nasdaq, Deutsche

Borse, and the London Stock Exchange and found a U-shaped intraday volatility pattern which was attributed to spreads, price discovery, market impact and momentum trading. Heston, Korajczyk, and, Sadka (2010) examined the intraday patterns in the cross-section of NYSE stock returns and found, on the one hand, a continuation pattern of returns at half-hour intervals that are exact multiples of a trading day while on the other hand bid-ask spreads, volume, and volatility exhibit similar patterns, but do not explain the return patterns. Bollerslev et al. (2013) further showed dependencies in S&P500 returns, realized volatility, and options implied volatility and that the variable risk premium results in return predictability over inter–daily and monthly horizons. Finally, Pagano et al. (2013) found that the volatility of NASDAQ follows "a relatively flat U-shape with large jumps in the first and last five minutes of trading."

In addition to the US Market, some studies showed that the anomaly seems to exist in several national stock markets. For example, Aitken, Brown and, Walter (1996) established that an 'end of the day' anomaly is evidenced in Australia and that the size of the anomaly depends on firm size and trading frequency. In addition, Brockman and Chung (1998) studied intra-day bid-ask spreads of the Hong Kong Stock Exchange (SEHK) and found that they follow a U-shaped pattern and Bildik (2001) examined intra-daily seasonalities of the Istanbul Stock Exchange and showed that stock returns and volatility follow a U-shaped and an L-shaped pattern respectively. Harju and Hussain (2006) found a reverse J-shaped pattern of the return volatility when they examined four European stock market indices, CAC 40, XDAX 30, FTSE 100, and SMI. Kucukkocaoğlu (2008) documented that the day-end closing returns are significant and positive and that stock prices systematically rise towards the closing minute for the Istanbul Stock Exchange (ISE). Hussain (2011) argues that the stocks of the German blue-chip index, namely XDAX 30, display the reverse J-shaped pattern while the aggregate trading volume follows the L-shaped pattern. Tian and Guo (2007) reported an L-shaped pattern for the return volatilities of the Shanghai Composite Stock Index. Karmakar and Paul (2016) used data set from sixteen high-frequency stock price indices across Europe, US, Asia, Australia, Latin America, and Africa and found that volatility is higher at the opening and towards the closing of the trading session and lower during midday. Padhi (2010) and Arora (2017) explored intraday seasonality of the NIFTY 50 index, India's stock market index, and found significant results for Monday and Friday's return. Calendar anomalies and especially day of the week effect was also confirmed by Seif et al. (2017).

2.1.3.4. Seasonality explained by Market Structure.

Apart from the information imbalances, the institutional setup and trading characteristics of a stock market can be an essential factor in explaining possible return regularities. As depicted earlier, market structure and price discovery depend on the environment within which investors are operating. The implicit assumption in standard pricing theories that the specific institutional market structure does not affect security prices is challenged by the growing market microstructure literature, which focuses on the specific possible effects of the markets` institutional structure on the price formation process. The analysis also explicitly takes into account the behavior of specific types of market participants: institutional investors, nonprofessional investors, specialists, dealers, and speculators. What matters in respect of the microstructure perspective are those issues that deal with the actions of market makers, the role of regulated specialists, how the market's structure affects trading and consequently stock prices, and how the trading system's overall performance affects investors. (Cohen, Maier, Schwartz, and Whitcomb, 1986).

Considering the behavior of specific market participants like Market Makers, Brock and Kleidon (1992) gave another theoretical explanation on the reasons for the existence of seasonality in a trading day. This was the existence of liquidity providers trying to identify the liquidity demand at the start of the day. The authors stated that what drives the seasonality in trading sessions is, on the one hand, the inelastic demand of investors, and on the other hand, the monopoly power of market makers and their intention to have the desired position at the open and close of the trading day. Their model indicates that the willingness to trade at the opening and closing in order to rebalance the portfolio can lead to a U-shaped pattern for volume and spread since higher volume towards the end of the trading day reflects the trader's appetite to unwind positions acquired during the trading day. Abhyankar et al. (1997) tested the model of Brock and Kleidon investigating the regularities of intraday behavior on London Stock Exchange and showed that participation of market makers drive intraday spreads and volatility at the highest levels at the market open, stay relatively constant during the day and become larger again at the close.

Another microstructure approach that emerged explaining the positive returns at the end of the trading period and especially the closing price formation is the so-called "end of the day" effect, where the closing price is higher than the prices configured during the trading day. As Harris (1989) observed, closing prices are the most important ones among all the stock price transactions observed during the trading day. The formation of the closing price is critical since it is used by regulators, market operators, most technical analysts for their reports and forecasts as well as by mutual funds in order to calculate the value of their units, trading and clearing participants, post-trade facilities, listed companies, data vendors, and index providers. Given the fact that the closing price of a stock is a widely used stock market indicator, it would be of significant interest in case of possible market manipulation.

The new EU law regarding market manipulation[6] takes a particular interest in those trading behaviors that involved the trader tries to create patterns and arrange his trades to change other traders' opinions. This contradicts the idea of efficient markets and is illegal in the EU, the US, and many other developed countries. There are various reasons why people manipulate closing prices: Fund managers who want to increase fund performance and net asset values (NAV); Brokers profiting from positions in derivatives on the underlying stocks/indices; corporate decision managers who use stock price reactions to inform on whether to proceed with proposed mergers or to inform on decisions about the optimal level of product differentiation. With these apparent incentives, the persons mentioned above might be tempted to manipulate closing prices (Comerton-Forde & Putninš, 2011). The closing price mechanism that is used by almost all major securities exchanges in the world is the closing call auction mechanism since it uses a transparent mechanism that takes under consideration the interaction of bid and ask prices, and generates a consensus price. Over the last few years, the turnover in the closing auction in the EU has increased as a percentage of the

[6] EU Market Abuse Regulation (596/2014)

total turnover traded over the trading day, concentrating the bulk of trading into the last few minutes of the trading session (Reuters 2019).

A market structure characteristic that influences closing price might be the presence of short sellers (as one-day traders) who, according to Miller (1989) they try to close out their positions at the end of the day in order not to become insolvent at the settlement. Therefore, stocks sold short needed to be traded at the end of the day to close out the position driving the closing price up at the end of the day.

Another explanation based on microstructure theory linked to the market structure can be found in the security settlement cycle procedures. The settlement cycle procedure has to do with the period between the final transaction and final delivery (receiving) of the stock title and the relevant cash compensation since the period settlement affects the day of the week anomaly pattern of the stock market, Patel and Mallikarjun (2014).

2.1.3.5. Seasonality explained by Investors Sentiment.

Apart from microstructure characteristics, investors' sentiment, or in other words, investors' psychology, can be another source of the observed intraday causing the seasonality effect phenomenon. The behavioral finance science attempts to give answers in the way that emotions and errors of predictions affect investors' decisions. According to the EMH, investors are rational, in the sense that they behave according to the projections of the economic theory, and sentiments like optimism or pessimism do not influence them. In periods of financial crises, where the prices fall harshly, the investors are swamped by panic and make irrational decisions. On the other hand, there are periods that the prices rise continuously, and the investors behave more optimistically related to the events than expected. As a result, the overreaction of the investors to the new information on the market is not consistent with EMH. Pieces of research have proved that individuals maintain their initial beliefs and take consecutive and irrational decisions. As a result, they over or underreact to the arrival of new information. Following this anomaly, a lot of financial crises have occurred, and there are shreds of evidence for the failure of market efficiency. Nevertheless, this rationality assumption has been significantly challenged, especially during the last fifteen to twenty years, with the development of the behavioral approach to finance.

An essential aspect of behavioral finance is how less sophisticated investors, known as “noise” investors as defined by Black (1986), exploit the information about asset pricing. Noise investors are small retail investors, economic illiterate, that base their investment decisions upon emotions and rumors and not upon macro or micro fundamentals about these assets. According to De Long et al. (1990), noise traders create a risk of a spill-over effect (overreaction) for a bullish behavior over consistent days that must be borne by rational investors. Because rational investors, who is risk-averse, bear the risk of the unpredictable behavior of the noise traders, which cause asymmetry pricing and, therefore, higher risk for their investment, they demand a risk premium to trade these assets and are reluctant to enter the market under stressful periods. There is a connection between returns, volatility, and noise trading activity, in a sense that increased asymmetry pricing caused by noise trading activity increases the return volatility as well as accompanying returns due to the fact that rational investors do not absorb the asymmetry. (Campbell & Kyle, 1993).

In a recent paper by Renault (2017) concerning the role of investor sentiment in predicting intraday stock returns, he explored the relation between online investor sentiment and intraday S&P 500 index ETF returns. According to the evidence presented, the first half-hour change in investor sentiment predicts the last half-hour return but also, the short- term sentiment-driven price pressure is followed by a price reversal on the next trading day, something which is consistent with the presence of a non-rational type of investors (noise traders) in the market. Rupande et al. (2019) showed that investor sentiment and stock return volatility are connected and that the behavioral finance can significantly explain the behavior of stock returns on the Johannesburg Stock Exchange. Also, Sun et al. (2016) examined the predictability of intraday market return for the S&P 500 with changes in high-frequency investor sentiment and found strong evidence that changes in investor sentiment have predictive values for the intraday market returns, especially during the last two hours. They also showed that the sentiment-driven return predictability appears to come from noise trading since that predictability is much stronger during economic expansions and high trading volume days. In contrast, predictability is weaker during economic recessions and mostly dissipates during low trading volume days. A reasonable assumption here is that noise traders' participation in the market increases when investor optimism is rising, since noise traders' "trade more aggressively in high-sentiment periods" (Yu and Yuan 2011). Thus, noise traders invest in the market, causing asymmetry pricing, more in high sentiment periods than in low sentiment periods when a pessimistic view is prevailing and consequently, these traders are reluctant to take on positions in their portfolios (Shen et al. 2017 and Antoniou et al. 2015)[7]. This leads to overpriced stocks during a high-sentiment period and more rational pricing during low sentiment periods because rational investors are more moderate when there are obstacles in short selling (Diether et al., 2009, Hirshleifer et al. 2011, and Stambaugh et al. 2012)[8].

Empirical research on bullish or bearish sentiment periods proved the implication between stock pricing and investor sentiment. Concerning the U.S. market, Abdelhédi-Zouch, Abbes, and Boujelbène (2015) investigated the subprime financial crisis in the U.S. as a period characterized by high sentiment, and found that "investor sentiment plays a determinant role in the spillover of volatility to returns during the subprime crisis, implying high volatility of returns." Uygur and Taş (2014) found that sentiment affects conditional volatility in the U.S., Japan, Hong Kong, U.K., France, Germany, and Turkey financial markets when sentiment is high. Chuang, Ouyang, and Lo (2010) showed that investors' sentiment in Taiwan Stock Exchange is affected by market volatility changes during upward (bullish) sentiment periods since volume and volatility rise all together and that this is an indication of noise trading in high sentiment periods.

2.2. Price formation Process and Market Manipulation

In its fourth application, there is strong evidence that market structure has an effect on the trustworthiness and creditworthiness of the markets. It is widely recognized that stock market prices can be manipulated so that some

[7] See also, for example, Barberis et al. (1998), Brown and Cliff (2005), Baker and Wurgler (2006), Kumar and Lee (2006), Kaniel et al. (2008), Baker et al. (2012), Stambaugh et al. (2012)
[8] For short-sale constraints see also, Ofek et al. (2004), Boehmer et al., (2013) and Engelberg et al. (2018)

groups of investors may benefit at the expense of others. Stock price manipulation can take many forms and is the prime reason for stock market authorities to operate market surveillance departments since fighting market manipulation improves confidence, liquidity, and fairness of markets. Accordingly, authorities need to have adequate systems and procedures in place to detect, investigate, and prosecute market manipulators, IOSCO (2000). Additionally, trading venues have responsibilities to maintain orderly markets and prevent manipulation by imposing strict rules in their Rulebook, promoting confidence and efficiency in their markets.

While it is a common knowledge that market manipulation harms the effectiveness of the markets, new methods, and opportunities for developing new manipulative technics continue to evolve. The risk of manipulation continuously increases due to the growth of trading in global markets. Exchanges monitor the trading process and develop new trading structures in order to reduce manipulation instances. This is why microstructure analysis is quite useful to analysts, stock exchanges, and supervisors.

The recent E.U. Law for Market Abuse was designed to improve the confidence and integrity of the European financial market and promote greater cross-border cooperation. Going a step further, infringements on insider trading and market manipulation were identified, and obligations were imposed on companies to disclose information. The general objective of the anti-abuse Laws is to eliminate information asymmetries, which harms price determination and which can lead even to market failure. No matter the form, successful market manipulation distorts, even temporarily, a security's price, making deviate from its fundamental value. The overall aim of the manipulators is to drive the price in the direction beneficial to them after liquidating their holdings or cover their short positions at a price better than the efficient implicit price in full-information equilibrium. The existing microstructure literature on market manipulation focuses mainly on modeling multiple forms of manipulation, while different modeling frameworks result in different predictions.

Price formation is unique to financial markets. This unique element gives rise to an important function of a stock exchange, which is an information-gathering process that ensures that market participants are sufficiently informed about the prices of the assets. This is a central ingredient to the well-functioning of financial markets. But price formation is important not only for those who participate in the stock exchange directly but also for the financial professionals who use stock prices to make effective investment decisions, as well as to monitor, advise and validate transactions after they are executed. The applications that the prices produced on stock exchanges can be used are:

(1) marking to market (portfolio valuation by fund managers); (2) derivative pricing (many derivative and structured products like equity options, equity futures, equity exchange-traded funds, equity swaps, warrants use stocks as underlying's. Therefore, the pricing of the derivatives depends directly on the accuracy of underlying stock prices; (3) indices—index providers, use the prices to calculate and update indices; (4) valuation of mutual fund cash flows; (5) valuation of private companies or estates—one of the most commonly used approaches to valuing private or non-traded assets in corporate finance relies (directly, or indirectly) on the prices of comparable firms traded on stock exchanges; (6) corporate decision-making—managers use stock price reactions to inform on whether to proceed with proposed

mergers or to inform on decisions about the optimal level of product differentiation; (7) Manage clearinghouse risk - The primary purpose of margining participants is to manage clearing house risks. In practice, these risks are concentrated in large capitalisation stocks, so the focus of the settlement price policy is on ensuring the best possible pricing of these securities in the most efficient, transparent, and easy to calculate method.

Investors and trader's decisions about where to trade clearly value fairness in trading, confidence that their trades are executed at prices close to the fundamental prices, and that market professionals do not engage in insider trading, front running, or market manipulation. The set of rules and monitoring activities of the stock exchange facilitate the fair treatment of order flows and reliable price formation, supporting market fairness. Examples include the clearly defined rules about the matching process of the orders and the closing auction algorithms, the rules, and monitoring activities preventing manipulative behaviors. The importance of reliable price formation to market fairness is widely recognized by regulators. For example, according to the Objectives and Principles of Securities Regulation of the International Organization of Securities Commission: Regulation should promote market practices that ensure fair treatment of orders and a price formation process that is reliable. (International Organization of Securities Commissions-IOSCO) (2003)[9].

Following the 2008 global financial crisis, transparency, efficiency, and fairness within financial markets have received renewed attention. The regulatory response aimed at promoting transparency as a core principle of

[9] See Oxera (2019) The design of equity trading markets in Europe An economic analysis of price formation and market data services Prepared for Federation of European Securities Exchanges March 2019

the financial markets' regulatory framework. Regulation against market manipulation is based on the principle that it is illegal to perform trading on securities to deliberately affect the market price or other conditions of the security (e.g., volume) in an undue way, or give misleading information to buyers or sellers of securities in any way. Even though market manipulation might have been more severe in the early years of financial markets, it is still of great interest since market manipulation has become more intense with the growing volume of transactions and an increased number of participants. In this aspect, the implementation of the Market Abuse Directive (MAD) at 2003, replaced by the Market Abuse Regulation (MAR) and the Directive on Criminal Sanctions for Market Abuse known as CSMAD or MAD II at 2016, as an E.U. market abuse regime with the general objective to eliminate information asymmetries, came on the surface. The general term of market abuse was divided into terms of insider trading and market manipulation. Both these forms of market abuse mainly rely upon information asymmetries that can be profitable for some market participants and source of losses for others. Trading as an insider means the use of information that is only available to the insider, who is taking advantage of it in order to make a profit at the expense of the other, less informed market participants. By contrast, stock market manipulation exists in a wide variety of forms, namely, quote stuffing, wash trades, layering, spoofing, painting the tape, improperly matched orders, trash and cash, momentum ignition, advancing the bid, front running to name but a few.

In this thesis, we focus on the second case of stock market manipulation. Research on stock market manipulation can be categorized into two major strands. One strand is based on theoretical models explaining market manipulation; another strand is based on prosecuted case studies or econometric models, which empirically investigate if the manipulation has taken place. We review both strands next.

2.2.1 Theoretical studies on manipulation

Allen and Gale (1992) built a theoretical model and divided manipulation into three different types: information-based, action-based, and trade-based. Information-based manipulation refers to the release and spreading of rumors and false information about stocks. Action-based manipulation is carried out through actions other than trading that change the actual or observable value of the assets. Trade-based manipulation has to do with information asymmetry. A trader can manipulate a stock profitably simply by placing bid and ask orders, thus creating uncertainty on whether they buy or sell shares because they are undervalued or because they try to manipulate the share price. In this way, trade-based manipulators arrange their trades accordingly in order to create stock price patterns and change other traders' opinions.

The model proposed by Jarrow (1992) recognizes that large traders are better suited to engage in stock manipulation due to the large volume of trading they engage in and that such strategies may reward them with virtually riskless positive returns. Van Bommel (2003) built a model on information-based manipulation, in which traders that spread rumors increase their profits at the expense of uninformed liquidity traders. Hillion and Suominen (2004) presented an agency-based model of closing price manipulation, where a broker acts as a manipulator in order to give a good impression of his execution quality to his customer.

2.2.2 Empirical Studies on manipulation

Regarding prosecuted cases, Aggarwal and Wu (2006) proposed a theory related to trade-based manipulation, extending the framework of Allen and Gale (1992), examining the interaction between manipulators and other traders. They analyzed more than one hundred cases of manipulation discovered during the '90s by the U.S. regulation authority SEC. They argue that stock market manipulation may have an essential impact on market efficiency since informed investors and market makers are likely to act as manipulators. Also, they argued that illiquid stocks are more susceptible to manipulation. Based on Aggarwal and Wu's methodology, Aktaş and Doğanay (2006) built a data set from prosecuted manipulation cases of the Istanbul Stock Exchange and found that through trade-based manipulation, the manipulators could obtain wealth at the expense of other traders. Comerton-Forde & Putniņš (2011, 2013), using a sample of actual closing price manipulation cases from U.S. and Canadian stock markets, empirically demonstrated that due to manipulation, returns, spreads and trading activity at the end of the day, as well as price reversions the following morning, all increased significantly. Huang and Cheng (2013), collected data on prosecuted cases of manipulation of the Taiwan stock markets, and showed that manipulated firms had indicated increased volatility, large trading volumes, and, are the worst off regarding market efficiency during the post-manipulation period. Gerace et al. (2014) empirically examined stock market manipulation on the Hong Kong Stock Exchange through forty (40) cases of market manipulation from 1996 to 2009 that were successfully prosecuted by the Hong Kong Securities & Futures Commission. Manipulation was found to affect bid-ask spread and volatility negatively, and that Markets were characterized by information asymmetry due to manipulation. Also, manipulators achieved to raise the prices and successfully exit the market. Shah et al. (2019) investigated the firm's specific characteristics of manipulated firms in East Asian emerging and developed markets using manipulation cases between 2001 and 2017. Their results showed that liquid firms with large capitalization and high levels of free float in both emerging and developed markets were more likely to be manipulated.

Some empirical studies departed from examining cases on stock market manipulation and used quantitative model solutions like Kong and Wang (2014), who studied manipulation for listed shares in China (Shanghai and Shenzhen stock markets) and reported a particular increase in volatility, stock prices, and market activity during the possible manipulation period. In addition, Chaturvedula et al. (2015) found front running effect of bulk trade in India over the period 2004–2012.

On the side of the researchers that used end-clients' or brokers' unique data as identification in order to study their investment appetite were Felixon & Pelli (1999), who examined the closing-price manipulation of the Finnish stock market. Their methodology was based on a regression model to test for closing price manipulation by using a traders group for every single day. They studied whether those traders could manipulate closing prices by examining who buys (sells) a large sum of shares on a daily basis.

The following models (I and II) were used in order to measure the buyer and seller side for possible manipulation. If prices are manipulated, then the return for the stock for the period before the close is equal to the normal return plus the effect of manipulation and a noise term,

$$\text{Return}_{i,c-t} = \text{Normal return}_{i,c-t} + \text{manipulation effect}_{i,c-t} + e_{i,c-t}. \qquad \text{(I)}$$

For the period after the close, it is equal to the normal return plus the reversal effect of the manipulation, (Figure 2.1)

$$\text{Return}_{i,c+d} = \text{Normal return}_{i,c+d} + \text{reversal effect}_{i,c+d} + e_{i,c+d}, \qquad \text{(II)}$$

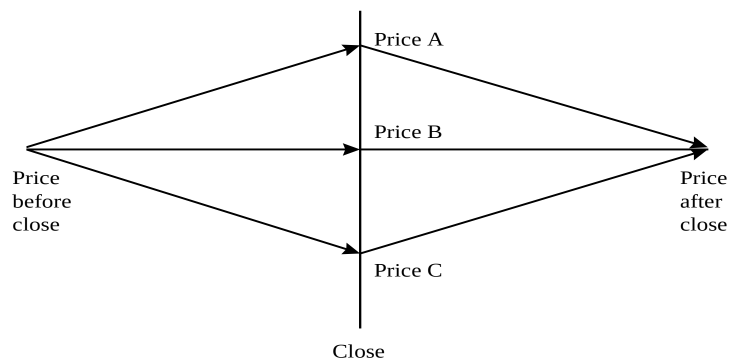


Figure 2.1: Price behavior before and after the close

Their model, as depicted in Figure 2.1, considers that a significant stock purchaser and a significant stock supplier of every particular trading day may be at the manipulative side of the equations in the following sense. A stock purchaser (supplier) will try to drive and manipulate the closing price at a higher (lower) level than the reference price (i.e., the price just before the closing price) in order to increase his daily performance. The next day's morning opening price will return to its normal value, freely of the previous day manipulation. Their results seemed to be in line with their hypothesis for the pre-closing period but with very weak evidence for the after closing period. Kucukkocaoğlu (2008) and Kadioglu, Kucukkocaoğlu and Kılıç (2015) adjusted the model developed by Felixson and Pelli (1999) to test for closing price manipulation in the Borsa Istanbul, and their findings show the existence of closing price manipulation and that the implementation of closing call auction sessions significantly eliminated closing price manipulation. The same results were found in a most recent research by Saputra and Prijadi (2017) concerning the existence of closing price manipulation in Indonesia stock market and the reduction of closing price manipulation after the introduction of a pre-closing auction. Finally, Khwaja and Mian (2005) investigated the own brokerage trades on Pakistan's stock exchange and identified characteristics of stock-price manipulation by collusive brokers.

2.2.3 Closing Auction Studies

Based on the evidence of stock price manipulation, academic researchers, policymakers, and regulators focused on designing efficient mechanisms to deter market manipulation, like different closing methods as a tool to end–up with the most representative closing price. Closing call auction is one of the methods used as a good mechanism in order to avoid price manipulation. Here we note again that there are various strong incentives why investors may manipulate closing prices. For example, fund managers who want to signal good fund performance and high net asset values (NAV); brokers profiting from positions in derivatives on the underlying stocks; valuators wanting to value private or non-traded assets as these are compared to companies traded on stock exchanges; corporate managers who use stock price fluctuations as a signal for proposed corporate actions like mergers. With the incentives as mentioned above, certain market participants might be tempted to manipulate closing prices, Comerton, Forde, and Putninš, (2011).

Most of the studies conclude that the closing auction mechanisms increase liquidity, price discovery, and at the same time, decrease price volatility, and the probability of price manipulation. The reason behind this is that a closing call auction mechanism is believed to improve price discovery, and makes price manipulation costly and hard to perform. This is because auctions are “particularly beneficial when the market is stressed by extreme liquidity shocks” (Barclay et al., 2008). Concerning the introduction of a closing call auction at the Paris Bourse, Pagano and Schwartz (2003), confirmed that led to more efficient closing prices and Hillion and Suominen (2004), showed that it reduced manipulation and closing prices became a better representation of the fair value of the traded assets. Pagano and Schwartz (2005), and Pagano et al. (2013) focused on NASDAQ’s closing call auctions, which were introduced in 2004 and found much more efficient pricing after their introduction. Comerton-Forde and Rydge (2006) indicated that“…manipulation has a significant impact on call auction prices, with some algorithm designs more effective than others at reducing the impact of manipulation.” Comerton – Forde et al. (2007) examined the introduction of a closing call auction at the Singapore Exchange and found a significant improvement of the market quality since order aggressiveness at the close was reduced and hence reduced possible manipulation. Kandel et al. (2012) studied the effects of the introduction of a closing auction in Borsa Italiana and Paris Bourse and found a dramatic effect during the last minutes with a sharp decline in volume, spreads, and volatility. Pinfold and Danyang (2012) used the methodology of Pagano and Schwartz (2003), for the periods before and after the introduction of the closing call auction in the New Zealand Stock Exchange and found that closing auction reduced the prevalence of market manipulation. Huang and Chan (2014) proved that the change of the closing mechanism to a five-minute call auction in the Taiwan Stock Exchange in 2002, improved the fairness of the closing price since that change made it more costly and hard to influence closing prices. Finally, Cordi et al. (2018), examined the change of closing mechanism in a comprehensive sample of 43 exchanges around the world for stocks with different levels of liquidity and found that call auctions, significantly improved price efficiency.

Despite the belief about the usefulness of closing auctions against manipulation, some research studies give opposite results. Aitken et al. (2005), found that the introduction of closing call auction in the Australian Stock Exchange caused an increase in volume probably due to the increased activity by arbitrage traders and passive index fund managers trying to achieve the closing price but no significant effect on bid-ask spreads at the end of the trading day concluding that “this suggests that the closing call auction provides a mechanism for consolidating liquidity and allowing investors to achieve the closing price without any adverse influence on the cost of trading during the continuous trading period.” A study at the National Stock Exchange of India by Camilleri and Green (2009), concerning the impact of the suspension of the opening and closing call auction, showed that the suspension improved liquidity, price discovery, and volatility in less liquid stocks. Comerton–Forde, and Rydge, (2006), ended up in the same conclusion regarding the deterrence effect of the auction mechanism to the manipulation of illiquid stocks. Suen and Wan (2013), and Park et al. (2018), similarly studied the suspension of a call auction at the Hong Kong Stock Exchange and challenged the call auction’s ability to deter price manipulation since they conclude that closing prices are more vulnerable to manipulation under a “plain vanilla” call auction mechanism, i.e., a call auction without any manipulation-deterrence features.

2.2.4 Call Auction Design Studies

The literature examining the effects of different mechanisms of call auction used in stock markets and its impact upon closing price manipulation is quite limited. Many choices could be made by trading venues which define the auction mechanism since there are four parameters that can have effect on the design of auction mechanisms: a) ability to modify/cancel orders within the auction period, b) randomization of the auction time, c) use of volatility interruption systems and d) dissemination of the projected closing auction price and the full order book, Domowitz, and Madhavan (2001). Although E.U. trading venues began getting familiar with closing auctions since the early '00s, they did not use the same characteristics and mechanisms characterizing their structure. For example, in U.K. (London Stock Exchange) closing price is determined by a closing auction unless there is no trade during the auction or the volume is not representative of the twelve prior month volume, for these cases a ten (10) minute VWAP is chosen as a closing price. In Germany, for the Deutsche Bourse, a five (5) minute auction phase determines the closing price unless the case that the price exceeds a threshold (dynamic-static tolerance percentage); then, the auction is extended for another two (2) minutes. In the Nordic exchanges of OMX and Oslo Bourse, a closing auction of 5-minutes is performed and can be extended if a dynamic or static limit is breached. In Euronext, a closing auction is performed as well. In Poland for the WARSAW Stock Exchange, a 10-minute closing auction is performed, and in case that dynamic or static limits are breached, then the Chairman of the exchange can define a new dynamic limit or appoint the last price or the previous close as the closing price. Comerton-Forde and Rydge (2006), claim that certain algorithm designs are more effective at reducing the impact of closing price manipulation and that alternate call auction design features, such as transparency features and volatility extensions that allow investors to reevaluate their strategy when there is a price shock, may be necessary to reduce closing price manipulation. Similarly, Camilleri and Green (2009), stated that even small changes within a specific auction mechanism might have compelling effects.

The ability to allow participants to freely submit, modify or cancel orders during auctions has been empirically documented, by Biais et al. (1999), who argued that this ability affect the price discovery process of the pre-open phase in Paris Bourse since as the market gets closer to the auction phase market manipulation and price volatility is reduced. In the same line, Domowitz and Madhavan (2001), stated that in Paris, too much transparency during the auction makes traders unwilling to insert orders before the auction, suggesting manipulative behavior because of less liquidity and increasing of price volatility. They conclude that there is no auction method that “is best” for all markets and that transparency and participation of Market Makers are the most critical aspects of the pre-call phase.

Arbitrary closing auction time improves price reliability and helps the trading venues to combat price manipulation since the uncertainty of the exact auction time makes manipulation more costly for investors who act mainly in the last seconds of the trading session. As Malaga et al. (2010) argued, the insertion of the random auction price, in which bidders do not know precisely the auction time, increases execution risk for bidders acting at the close of the market and leads to better price discovery and lower volatility, hence lead to a lower level of manipulation.

Many E.U. markets have implemented volatility interruption systems during the closing auction mechanism. These systems include (a) volatility extensions, which extend the duration of the auction period if the projected closing price exceeds a specific threshold, and (b) price volatility bands (dynamic and static), which allows the closing price to fluctuate between pre-defined thresholds. Felez-Vinas and Hagstromer (2017), empirically studied volatility interruptions in the closing call auction of NASDAQ OMX Stockholm. They found that the volatility extension improves market integrity at the end of the trading day and that the incidence of extraordinary closing price volatility at the market, measured in accordance to the volatility bands, is reduced by about 40% for small-cap stocks while for the mid-cap and large-cap stocks, there is virtually no extraordinary closing price volatility, neither before nor after the event of introducing volatility interruptions.

Continuous dissemination of the projected closing auction price and the full order book is the last auction characteristic under consideration or else transparency measure throughout the pre-close period. In a recent research by Cordi N. et al. (2018), they investigated the change in closing mechanism to a closing auction of 43 exchanges around the world. Their results suggest that randomized closing times provide significant improvements to closing price efficiency and consistently traders' ability to manipulate the close. As far as the flexibility to enter and cancel orders is concerned, they found that it deteriorates liquidity, volatility, and market integrity but improves price discovery. Transparency of the indicative closing price harms all measures of efficiency but reduces manipulation, and the use of stabilization systems improves market integrity, although they do not have a significant impact on closing price efficiency. Finally, Park et al. (2018), found no evidence of manipulation when the Hong Kong Stock exchange introduced manipulation-deterrence features, such as random closing time, and biding price limit. The impact that the introduction of auction mechanisms with different design features has on market quality for liquid stocks remains an empirical question, and this thesis deals with that.

3. The Institutional Set Up of the Athens Stock Exchange (ASE)

The institutional setup and trading characteristics of a stock market can be an essential factor in explaining return regularities. It is vital at this point to give a brief description of the functions of the Greek Stock Market[10].

Athens Exchange SA (ATHEX) has the authority to manage and operate the organized market and the Multilateral Trading Facility (MTF). The instruments that are traded in Athens Exchange are Stocks, Rights, Securities Trading Certificates, Greek Depository Receipts, genuine Share Receipts, Exchange Trading Funds, Structured Products, and Derivatives Products.

The trading of financial instruments on the Athens Stock Exchange (ASE) is performed on an electronic order-driven system called OASIS, with Market Makers participation based on ATHEX's Rule Book.

By the end of the first half of 2019, ASE had 192 listed instruments with a combined total market capitalization of 59,372 million Euros and 67 million Euros Average Trading Value- A.D.T.V/ (see Table 3.1 below for a breakdown of trading activity and Capitalization from 2014 onwards).

Table 3.1

ATHEX Markets Detail Trading Statistics

Breakdown of Trading Activity & Capitalization

[10] For a thorough analysis of the trading structure of ASE see ATHEX Rulebook

	Market Capitalization (€ bn.; end of period data)						Average Daily Trade Value (€ mil.)					
Year	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**
Jan	***47.2***	**58.6**	**42.4**	**40.5**	**43.3**	**66.8**	***37.9***	**76.4**	**39.9**	**74.8**	**107.1**	**102.6**
Feb	***50.3***	**56.6**	**44.5**	**37.4**	**51.6**	**73.8**	***44.3***	**65.1**	**43.5**	**60.7**	**155.4**	**88.6**
Mar	***51.6***	**54.4**	**46**	**41.4**	**45.4**	**75.2**	***57.1***	**73.7**	**41.4**	**80.1**	**89.3**	**132.7**
Apr	***53.8***	**58.1**	**47.9**	**42**	**48.1**	**71.1**	***62***	**61.4**	**44.8**	**58.2**	**78**	**161.5**
May	***56***	**52.7**	**51.9**	**46.2**	**49.4**	**76.9**	***111***	**81.1**	**101.2**	**103.1**	**84.2**	**232.9**
Jun	***59.4***	**52.5**	**54.4**	**39.1**	**48**	**76**	***86.3***	**49.4**	**78.9**	**79.3**	**97.3**	**179**
Jul	***0***	**53.5**	**53.8**	**40.7**	**0**	**72.6**	***0***	**25**	**78.4**	**41**	**0**	**101.3**
Aug	***0***	**51.8**	**55.2**	**41.4**	**36.2**	**72.9**	***0***	**36.4**	**41**	**38.5**	**43**	**99.5**
Sep	***0***	**49.9**	**51.5**	**40.3**	**37.4**	**66.9**	***0***	**50.9**	**72.6**	**37.5**	**30.1**	**99.8**
Oct	***0***	**46.2**	**51.9**	**41.7**	**40.6**	**58.1**	***0***	**47.4**	**41.5**	**45.6**	**37.2**	**143**
Nov	***0***	**45.8**	**50.5**	**44.3**	**36**	**59.8**	***0***	**60.7**	**50.8**	**55.1**	**43.5**	**82.4**
Dec	***0***	**45**	**54.2**	**45.2**	**46.8**	**53**	***0***	**42.1**	**71.2**	**57.4**	**187.7**	**102.7**
Average Year	***53.05***	***52.09***	***50.35***	***41.68***	***40.23***	***68.59***	***66.43***	***55.80***	***58.77***	***60.94***	***79.40***	***127.17***

In addition, ASE is ranked in the 12th place of the Eurozone regarding its total turnover for the years 2016 until 2017 as shown in Table 3.2

Table 3.2

Turnover ranking of the twelve (12) highest Trading venues in Eurozone

Period 01/01/2016 – 31/12/2017		
A/A	Country	Value of Trades **EURbn**
1	UK	3 793.07
2	GERMANY	2 117.77
3	FRANCE	1 884.19
4	ITALY	1 261.16

5	NETHERLANDS	912.38
6	SPAIN	530.42
7	BELGIUM	198.6
8	FINLAND	182.07
9	AUSTRIA	43.84
10	IRELAND	42.83
11	PORTUGAL	40.82
12	*GREECE*	*25.71*
Total		**11 032.86**

Notes: The table presents the 12 highest, with respect to turnover, trading venues in Eurozone.
Source: fragmentation.fidessa.com

In the OASIS system, the following trading methods are supported based on the executing criteria of the corresponding orders:

3.1 Method 1: Continuous Automatic Matching Method (CAMM)

The Continuous Automatic Method –CAMM- is the central and most time-consuming trading method in ASE. Members continuously enter orders, and the system executes them according to price-time priority. Each order entered is timestamped by the system representing the time it was inserted in the system. The relevant information of order entry in the system that must be recorded by the members is determined in Appendix I – Orders' data.

All traders have access to the full order book of active orders which is preserved unstoppably in the trading system. The unexecuted buy orders are displayed separately from the unexecuted sell orders, and they are exposed in two different groups, bid and ask, according to price/time priority. Every order that is entered, the system checks if the trading (matching) conditions are satisfied and if not, the system records the order in the order book at the equivalent ranking (price/time). Market orders are canceled if no existing opposite order is present in the system.

The orders are executed automatically in OASIS, as long as the trading criteria are fulfilled. These criteria for sell orders are to have a worse (lower) price or equal to the highest live sell order price while for buy orders to have a worse (higher) price or equal to the lowest live buy order price. The trading criteria are fulfilled upon the existence of opposite orders in the order book at the specific time of the order insertion, or not. This means that upon an order entrance the system checks the price and the entry time of the top ranking orders lived in the order book. In the situation of fulfilling the trading criteria by an existing opposite order, matching of orders is taking place, and this trade is logged in the system. The price of the trade is determined from the price of the prevailing order in the order book. In the case that the orders (entered and existing one) are completely fulfilled, at this specific moment they are detached from the order book.

When the volume of the incoming order is not fully executed by the prevailing orders in the order book, meaning that this particular order has an active status in the order with unexecuted volume, then this order is logged in the order book at a ranking equivalent to it, following the price/time criteria. In case that a market order is entered into the system and is partially covered, then the remaining part of that order is transformed to a limit order. The price of this transformed order is equivalent to the price of the last order against with the market order was executed.

In the case that the incoming order can be matched against more than one prevailing order in the order book, then the matching is performed by taking into account the price/time priority. When the matching of prevailing orders leaves unexecuted volume of an order, then this particular order remains in the order book with a volume corresponding to the remaining part of volume as the quantity of the incoming order reduced it.

3.2 Method 2: Call Auction Method (CAM)

The Call Auction Method includes two steps.

Step 1 - Pre-Call Phase: The Orders are entered freely during the Pre-Call period with a pre-defined start and a random end, called the rule of Random Time Period-RTP. During this phase, the ASE Members enter orders which are recorded in the main order book according to price/time priority, as described in Appendix I Orders' data.

All types of orders are allowed during this phase which are entered with a volume at a multiple of the trading unit[11], and a Projected Auction Price is continuously displayed (called PAP), which gives the participants the possibility to view the estimated auction price during the whole pre-call period. During the activation of the PAP functionality, every new order that is entered alters the projected auction price, which gives the participants the ability to identify the auction price at every single moment.

Step 2 – Auction Phase: After the end of the pre-call phase, the system calculates the auction price automatically and the orders are matched at this price. The full depth of the order book take part to the calculation of the auction price. The auction algorithm is performed to maximize the volume at a specific price. Right before the execution of the Auction, the trading system creates a list of possible auction prices at which the volume that could be executed is maximized. In case the volume is maximized in more than one

[11] The trading unit for all the entered securities trading certificates is one (1) according to the ASE Regulation.

price, then the price closest to the reference price is chosen by the system. The reference price is the price just before the auction commences. Thus, the price just before the auction is very crucial, because it is the possible price that the system will choose the price to maximize the volume.

After the calculation of auction price, the system matches buy orders which have a better price than the auction one (higher or equal), and the existing sell orders which have a better price than the auction one (lower or equal) are matched according to the price/time priority. For the priority among price orders market (MKT), At the Open (ATO), and limit (LMT) orders, see Appendix II.

An unexecuted market order is canceled automatically whereas the non-executed part of a market order, if any, continues to be active in the order book of the following phase, as a limit order but with a price equivalent to the auction price and with a time stamp equivalent to the auction time. The system cancels non-executed or partially executed At the Open orders. For the auction mechanism and how the maximization of the volume is performed, see Appendix III.

3.3 Method 3: At The Close Price Trading (ATC)

According to this method, orders are executed solely at the close price. The orders with a limit price better than the closing price that has been entered to the system during the continuous phase (CAMM) or Call Auction Method (CAM), which precede the ATC phase and also ATC orders, can be executed during the ATC trading period.

3.4 Method 4: Hit & Take

The Hit & Take method can only take place at the Special Terms Board where orders have the following conditions exclusively:

All or None (AON): AON order can be executed totally and not partially.

Minimum Fill (MF): MF order requires that a minimum number of units can be executed.

Multiples Of (MO): MO requires that only multiples of a certain number of units can be executed.

The ranking of orders follow the criteria of price and time:

- Concerning Price, for sell orders, the ranking is ascending while for buy orders, the ranking is descending,
- Concerning time, in case orders are entered at the same price, the entry time of the order is taken into account.

In the Special Terms Board, the system does not perform any automatic matching but the members can choose any order existing in the order book which satisfies his criteria, and "Hit it manually" in order to perform the trade (Hit & Take).

3.5 Method 5-1: Forced Sales

Forced sales method is applied in the forced sales market, and the trading of securities is performed by the CAM method. The trades that are executed during the forced sales period do not affect the securities dissemination information concerning the last price, open price, close price, and indices value.

3.6 Method 6: Pre Agreed trades (Block-Trades)

Pre-Agreed Price trading method is applied for the execution of bilateral trades that have been agreed among ASE members and the trades are executed from orders that belong to different clients. They are separated into:

- Method 6-1. Simple block trade
- Method 6-2. Settlement block trade (spot1 & spot2)
- Method 6-3. Restitution block trade

In the following Table 3.3, the percentage of the block trades concerning the Average Daily Trade Value for the years 2015 onwards is presented.

	Table 3.3						
Period	Block Trades - Average Daily Trade Value (€mil; period average)						
-	2019	Δ PoP	2018	Δ YoY	2017	2016	2015
Jan	5.25	-----	9.5	-44.8%	3.9	5.5	17.4
Feb	4.28	-18.5%	8.3	-48.2%	3.3	4.7	11.2
Mar	8.99	110.0%	22.1	-59.4%	3.4	8.2	11.1
Q1	6.10	-----	13.4	-54.5%	3.5	6.1	13.2
Apr	6.86	-23.7%	9.3	-26.6%	3.9	4.4	6.4
May	25.54	272.5%	20.3	25.8%	7.5	12.0	4.0
Jun	6.62	-74.1%	8.2	-18.8%	9.6	6.5	4.2
Q2	13.75	125.4%	12.8	7.7%	7.1	7.6	4.8
H1	9.86	-----	13.1	-24.7%	5.3	6.9	9.1
Jul	7.20	-47.6%	3.6	100.5%	18.0	4.1	
Aug	4.40	-38.8%	5.2	-14.8%	3.9	14.8	4.7
Sep	5.39	22.4%	6.6	-18.3%	5.8	3.9	2.3
Q3	5.71	-58.5%	5.1	12.6%	9.2	7.7	3.5
9Month	8.40	-----	10.3	-18.7%	6.6	7.2	7.6
Oct	6.73	24.9%	8.9	-24.4%	4.8	17.6	4.9
Nov	8.12	20.7%	15.3	-46.8%	6.2	8.5	3.1
Dec			6.3		18.3	9.9	38.2
Q4	7.30	27.7%	10.4	-29.8%	9.3	11.8	15.4
H2	6.29	-36.2%	7.7	-18.5%	9.2	9.7	10.5

Year	8.22	-----	10.3	-20.6%	7.3	8.3	9.8
	Blocks vs Market						
	12.32%		18.58%		12.42%	13.79%	11.44%

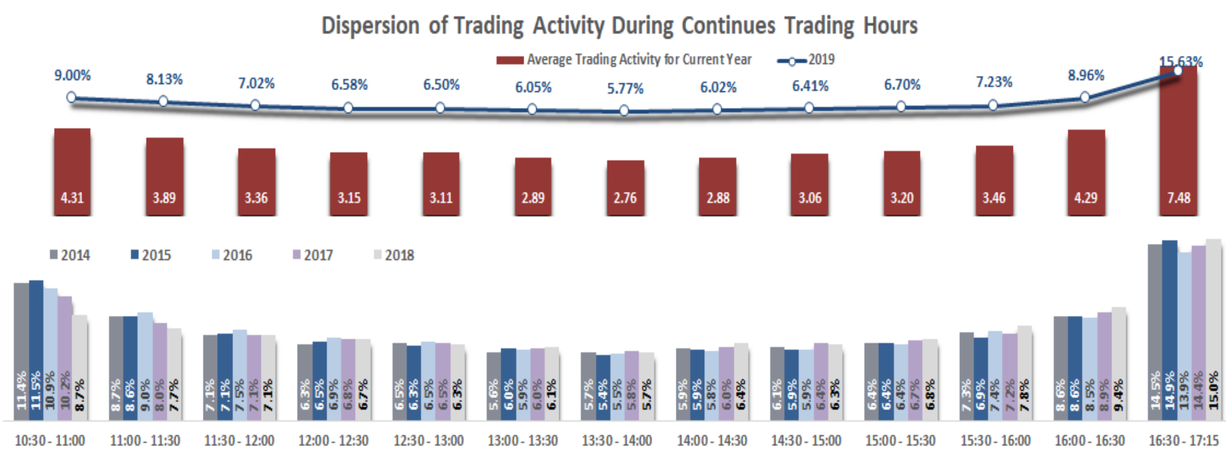
Source: ASE Monthly Statistics Bulletin

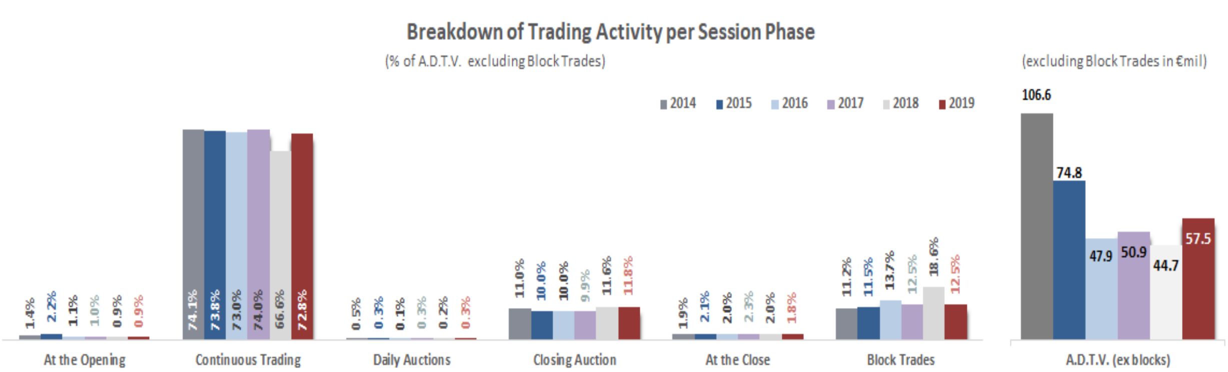
It is obvious from Table 3.3 that block trading constitutes a large magnitude of the daily trading in ASE since it covers a percentage of 11,44% to 18,58% for the aforementioned corresponding years.

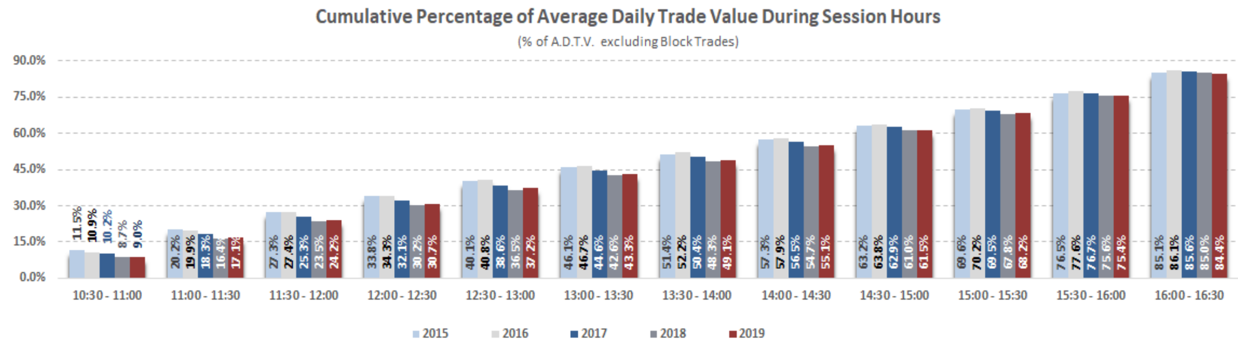
3.7 Trading Dispersion among the trading faces

How trading is dispersed through the trading as mentioned above methods and phases for the years 2014 onwards is given below in Table 3.4.

Table 3.4







Source: ASE Monthly Statistics Bulletin

It is obvious that trading activity, apart from the Continuous phase, which is the main phase of the transaction process, and block trading, which represents bilateral agreements between Members of ASE, an average of 10.5% of the daily transaction is performed at the closing auction. This is quite common in European exchanges since, over the last few years, the turnover in the closing auction in the EU has increased as a percentage of the total turnover traded over the trading day.

3.8 OTHER TRADING CHARACTERISTICS

In order for ASE to handle extreme price movements, it has implemented price collars and volatility interrupters. EU regulation for capital Markets, MiFID II, addresses the importance of the call auction design. According to Article 19, §1, of the Markets in Financial Instruments Directive (MiFID) II, "Trading venues shall ensure that appropriate mechanisms to automatically halt or constrain trading are operational at all times during trading hours" (European Securities and Markets Authority, 2015, p. 268). Thus, all European Union (EU) trading venues are required to apply volatility interrupters in their call auctions mechanism by January 2018. In that respect according to Guidelines issued by ESMA "Calibration of circuit breakers and publication of trading halts under MiFID II" 06/04/2017, ESMA70-

872942901-63, trading halts include mechanisms that extend the period of scheduled or unscheduled call auctions in case of price divergence concerning a pre-defined reference price at the end of the auction.

3.8.1 Daily Price Limits

Daily Price Limits are defined according to the start-of-day price at the beginning of the trading session and correspond to the highest (limit-up) and the lowest (limit-down) price that the price of the stock can take values in between. The corresponding prices are always adjusted to the security corresponding price tick.

For the newly listed companies, the daily price limits are infinite for the first three days of securities trading. Also, daily price limits are infinite for rights during their whole trading session.

3.8.2 Volatility Interrupters

ASE introduced volatility interrupters at 16/7/2007. Volatility Interrupter (also known as circuit breakers) is defined as the automatic halt of the trading of specific security and the simultaneous activation of auction (Volatility Interrupter Auction). The activation is taken place when the price of a potential trade exceeds specific price thresholds, as set by ASE. These thresholds are the Static and Dynamic Price range:

The Static Price range is set as the percentage deviation of the price of a security from the last auction price (Reference price of Static Limit) of a particular security.

The Dynamic price range is set as the percentage deviation of the price of a security with reference to the last trade price (Reference Price of Dynamic Limit), which was executed of a particular security.

The extension of the Pre-Call phase is defined as the determined time during which the pre-call phase of an auction may be extended. The extension can be caused either due to the deviation of auction price from the last auction price (Price Tolerance Rule) or because the auction volume has resulted from market orders (Market/ATO Order Rule). Price tolerance rule is the extension of pre-call auction phase, due to the deviation of a price because of the potential execution price (of a scheduled auction or a Volatility Interrupter auction), which deviates according to the reference auction price. This deviation is determined as the percentage of Price Tolerance Range.

3.8.3 Volatility Interrupters during Closing Pre Call

The schedule of the closing Pre-Call phase is from 17:00 to an auction with a random time between 17:09 to 17:10. The closing price is calculated with an auction in conjunction with another alternative algorithm when Volatility Interrupters are in effect. The closing pre-call is extended, provided that:

the projected auction price deviates by more than 3% (Price Tolerance range)

or

the projected auction volume is in its entirety from market orders (MKT/ATO order rule). The extension period is 2 min, with a random extension time of 1 min.

After the extension of the closing pre-call phase, the auction finally takes place unless there is no matching of orders, and in that case, the VWAP of the trades of the 20 min before the auction is taken under consideration.

3.9 Market Making

The trading system of securities supports the operation of Market Making functionality. According to the regulation of ATHEX, Market Makers are obliged to entry quotes on a continuous basis, in order to strengthen the liquidity of the company shares that are responsible for.

In particular, the entry of quotes in the system must be performed according to the following rules:

- Spread: The formula that is used for calculation of the spread is the difference between the sell and the buy prices of the corresponding orders which constitute the two legs of the quote, divided by half of their sum. The price deviations for each leg of the quote should be within the permissible price deviations for each security.
- Minimum Disclosed Volume: The Minimum Disclosed Quantity for each Security is calculated by ASE quarterly and published on the first working Monday after publication in the Daily Official List of ATHEX and if this is a holiday, on the next business day. The formula that is used for the calculation of the minimum volume for each leg of the quote for every security is:
    - MDQ = (ATV/C) x 0,25% where ADV= Average Daily Value of trades (without block trades) during the

immediately preceding 3 months and C= Average daily closing price of the share during the 3-month period

- Time Limit: Is the maximum period of time within which a Market Maker must re-enter a market making order from the moment of the full or partial execution of its previous order. In the event of non-fulfillment of market making obligations, the System automatically activates an **alarm** every two minutes (2') from the moment of non-fulfillment, with a relevant **warning** to the Market Maker one (1) minute after non-fulfillment (set per instrument type).

The quotes of Market Maker should be entered through a separate member code, which the Market Maker will notify at ATHEX and will use it exclusively for this purpose. A Market Maker is allowed to enter limit orders, as well as quotes, the price of which must at all times be within the existing price spread of his quotes or if there is not one, of the immediately preceding executed market-making quote.

Market Maker is not obliged to enter quotes of the security for which he is responsible, when and for as long as security's price is estimated at limit up or limit down. The same stands for emergency cases of sudden fluctuations, especially in cases of a general change of prices during a trading session of ATHEX or important technical problems, disruption of the normal operation of the exchange trading market, or if there is an important cause that increases a market maker's risk.

3.10 Market Indices

The Stock Market Indices measure the movements of investment products (stocks, bonds, commodities), and their price reflects the overall behavior of the whole or part of the market they follow. Due to the fact that they are generated by a representative subset of the shares they follow, and they are calculated by reference to a base period, they function as a crucial measurement of comparison of specific returns. The General Index of ATHEX exchange consists of the 60 largest stocks of the exchange based on market capitalization, it is disseminated every 30,'' and the calculation formula is as follows:

$$\text{Index} = \frac{\sum_{\text{for all securities in the index}} (\text{Outstanding} * \text{Weight} * \text{Price})}{\text{Index Base Market Value}}$$

In the following Table 3.5, the returns of the General Composite Index for the 60 largest stocks with respect to their capitalization is presented

Table 3.5						
Period	**General Index - Return** (return from previous period)					
-	2019	2018	2017	2016	2015	2014
Jan	*3.5%*	*9.5%*	*-5.0%*	*-12.4%*	*-12.6%*	*1.2%*
Feb	*11.5%*	*-4.9%*	*5.6%*	*-6.5%*	*22.0%*	*11.3%*
Mar	*2.0%*	*-6.6%*	*3.1%*	*11.7%*	*-11.9%*	*1.9%*
Q1	17.6%	-2.7%	3.5%	-8.6%	-6.1%	14.9%
Apr	*7.2%*	*10.0%*	*6.9%*	*1.1%*	*6.1%*	*-7.8%*
May	*7.4%*	*-11.9%*	*8.9%*	*10.8%*	*0.3%*	*-0.7%*
Jun	*4.6%*	*0.2%*	*6.3%*	*-16.2%*	*-3.4%*	*-0.7%*
Q2	20.4%	-2.9%	23.7%	-6.1%	2.8%	-9.1%
H1	41.6%	-5.6%	28.0%	-14.1%	-3.5%	4.4%
Jul	*3.6%*	*0.5%*	*-1.4%*	*5.4%*		*-3.7%*
Aug	*-3.5%*	*-4.2%*	*1.6%*	*1.1%*		*-0.6%*
Sep	*0.0%*	*-5.2%*	*-8.5%*	*-2.1%*	*4.8%*	*-8.6%*
Q3	0.0%	-8.7%	-8.3%	4.3%	-18.0%	-12.6%
9Month	25.6%	-8.5%	33.6%	-13.6%	-38.4%	4.7%
Oct	*1.6%*	*-7.5%*	*0.5%*	*4.5%*	*7.2%*	*-13.7%*
Nov	*0.1%*	*-1.5%*	*-2.5%*	*6.4%*	*-9.5%*	*5.2%*

Dec		*-2.7%*	*8.4%*	*2.4%*	*-0.5%*	*-14.2%*
Q4	1.7%	-11.3%	6.2%	13.8%	-3.5%	-22.2%
H2	1.7%	-19.0%	-2.6%	18.7%	-20.8%	-32.0%
Year	44.0%	-23.6%	24.7%	1.9%	-23.6%	-28.9%

Marketability of the stocks in ASE is quite concentrated to a small number of stocks since the concentration of the trading value for the stocks comprising the FTSE/ATHEX Large Cap Index for the 20 largest stocks with respect to their capitalization (see Table 2.6) is above 90% for most of the years from 2014 up today.

	Table 3.6					
Period	**FTSE/ATHEX Large Cap Index** (concetration of trade value #)					
-	2019	2018	2017	2016	2015	2014
Jan	*93.0%*	*88.4%*	*88.0%*	*97.0%*	*95.3%*	*83.1%*
Feb	*94.8%*	*90.6%*	*95.7%*	*95.4%*	*95.5%*	*84.9%*
Mar	*95.0%*	*76.4%*	*93.8%*	*97.4%*	*93.1%*	*83.2%*
Q1	94.3%	84.9%	92.5%	96.7%	94.8%	83.6%
Apr	*93.2%*	*93.8%*	*96.1%*	*96.8%*	*95.6%*	*88.8%*
May	*81.1%*	*94.6%*	*95.2%*	*96.5%*	*94.0%*	*74.7%*
Jun	*92.9%*	*90.3%*	*94.0%*	*95.7%*	*94.9%*	*94.2%*
Q2	87.4%	93.2%	95.0%	96.3%	94.8%	84.6%
H1	89.8%	88.7%	94.1%	96.5%	94.8%	84.2%
Jul	*89.4%*	*86.6%*	*95.4%*	*95.5%*		*90.8%*
Aug	*93.3%*	*95.5%*	*95.5%*	*97.5%*	*95.3%*	*93.3%*
Sep	*92.5%*	*95.2%*	*96.5%*	*94.7%*	*95.9%*	*94.0%*
Q3	91.5%	93.3%	95.9%	95.9%	95.6%	92.6%
9Month	90.4%	89.7%	94.7%	96.4%	94.9%	86.4%
Oct	*94.0%*	*95.1%*	*95.7%*	*62.7%*	*95.8%*	*94.1%*
Nov	*95.1%*	*77.5%*	*96.4%*	*96.0%*	*94.8%*	*90.2%*
Dec		*91.8%*	*94.4%*	*87.4%*	*99.2%*	*93.0%*
Q4	94.5%	86.9%	95.4%	83.8%	98.0%	92.8%
H2	92.5%	89.7%	95.7%	89.0%	97.5%	92.7%
Year	**91.1%**	**89.1%**	**94.9%**	**93.6%**	**95.8%**	**87.8%**

3.11 Short Selling

Short selling was allowed as long as trades that referred to short selling should have a higher price than the last trade executed in the Athens Exchange (Uptick rule). The Uptick rule did not apply to Short selling At The Close of the trading session and for Block trading. Members that execute short selling or buy to close orders should declare this when they enter the order into the ATHEX trading system (flagging). Physical or legal entities that accumulate a net short position higher than the 0.10% of the total number of shares of an issuing company should declare this to the HCMC and publish this information to the ATHEX gazette. This declaration should take place not later than one day after they exceed 0.10%. The same applies to any other change of this percentage.

The short-selling allowance was valid until Regulation of the European Parliament and the Council on Short Selling and Credit Default Swaps 236/2012 was implemented. What is under the provision is that short selling prohibition is at the discretion of the Competent Authority, in case of a significant price fall from the previous day's close (for liquid shares) 10%. For illiquid shares and other financial instruments, the threshold is determined by the Commission in a delegated act. Then a temporary short-selling prohibition for the remainder of the day and the following trading day is issued and can be extended for up to two further trading days in case of a further significant price fall.

3.12 Member's Guarantee

The limit of transactions of every member depends on a guarantee, which is provided by the member for good fulfillment of its obligations. The guarantee of every member consists of the value of a member's share in the

Supplementary Fund, the cash, and the guarantees of third persons (letter of guarantee).

Supplementary Fund was formed to safeguard the market from any instabilities in the clearing cycle that might be caused by member default and is managed by the ATHEX BoD. The initial participation amount at the supplementary fund account is 50.000€ for a new ATHEX member and is fixed for the first 24 months. The third person's guarantees represent a letter of guarantee issued by a Greek bank.

3.13 Member's Credit Limit

Every member is obliged to have some money disposables in order to execute transactions. An electronic system informs the credit limits of every member of transactions after clearing & settlement of transactions have been achieved. Given that for each security, a general and special risk is defined, each member should apply to the following rule:

Member's Covered Credit Limit = [(Value of non-executed orders, buy and sell) x 50% (% General Risk+% Special Risk)] + {[|Buying Vol.-Sell Vol.| x 50% (% General Risk)] + [(Buying Vol. + Sell Vol.) x 50%(% Special Risk)]} where,

The General Risk is defined as a percentage of the entire risk that affects a financial market and not just specific securities, and as a result, it estimates the consequences of the trend of the entire market and

The Special Risk is defined as a percentage of the risk particular of stock, and as a result, it estimates the consequences of the trend of stock opposite to the entire market.

For all stocks in the Greek market, the General Risk is defined to 15% and the Special Risk to 10%. Respectively for bonds, the General Risk is 7,5%, and the Special Risk is 5%. For stocks that are suspended and stocks traded in the Surveillance market, the Special risk is equal to 100%. The block trades are not affecting member's credit limit because those are bilateral pre-agreed trades; hence they are not bearing market risk. The Member obtains a warning message in OASIS when it has reached the 70% percent of its credit limit within the day. When a member exceeds its Member Credit Limit, new orders are not allowed to enter into the market.

3.14 Clearing and Settlement Procedure

ATHEX is the main institution that has undertaken the clearing & settlement of the exchange transactions, as well as the administration of DSS, in which dematerialized securities are registered, and the transactions over these are monitored through the Shares and the investors' Securities accounts, which are kept in DSS.

The stages of clearing & settlement procedure are the following:

Day	**Procedure**
T	Closing of transactions in ATHEX ▪ Download the trade file from the ATHEX. ▪ Confirmation of the transactions. Data related to the transactions appear to the Operators though DSS,

	and they are informed of their obligations and their respective claims.
T to T+1	Transfer of the clearing of the exchange transactions.
T to T+2	Allocation of buyers and sellers from the Operators.
T+2	Settlement ▪ Repeated Settlements. ▪ Block money in the Operator accounts. ▪ Payments. ▪ Transfer of Securities.
T+3	Late Settlement.

3.15 Clearing Procedure

After the closing of the trading day (Day T), ASE transmits a file to DSS with information corresponding to securities and values of transactions (purchases or sales). This information is presented per security, per investor, per broker, and per type of trade; the weighted average value of the trades is included, which is calculated by dividing the total value of the trades over the volume traded of securities (trade averaging). Then, the confirmation of the transactions takes place.

In the case that a Custodian/bank that participates as Operator in DSS has undertaken the clearing and settlement of the trade, the broker that executed the trade passes the responsibility of the trade's clearing to the Custodian bank. Hence, the Custodian undertakes all obligations and claims of the broker regarding the clearing process. The trade transfer of a specific buy/sell is done after the confirmation of trade and before the notification of the Operator's Account. The trade transfer should be done until T+1 at 20:00 the latest if the trade is settled on T+3 and until T+1 at 10:30 if the trade is settled on T+1. For the correction of wrong give-ups, the member that gave-up the trade still has the obligation for the settlement, in case that the Custodian bank does not fulfill its obligations.

Operators should connect each trade with the investor's Securities Account, who ordered the trade so that the securities will be credited or debited into the account. The notification of the operator's account should be done:

a) By the ASE Member before the beginning of the last settlement cycle and

b) By the custodian bank within the settlement day till 13:30 or until 16:00 in case of a re-transfer of the trade.

3.16 Allocation Procedure of the Sub- Account

After the verification and confirmation of the transactions, follows the allocation of DSS about the investor, from whom or to whom the securities subject to Sells or Buys are credited or debited, respectively.

Allocation of the Sub-Account shall be handled either by the Member Operator that performed the specific trade (buy or sell), until the opening of the last settlement batch or by the Custodian bank to which the Buy or Sell instruction has been given up, until 13:30 on the settlement day or until 16:00 in case of a new given up by the Member, according to the Regulation of settlement transactions. The Member or the Custodian bank may proceed to the allocation of the Sub-Account only for those Securities Accounts of the Investor Shares for which is allowed to act as Operator.

A Sub-Account allocation should not be accepted if the quantity of securities that are held in the allocated Account is less than the volume of securities that have been sold. In case of failure or delayed allocation of an Account by a Member, upon commencement of last settlement batch, on the settlement day, shall be allocated as Account the Account of the Member's Share. Only one Sub – Account is allowed for each Buy or Sell instruction and for only once.

3.17 Shaping of a transaction.

After the confirmation of transactions (buys or sells), they may be shaped only in the following cases:

1. By the Operator (Member of ATHEX), when an incorrect quantity of securities has been introduced in the buy or sell order in the ATHEX trading system.
2. By the Operator (Member of ATHEX), when the clearing of a transaction requires the involvement of more than one Operators (Custodians).

3. By the Custodian, where the allocation of Sub-Accounts of more than one investor is required.

In the cases mentioned above, the Operators may shape the volume of securities of one trade (buy or sell) instruction to more trades (buy or sell), respectively. The sum of volumes of securities must be equal to the total quantity of securities before the shaping. During this procedure and exclusively for clearing purposes, the total monetary value of each shaped trade is automatically calculated via the DSS, by multiplying the Average Unit Price with the volume of securities. In case of decimals, these are rounded up to an integer, while the price of securities of the last buy or sell instruction that is shaped is set in such way that the sum of the prices of securities of all Sells or Buys after the shaping is equal to the price of securities of the trades (Sells or Buys) prior to the shaping of the instructions.

After the completion of the above procedure, the shaped instructions are handled in the DSS as individual trades (buys or sells). The operator that conducted the shaping of transaction may only revoke it as a whole, provided that it has not been given up and that it has not allocated an Account administered by another Operator for any of the shaped transactions.

No shaping of instructions is allowed for transactions resulting from orders that have been placed on account of a group of investors.

3.18 Settlement Procedure- Multilateral Settlement

On the second business day (T+2) following each trading day, in time intervals determined by ATHEX, multilateral Settlement takes place. The settlement of transactions on bonds and debentures takes place on the first business day (T+1) following each trading day.

During this stage, the ATHEX transfers the securities from the Securities Accounts of the Sellers to the Securities Accounts of the Buyers-investors and simultaneously executes the equivalent debits and credits of the Operators Cash Accounts in the Cash Settlement Bank.

The features of Multilateral Settlement are the following:

- The settlement involves all Operators (Member of ATHEX), while the obligation or claim of an Operator is independent of the performance of the obligations of its Counterpart.
- The Partial Settlement is allowed.
- ATHEX executes repeated batches of the Settlement Procedure.
- The requirements of each operator are satisfied up to the sum of his limit (guarantee= cash in his account + value of the delivered, sold securities)

The provision of securities and cash to an Operator, as a result of Settlement, by the completion of each Settlement batch, is considered as a partial provision which cannot be renounced by any Operator.

Every procedural or technical detail concerning the performance of Settlement, e.g., the particular specifications about the Settlement algorithm, the number of settlement batches, and the actual time that each batch is executed, are specified by ATHEX.

Every Settlement Batch is divided into the following phases:

- Phase A: Settlement of enriched Buys, which correspond to enriched Sells in the same security performed by the same OASIS trading code and administered by the same Operator.
- Phase B: Settlement of the remaining enriched Buys.

The settlement is carried out in settlement Batches. During each Batch, ATHEX seeks the settlement of all transactions.

The first settlement Batch involves two stages and is completed during the following:

- Stage A: The settlement is performed by ATHEX, with the DvD (Delivery Versus Delivery) method in the T+2 business date, before the cash settlement. By this procedure, the algorithm settles per security, calculating the Buys and Sells, for which the operator's account has been enriched. This procedure is realized without the participation of the Cash Settlement Bank.
- Stage B: The settlement is performed by ATHEX, with the DvP (Delivery Versus Payment) method, as follows:
    - The money into Cash -Accounts of the buyer/operator is blocked through the Cash Settlement bank (bank of Greece).
    - The securities are transferred from the Sellers-investors Accounts to the Securities Accounts of the buyers' investors.
    - Payment is made in the Cash Accounts of sellers Operators through the Cash Settlement Bank.

Every purchased security is transferred to the buyer's Securities Account, only when the monetary value of purchase has been disbursed or netted. The cost of the sold security that has not been netted is dispensed to the Operator of the seller, only when the security has been previously delivered during Settlement. Netting occurs only in the multilateral settlement procedure and only in the part of cash clearing. HELEX nets the financial claims and obligations of each Operator that have arisen from transactions that have been concluded during the same trading day. The settlement is considered final and not reversible, concerning the effects that bring to the Investors Securities Account and to the Cash Settlement Accounts of the Operators.

During each phase or stage of a Settlement Batch, ATHEX calculates τhe coverage limit of each operator, which is equal to the monetary value of enriched Sells, plus the amount that is deposited in the Operator's Cash Settlement Accounts and is blocked by ATHEX up to the total amount of buys to be settled minus the monetary value of buys which have already been settled. By exception, during stage A of the first Settlement Batch (DvD), the Operator's Coverage Limit is equal to the monetary value of the enriched Sells. The Settlement limit of each Operator is equal to the total monetary value of its enriched Buys.

3.19 OTC Trades

With the implementation of MiFID I, all restrictions regarding the conduct of off-exchange (out of ATHEX) transactions are abolished. All such transactions are completed only when the transfer of the ownership of the involved securities are registered via book-entries in the DSS accounts of the counterparties. The OTC functionality to ATHEX is effective by 18/02/2008.

It is concluded at the DSS (Dematerialized Securities System) by the custodians (General Operator). Trade between the seller and the buyer is concluded off-exchange. The two counterparties instruct their account operators to exchange the securities with cash or to transfer the ownership of the securities, providing the necessary details.

The account operators enter the relative instructions into the DSS.

DSS receives the instructions and match them. Account operators have real-time information regarding the status of their orders (matched, pending).

On the instructed settlement date, matched instructions are executed, provided that the securities and cash are available.

As far as the percentage of OTC trades with respect to Average Daily trade value of ASE is concerned, the following Table 3.7 presents the magnitudes, from which it is evident that OTC trades are quite popular for ASE participants.

	Table 3.7						
Period	**Total OTC - Average Daily Trade Value** (€mil; period average; single count)						
-	2019	Δ PoP	2018	Δ YoY	2017	2016	2015
Jan	*11.05*	-----	*13.4*	*-17.4%*	*4.6*	*25.5*	*13.5*
Feb	*7.72*	*-30.1%*	*10.9*	*-29.3%*	*7.4*	*10.4*	*30.0*
Mar	*12.08*	*56.5%*	*22.9*	*-47.2%*	*12.9*	*27.4*	*14.3*
Q1	10.28	-----	15.8	-35.1%	8.5	20.8	19.0
Apr	*15.30*	*26.6%*	*16.5*	*-7.1%*	*4.7*	*6.9*	*14.1*
May	*21.11*	*38.0%*	*9.7*	*118.1%*	*12.9*	*28.3*	*16.9*
Jun	*20.33*	*-3.7%*	*15.0*	*35.2%*	*17.0*	*12.8*	*26.6*
Q2	19.08	85.6%	13.6	40.4%	11.9	16.0	19.3
H1	14.61	-----	14.7	-0.9%	10.1	18.4	19.1
Jul	*9.28*	*-51.4%*	*7.3*	*27.1%*	*14.0*	*9.6*	
Aug	*21.21*	*128.6%*	*7.7*	*175.9%*	*8.6*	*10.2*	*9.6*
Sep	*10.69*	*-49.6%*	*13.5*	*-20.9%*	*9.7*	*4.8*	*5.5*
Q3	13.59	-28.8%	9.4	45.0%	10.8	8.2	8.1
9Month	14.25	-----	12.9	10.6%	10.4	14.8	16.2
Oct	*22.45*	*110.1%*	*17.8*	*26.4%*	*9.4*	*10.5*	*3.8*

Nov	*8.75*	*-61.0%*	*11.4*	*-22.9%*	*7.6*	*5.4*	*8.0*
Dec			*18.0*		*34.4*	*26.8*	*83.6*
Q4	16.90	24.3%	15.6	8.4%	16.3	14.2	31.8
H2	14.79	1.2%	12.5	18.7%	13.5	11.1	22.2
Year	**14.69**	-----	**13.6**	8.2%	**11.8**	**14.7**	**20.6**
	Total OTC vs Market						
	22.03%		**24.38%**		**20.13%**	**24.24%**	**24.01%**

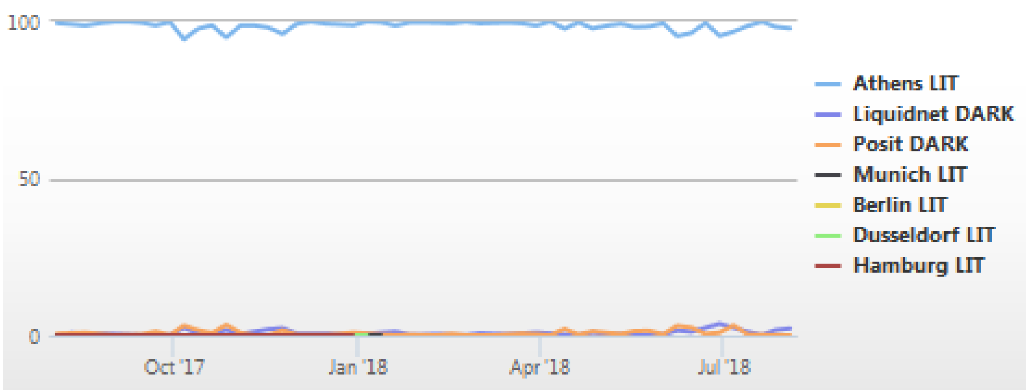
Source: ASE Monthly Statistics Bulletin

3.20 Investors Participation in ATHEX

The trading activity in Greek instruments do not appear to be fragmented beyond the local market since 98.85% takes place in ATHEX whereas 1.15% takes place in Posit and Liquidnet as it is shown in Table 2.8

Table 3.8

Trading Activity in ATHEX and other trading venues



Source: fragmentation.fidessa.com

Foreign investors' participation in ASE accounts for almost 56% of the total ASE's turnover, as shown in Table 3.9, while Algorithmic trading is allowed according to ASE Rulebook accounting for almost 27% of the total trading volume in stocks trading for the year 2018[12].

[12] Source: ASE Data Feed

Table 3.9

Participation of Foreign and Domestic investors to ASE trading activity

	Weight (%)				
MONTH	Foreign Investors	Domestic Investors	Local Private	Local Institutional	Others
Total 2016	56.75	43.25	16.54	24.33	2.38
Total 2017	55.70	44.29	18.91	24.50	0.88
Total 2018	56.18	43.82	17.53	23.03	3.26
Total 2019	53.34	46.07	20.10	24.57	1.40

Source: www.athexgroup.gr

3.21 Mechanisms of Market Abuse Prevention in Athens Stock Exchange

In Greece, the ASE is the sole market operator as well as a frontline regulator. As a trading venue, ASE is responsible for monitoring all trades on its markets. According to Article16 of Regulation (EU) No 596/2014 (MAR), " Market operators and investment firms that operate a trading venue shall establish and maintain effective arrangements, systems and procedures aimed at preventing and detecting insider dealing, market manipulation and attempted insider dealing and market manipulation." So, as described in the ASE Rule Book 1.5.4 "Control and monitoring of transactions and Members, 1) ASE has in place suitable and adequate mechanisms for monitoring transactions in real and continuous time, and conducts periodic reviews of and internal controls on the procedures and arrangements for the prevention and detection of conduct that may constitute market abuse."

ASE ought to follow the market abuse directive and especially those behaviors, as depicted in Annex II of Commission Delegated Regulation (EU) 2016/522 supplementing Regulation (EU) No 596/2014 of the European Parliament and of the Council. In that respect ASE must check upon all trades that fall under the supervision of the Exchange by taking into account specific behaviors as they are defined in articles 7-8-11-12 and further in ANNEX I of Regulation (EU) No 596/2014 (MAR), which give indications on:

- market manipulation
- misuse of inside information

Thus, ASE authorities are obliged to detect a variety of different types of manipulative conducts that can be categorized as follows:

3.21.1 Layering

Placing multiple limited orders on one side of the order book to create the impression of liquidity when the trader's intention is ultimately to trade in the opposite direction. This behavior requires a minimum number of price levels that orders have to be entered from the participant to be characterized as layering and a percentage of the total order volume on the layering side to be considered as large.

3.21.2 Pinging

A participant repeatedly inserts orders which are shown on a public display facility to give the impression of activity or price movement in a financial instrument and immediately cancels them. This behavior requires a minimum specific volume threshold to be reached (i.e., small amount are excluded) and a specific number of orders to be inserted and consequently to be canceled.

3.21.3 Phishing

A participant repeatedly inserts a series of orders to trade in order to uncover orders of other participants and then entering an order to trade to take advantage of the information obtained. This behavior requires a minimum specific volume threshold to be reached by trades (i.e., small amount are excluded) and a specific number of orders to be inserted and be traded.

3.21.4 Ramping

Execution of a series of trades over a short time period between the same participants, which leads to sharp price movement over that period which is considered unusual. This behavior requires the setting of the percentage that is considered as unusual (or the number of ticks limit) and the time limit that the first and last unusual trade should be within.

3.21.5 Spoofing

A participant is placing orders in a stock to give the impression of supply/demand while executing only few trades and cancels them if they become likely to execute. This behavior requires a specific number of orders to be counted that represent a specific percentage of the volume for the top price levels.

3.21.6 Painting the Tape

A participant begins entering a large number of small trades on an order book, which are shown on a public display facility to give the impression of activity or price movement in a financial instrument. Following this increased activity, other participants start trading the instrument resulting in a price movement. This behavior requires setting the number of orders and the average trade size limit to be set.

3.21.7 Quote Stuffing

A participant defines the spread of a stock by entering a large number of orders to trade and/or cancellations and/or updates to orders to trade so as to create uncertainty for other participants, slowing down their process and/or to camouflage their own strategy. This may occur when someone, for example, tries to create a false midpoint and then trades in another order book where the midpoint is used as a reference price. This behavior requires setting the minimum number of updates to the spread required and the number of changes in a given time span that affects the spread on the bid vs. ask side.

3.21.8 Momentum Ignition

Entering a series of orders to trade, or series of transactions, likely to start a trend and to encourage other participants to extend the trend in order to create an opportunity to close out or open a position at a favorable price. It captures a manipulation strategy used to trick market participants in following a temporary price movement, creating an opportunity for an investor to trade against them. This behavior requires setting the minimum percentage increase in the short-term trade rate compared to the midterm trade rate.

3.21.9 Algorithm Trade Stuffing

It is used for detecting abnormal short-term spikes in trade activity caused by algorithms. This behavior requires setting the number of updates during a time period compared to a benchmark period by setting the Minimum number of updates required and the benchmark period.

3.21.10 Wash Trade

Identifies when the buyer is the same as the seller for a transaction, which actually modifies the valuation of a position while not decreasing/increasing the size of the position. This is also used for money laundering purposes. This behavior requires setting the aggregated volume of all wash trades for a participant during the day exceeds a percentage of the average traded volume for the order book.

3.21.11 Circular Trading

It identifies a pair of trades for which there is no (or small) change in beneficial ownership. This behavior requires setting how much the two trades' prices may differ.

3.21.12 Prearranged Trading

It is used to find prearranged trades. It tracks if two (2) orders are entered with similar volume within a (narrow) time span, hence resulting in a trade. This behavior requires setting how much the two orders' volume may differ.

3.21.13 Front-Running

When there is a series of trades by either Employee or Proprietary of an investment firm, and at least one of these trades needs to happen before the client trades. This behavior requires setting the difference Price percentage between the front runner trades and the client trades and the minimum volume of the front runner and the client.

3.21.14 Inside Trading

It detects suspected inside trading. This behavior requires setting the news event, and the number of days, before the news event, that should be checked for excessive trading.

3.21.15 Marking the Close

It analyzes the trades at the closing price for significant price movement. This behavior requires setting the percentage limit or the number of tick sizes that can be characterized as abnormal.

3.21.16 Creation of a floor, or a ceiling

It analyzes the trades which have the effect of increasing or decreasing the prices falling below, or rising above a certain level like the VWAP (weighted average price) of the day or of a period during the trading session, mainly in order to avoid negative consequences deriving from changes in the price of the financial instrument. This behavior requires setting the percentage limit or the number of tick sizes that can be characterized as abnormal concerning the VWAP of x days.

3.21.17 Pump and dump – (Trash and Cash)

It analyzes the trades which have the effect of a long (short) position in a financial instrument, and then undertaking further buying (selling) activity and/or disseminating misleading positive (negative) information about the financial instrument, with a view to increasing (decreasing) the price of the financial instrument, by the attraction of other buyers (sellers). When the price is at an artificial high (low) level, the long (short) position held is closed out. This behavior requires setting the news event, and the number of days, before the news event, that should be checked for excessive trading.

3.21.18 Order-To-Trade Ratio

It analyzes whether a participant exceeds a configured order to trade ratio. It captures a manipulation strategy used to trick market participants in following a temporary price movement, creating an opportunity for an investor to trade against them. This behavior requires setting the Ratio limit between orders and trades.

3.21.19 Abnormal Member Market Share Alert

It analyzes whether a participant's market share on a trading day is unusual, given the history of the participant's market share in that security. This is done by comparing today's turnover to the historical turnover. This behavior requires setting the percentage limit of the average participant turnover and the number of days that define the participant trading history.

Taking into consideration all the aforementioned manipulative practices, it is obvious that investors and trader's decision about where to trade, clearly value fairness in trading, confidence that their trades are executed at prices close to the fundamental prices and that market professionals do not engage in insider trading, front running, or market manipulation. Especially, Closing price manipulation is important for market practitioners and market regulators because the closing price is arguably the most important signal to market participants ranging from institutional to individual investors, as it reflects the final valuation assessment during a trading session; therefore, the one typically reported in the news.

On the one hand, the closing price is particularly relevant to academics/researchers, and most of the empirical research focusing on stock market dynamics uses the closing price to construct the logarithmic return. In technical analysis the closing price is also widely relevant either as an individual quantity of investigation (Batten, Lucey, McGroarty, Peat, & Urquhart, 2018; Wong, Manzur, & Chew, 2003) or used in the construction of popular technical analysis indicators, like the moving average convergence divergence (MACD) and the relative strength index (RSI) (Edwards, Magee, & Bassetti, 2018). Recent advances in machine learning techniques, see for example Dash and Dash (2016), also rely on the closing price.

On the other hand, the closing price is important to market practitioners, most notably in the mutual fund industry. Derivatives and structured products like stock options, futures, swaps and exchange-traded funds (ETFs) depend on the underlying stocks for their pricing. Thus, close prices serve as benchmarks for the value of derivative products and are also used for margin maintenance and settlement of derivatives contracts at expiration. The closing price may also be relevant in a range of corporate activities. Thus, several market participants may have an incentive to manipulate closing prices. Thus, our results would be of interest to international market professionals and regulators as the implementation of closing auctions concentrates the bulk of trading into the last few minutes of the trading session (Reuters 2019).

Closing auctions contribute to making companies listed in exchanges visible and tradeable at large quantities with a certain degree of execution probability and reliable price. Closing auctions' popularity is due to the fact that this mechanism succeeds in optimizing the benefits of centralized liquidity in order to serve investors. This results in determining a much-needed reference price and ultimately leads to a lower cost of capital for companies. As such, closing auctions are a crucial aspect of modern market structure and the value they provide should not be overlooked.

4. IMPACT OF SEASONALITY ON PRICE DISCOVERY

4.1 Introduction

As analyzed in Chapter 2, the Efficient Market Hypothesis (EMH) implies that in securities markets, where asset prices are determined freely due to demand and supply equilibria, the prevailing price should accurately mirror all relevant information that is accessible to the markets participants as hinted by Malkiel & Fama (1970) and Malkiel (2003, 2005). Only new information should affect stock prices; thus, past information should not have any power to envisage future performance. There is considerable literature in financial economics that provides empirical tests for market efficiency, intending to explain stock return predictability under a variety of asset classes and market conditions Toth and Kertesz (2006), Wilson and Marashdeh (2007), Yen and Lee (2008). Initial evidence finds lack of stock return predictability, yet later findings appear mixed, and possibly contradictory to the applicability of the EMH since its theory is not adequate to explain market anomalies Hong & Stein (1999), Barberis & Thaler (2003), Battalio and Mendenhall (2005), De Bondt et al. (2008), Cajueiro et al. (2009) and Kourtidis et al. (2011).

Contrary to the EMH, a vast number of researchers identified calendar abnormalities and patterns in the movements of stock prices. These patterns exhibited not only in the price returns but also in their return volatilities, which were also characterized by high persistence. Some indicative studies showing return and volatility abnormalities on Mondays and Fridays were Keim and Stambaugh (1984), Harris (1986), Agrawal and Tandon (1994), Mills and Coutts (1995). As technology evolved and allowed researchers to exploit information hidden in the high frequency intraday data, the so-called "U-shaped," reverse "J-shaped" or "L-shaped" patterns emerged in the intraday behavior for intraday returns. Similar intraday patterns have been observed in return volatility, and a vast number of justifications for this phenomenon arose in the last years.

The relevant results on the research on the EMH for the Athens Stock Exchange are mixed with most of them underlying the inefficiency of the Greek market. Positive Monday returns and Tuesday negative returns and also that Friday returns were higher and positive was demonstrated by several studies (Alexakis and Xanthakis 1995, Mills et al. (2000)). Coutts et al. (2000) specified negative returns on Tuesdays as well as on Wednesdays. As far as volatility is concerned, Apergis and Eleptheriou (2001) found positive returns for Wednesdays, Thursdays, and Fridays but negative returns for Mondays and Tuesdays. Al-Khazali et al. (2008) showed a strong day of the week effect, and Angelidis and Benos (2009), by using 30-minute intervals for prices of the Greek Stock Market, showed that the spread followed a U-shape pattern over the day. Dicle and Levendis (2011), found negative returns for Monday and Tuesday, and positive for Friday ones. Tsangarakis (2007) demonstrated that the day-of-the-week effect is not a dominant phenomenon and that there is not any regular pattern for the days of the week and Sariannidis et al. (2015) demonstrated that "Friday returns were lower than the corresponding Monday and Thursday returns, which contradicts previous research on the Athens stock market (higher returns on Friday, lower on Monday)."

In this chapter, we track intraday stock returns in order to identify whether they are time-dependent, or not. We focus on the possible abnormal returns on specific days of the week and in case that abnormality follows a consistent pattern in stock prices return then we try to specify if that returns and volatilities of all days are different from each other. In order to accomplice that we examine the behavior of intraday returns and return volatility of the General index of Athens Stock Exchange (ASE) for possible intraday seasonality for a long period, and different days of the week by discriminating between “bull” and “bear” markets.

The intraday seasonality pattern is an abnormality that could be attributed to market microstructure characteristics like market makers involvement in price formation process, pre and post trade information asymmetry between investors, short selling restraints, investors’ sentiment which is different during different market price movements (upward or downward) or financial crises. We believe that this is one of the contribution of this thesis. Several researchers have investigated intraday data in order to explore securities market seasonality during the financial crisis. Alexakis (2011) divided the banks traded in ASE according to their capitalization as small and large and studied their price movements during the financial crisis of 2008-2009. The results showed the importance of the ownership of the banks since big banks during the financial crisis showed affection by the negative sentiment of institutional investors. However, this thesis expands current research and investigates possible seasonality stock prices during different market phases or days of the week in conjunction with investors’ sentiment (bull and bear phases) as well as microstructure characteristics (information asymmetry during the different market phases each day of the week, market-making participation, short selling, clearing-settlement schedule).

Our results indicate that intraday returns, together with the volatility of returns, follow a U-shaped pattern. The results provide evidence that the return volatility is higher in close to open period than in the open to close trading period and that volatility is persistent for at least 30 min after the opening auction. Examination on a period basis indicates that the return pattern formation is different for a "bull" market that follows an upward trend which follows a U-shape pattern as compared to a "bear" market characterized by a downward trend in which there was no pattern existence. Finally, when intraday patterns are examined based on the day of the week, we have very strong evidence that the end of the trading period positive return is very significant for the case of Fridays especially in the "bull" market period, while for the opening price pattern, we observed significant positive returns on Wednesdays.

Following section two (2) presents the data sets used, and at the same time, gives a brief description of the institutional set up of the Athens Stock Exchange, which could be related to our results. Section three (3) presents the empirical findings and possible explanations. Finally, section five (4) summarizes the results and concludes.

4.2 The Data Used, ASE Market microstructure and the Models Employed

4.2.1 Data Used

Our data come from the Athens Stock Exchange (ATHEX), and we use intraday stock prices (P) of the General Index of the Athens Stock Exchange for the period begging of March 2006 to the end of September 2009. Our raw data are index values every 30 seconds. Our dataset features the General Index of the Athens Stock Exchange for the period March 2006 – September 2009, at the 30-second interval. The General Index is a specialized stock index covering the sixty largest companies regarding their capitalization.

For our analysis, we calculate the 15-minute logarithmic returns as follows: $r_t = \ln(P_t/P_{t-1})$, where r_t is the logarithmic return, and P_t, P_{t-1} are the index prices at time t and $t-1$, respectively. For every trading day, we use twenty-six 15-minute observations from the opening to the closing of the day; thus giving us 15,656 observations in total. The 15-minute interval has been used in similar studies (Harris, 1986), and hits a fine balance between the extra information contained in high-frequency data but without too much microstructure noise that is dominant in higher frequencies. Figure 4.1 depicts the evolution of the General Index during the period of study, with an upward trend visible in the years leading up to the global financial crisis, followed by a downward trend.

Figure 4.1. Evolution of the General Index in Athens Stock Exchange

Diagram 1: Athens General Index 2006-2009. 15 minutes observations

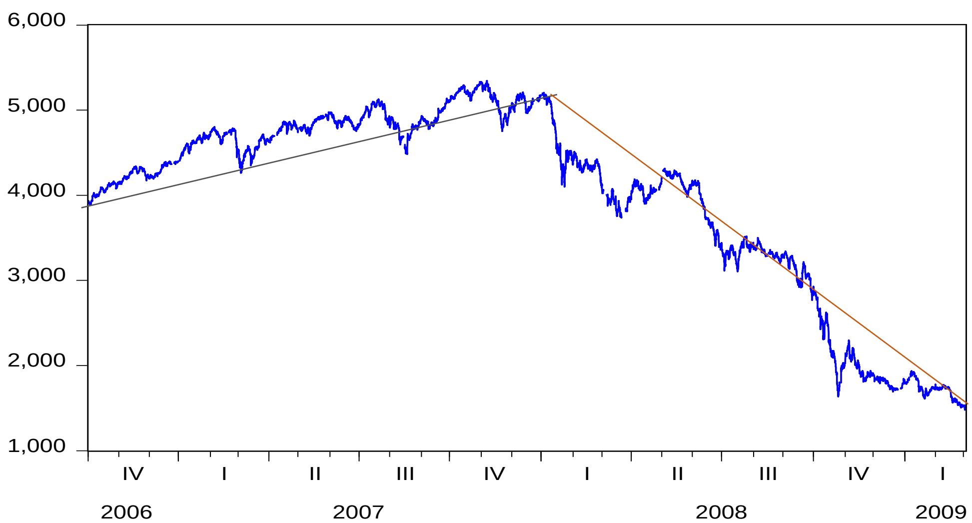


Figure 1 shows the evolution of the ASE index on a 15min frequency for the period 2/10/2006 to 3/3/2009. A first visual inspection verifies an upward trend till the end of 2007 followed by a downward trend as the financial crisis unravels and affects the Greek stock market.

Notes: The figure shows the evolution of the General Index in the Athens Stock Exchange on a 15-minute frequency over the March 2006 – September 2009 period. The two trend lines reflect: i) an upward trend from the start of the period under study till the end of 2007; ii) a downward trend from the beginning of 2008 till the end of the period under study.

4.2.2 ASE Market Microstructure

ASE microstructure characteristics can give convincing explanations for any apparent irregularities regarding the specific period under consideration. As depicted earlier in chapter 3, ASE trading is based on an electronic order-driven system with Market Makers' participation based on ASE's Rule Book. Market making is quite popular in Athens exchange since most of the stocks of the General Index have a market maker associated with them, and they are used as underlings to index and stock derivatives. More specifically, for the period under consideration, market makers are quite active and provide liquidity to more than half of the stocks that form the general index, as Table 4.1 shows.

Table 4.1. Market makers in the Athens Stock Exchange.

Period	#MM in stocks	Participation of MM in stocks	#MM in derivatives	Participation of MM in derivatives	% of MM to total value of transactions	% participation of MM in General index cap
2006-S2	10	47	9	66	*12%*	*97%*
2007-S1	10	62	7	80	*15%*	*92%*
2007-S2	9	71	8	80	*16%*	*91%*
2008-S1	8	76	7	93	*19%*	*91%*

2008-S2	10	95	7	117	*19%*	*95%*
2009-S1	11	92	8	95	*21%*	*95%*
2009-S2	11	81	6	90	*22%*	*94%*

Note: The table shows the liquidity provision of market makers (MM) to the stocks that comprise the General Index. S1 and S2 denote first and second semester, respectively. The stocks that have market makers assigned to them participate more than 90% in General Index capitalization; thus the movement of the price of the General Index is very closely connected to the trading of market makers to those stocks. The percentage of market-making participation in the total transaction value of the stocks that constitute the General index fluctuates between 12% to 22%, which actually shows very active trading participation of market makers to the stocks that they have an obligation to quote.

The ASE system provides for a similar regime as described by Abhyankar et al. (1997) for the London Stock Exchange. Market Makers have the responsibility to enter quotes for their own account continuously in order to strengthen the liquidity of the company shares that they are responsible, following the rules imposed by the Athens Stock Exchange regarding spread, minimum quote volume, and quoting frequency, as explained earlier in chapter 3.

During the particular time interval under consideration, the trading methods that are supported for securities trading are the Continuous Automatic Matching Method (CAMM) and the Call Auction Method (CAM). The closing method is performed through closing auction, and the trading hours are from 10:00 to 10:30 the opening auction, from 10:30 to 16:30 the main trading session (Continuous Automating Matching Method) and from 16:30 to 16:45 the Call Auction method, when at 16:45 the Closing price is determined.

The specific period, ASE was operating on a rolling settlement basis of T+3. Under this mechanism, the day of the week anomaly can arise due to the fact that the settlement of each day is completely independent of the settlement of the other days; thus, the threat that clearing and settlement will not end up successfully is reduced. The clearing is done per the final investor's level and not per member's level. On trade date T, after the closing of the trading day, ASE informs the Central Securities Depository (CSD) electronically, with the trade file of the day. This file is downloaded to the Dematerialized Securities System, where securities and values of trades (buys or sales) are added up per investor, per broker, per security, and per type of trade; then, the confirmation of the transactions takes place. The final settlement of the trade, i.e., the shares allocation to the investors' individual DSS account, will eventually take place at T+3, while the clearing of money transfer will take place at T+4 in the morning. For example, if an investor buys and sells stocks on Friday, the stocks will be settled next Wednesday and will receive his money from the sale on Thursday. This explanation seems to be very interesting because it explains the returns on specific days from our sample.

Finally, short selling was permitted given the fact that trades flagged as "short selling" had a higher price than the last trade executed in the ASE (uptick rule).

4.2.3 Methodology

The econometric model used to investigate the presence of stock return patterns is the model in which stock returns are set to be time-dependent, i.e.:

$$R_t = \alpha_1 D_1 + \alpha_2 D_2 + \alpha_3 D_3 + \ldots\ldots\ldots\ldots + \alpha_n D_n \qquad (4.1)$$

where:

R_t is the 15-minute logarithmic returns of the stock market index, and $D_{1,}$ $D_{2,}$ $D_{3,}$ … D_n are dummy (binary) variables taking the value one for the respective period within the day zero otherwise and refer to the stock returns of the intraday time intervals 1,2,3,……n.

The logarithmic returns are calculated as the ratio between the present time price (intraday or daily) to the preceding price time. To address non-stationarity of the time series data, the Unit-root test is used. Furthermore, as documented by Connolly (1989), when performing OLS estimation procedures we need to include in our methodology an autoregressive term of order one to identify any autocorrelation of the index returns. Furthermore, we estimate the equation using maximum likelihood and Newey-West robust standard errors.

Under the Efficient Market Hypothesis, it must be true that:

$$\alpha_1 = \alpha_2 = \alpha_3 = \ldots\ldots = \alpha_n = 0$$

i.e., stock returns should be independent of time

Nevertheless, intraday returns can be serially dependent, especially index returns, as a result of thin or non - synchronous trading or even slow reaction of the market to the news. In this case, we adjust our model to include additional explanatory variables the lagged returns. With this adjustment, we also avoid the possible autocorrelation problems due to misspecified dynamics, which would introduce bias to the statistical findings.

Thus, the model is adjusted to the following one:

$$R_t=\alpha_1 D_1+\alpha_2 D_2+\alpha_3 D_3+\ldots\ldots\ldots\ldots\ldots\ldots+\alpha_n D_n + \sum_{i=1}^{k} \beta_I R_i \qquad (4.2)$$

Where $D_1, D_2, D_3, \ldots D_{25}$ are dummy variables as before, and R_i is lagged intraday returns.

Under the Efficient Market Hypothesis, it must be true that:

$$\alpha_1 = \alpha_2 = \alpha_3 = \ldots = \alpha_n = 0 \text{ for all time intervals of the period}$$

In order to investigate the possibility that the above model may be valid for different days of the week, we estimated the model separately for each day of the week.

$$R_{tDAY} = \alpha_1 D_1 + \alpha_2 D_2 + \alpha_3 D_3 + \ldots\ldots\ldots\ldots\ldots\ldots + \alpha_n D_n + \sum_{i=1}^{k} \beta_I R_i \quad (4.3)$$

Where R_{tDAY} is the return series for the period under investigation for a specific day of the week, i.e. Monday, Tuesday etc., D_1, D_2, D_3,…D_n are dummy variables as before, and R_i are lagged intraday returns.

Under the Efficient Market Hypothesis, it must be true that:

$$\alpha_1 = \alpha_2 = \alpha_3 = \ldots = \alpha_n = 0 \text{ for every day of the week}$$

Rejection of the null hypothesis would give evidence against the EMH. Moreover, the magnitude and profile of the estimated coefficients (a_n) would show how the return patterns manifest themselves within a trading day.

If there is no day-of-the-week effect in mean returns, the coefficients are not significantly different from zero. Rejection of the hypothesis implies that at least one of the five daily rates of return is not equal to the others. The day-of-the-week effect is also examined by checking the significance of the coefficients a1 through a5. The existence of seasonality in returns will be confirmed when any of the coefficients of equations 4.2 and 4.3 are statistically significant (Brooks and Persand, 2001).

Volatility is calculated as the squared returns by using squared daily return:

$$\sigma_t^2 = r_t^2 \quad (4.4)$$

This calculation method is considered as an unbiased estimation of volatility that is simple and used broadly by investors and researchers, Patton (2011a).

4.3 Results and Discussion

4.3.1 Descriptive statistics

Table 4.2 presents key descriptive statistics for the 15-minute logarithmic returns of the General Index in the Athens Stock Exchange over the entire study period.

Table 4.2. Descriptive statistics

	General Index
Mean	-0.006306
SD	0.337649
Skewness	-1.013
Kurtosis	111.553
Observations	15,656
PP statistic	-23.061***
Q(5) statistic	13.018**

Notes: The table shows descriptive statistics for the 15-minute logarithmic returns of the General Index in the Athens Stock Exchange. The PP statistic denotes the Philips-Perron unit root test for the return series. The Q(5) statistic denotes the Ljung-Box serial correlation test statistic at the fifth lag. *, **, *** denote statistical significance at the 10, 5, and 1% significance level, respectively.

A cursory inspection of the descriptive statistics shows that returns exhibit the stylized facts of non-normality, serial correlation, and stationarity. The skewness and kurtosis of the observed distribution for the ASE General index returns depart from the theoretical normal distribution parameters where skewness and kurtosis should be equal to 0 and 3, respectively. The negative sign of skewness is indicative of the large frequency of occurrence of negative returns compared to positive returns. Investors judge return distributions on skewness when they care for extremes of the data rather than focusing solely on the average. For example, short- term investors are particularly interested in extremes because they are unwilling to hold a position that eventually has a probability to diverge from the average. A stock with negative skewness is one that has a large probability of frequent small gains and small probability of significant large negative returns. Also, a kurtosis larger than 3, indicates positive excess kurtosis signifying that the distribution of returns is leptokurtic meaning that the investors is probable to face sporadic extreme returns. The PhillipPerron Test is engaged to check for stationarity of the data, i.e. check the null hypothesis that the data is not stationary and that there is an existence of unit root.

The Bai and Perron (2003) structural breakpoint test is also used to split the sample into a bull and bear period, reflective of the upward and downward trends identified visually.

Table 4.3. Bai Perron statistics

Sample: 2/10/2006 - 3/03/2009
Included observations: 632
Break type: Compare information criteria for 0 to M globally determined Breaks
Break: 22/09/2008

Variable	Coefficient	Std. Error	t-Statistic	Prob.
2/10/2006 - 02/01/2008 -- 328 obs				

C	3.10E-07	3.33E-08	9.311607	0.0000
03/01/2008 - 3/03/2009 -- 304 obs				
C	1.53E-06	2.72E-07	5.611601	0.0000

Notes: The table shows descriptive statistics for the Bai Perron statistic where it is obvious that the crucial cut off day is the 02/1/2018 in order to define the two periods

According to these results, the bull period is defined from 02/10/2006 until 02/01/2008, while the bear period is defined from 03/01/2008 to 03/03/2009.

4.3.2 Return patterns identification

The results of Equation 4.1 estimation with the returns of the General Index as the dependent variable are reported in Table 4.4, with separate models for the full, bull, and bear market periods.

Table 4.4 Regression results on returns

	Full sample	Bull market	Bear market
Period $1_{Overnight}$	0.027**	0.067***	-0.018
Period $2_{10:30-10:45}$	-0.079***	0.021**	-0.199***
Period $3_{10:45-11:00}$	-0.025*	-0.006	-0.046*
Period $4_{11:00-11:15}$	0.003	-0.006	0.013
Period $5_{11:15-11:30}$	-0.014	-0.008	-0.032
Period $6_{11:30-11:45}$	-0.013	-0.013	-0.013
Period $7_{11:45-12:00}$	-0.010	-0.009	-0.019
Period $8_{12:00-12:15}$	-0.007	0.002	-0.019
Period $9_{12:15-12:30}$	-0.005	-0.001	-0.009
Period $10_{12:30-12:45}$	0.004	0.011	-0.007

Period $11_{12:45-13:00}$	-0.009	0.007	-0.032
Period $12_{13:00-13:15}$	0.005	-0.005	0.014
Period $13_{13:15-13:30}$	-0.010	-0.006	-0.016
Period $14_{13:30-13:45}$	-0.003	-0.001	-0.009
Period $15_{13:45-14:00}$	-0.001	0.005	-0.010
Period $16_{14:00-14:15}$	-0.023*	-0.020**	-0.024
Period $17_{14:15-14:30}$	-0.017	-0.012	-0.014
Period $18_{14:30-14:45}$	-0.007	-0.016*	-0.003
Period $19_{14:45-15:00}$	-0.013	-0.001	-0.030
Period $20_{15:00-15:15}$	0.003	-0.001	0.007
Period $21_{15:15-15:30}$	-0.008	0.010	-0.030
Period $22_{15:30-15:45}$	0.008	0.014	0.000
Period $23_{15:45-16:00}$	-0.019	0.002	-0.043*
Period $24_{16:00-16:15}$	0.002	0.007	-0.007
Period $25_{16:15-16:30}$	0.011	0.026**	-0.004
Period $26_{16:30-16:45}$	0.021*	0.013*	0.027
AR(1)	0.024**	0.06**	0.029**
Adjusted R^2	0.004	0.012	0.009

Notes: The table reports the estimated coefficients of Equation 4.1 where the dependent variables are the 15-minute logarithmic return of the General Index over the period 2/10/2006 – 3/3/2009. Each trading day is divided into 26, 15-minute time periods. The bull market is defined from 02/10/2006 until 02/01/2008, and the bear market is defined from 03/01/2008 to 03/03/2009. "Overnight" spans from 16.45 at day $t-1$ to 10.30 at day t period. *, **, *** denote statistical significance at the 10, 5 and, 1% significance level, respectively.

The first inspection of these results suggests that significant returns are observed at the start and the end of each trading day; thus, verifying the visual U-shape pattern of an earlier section. More specifically, positive returns are observed at the beginning of the trading day, as verified by the positive and significant Period 1 variable. However, in the next 15-minute interval, a reversion is observed in the stock market as the Period 2 variable is significantly negative. This implies that high opening returns quickly revert to negative. An exception appears to be during bull (bear) markets when the positive (negative) start appears more likely to continue over the next 15-minute interval. The last 15-minute interval before the closing of the stock market exhibits significantly positive returns. The significant opening returns may reflect overnight effects and/or new information released when the stock market was closed, and which is reflected at the opening. The positive returns immediately before the closing may be related to informed traders and/or price manipulation attempts, see, for example, Felixson and Pelli (1999).

Closing price manipulation may occur either for investors' own profit or to affect the reported closing price, which is used as a measure of performance within shareholders of the stock market. In particular, the closing price is reported to the financial newspapers, used by technical analysts for their reports and forecasts, as well as by mutual funds managers to calculate the value of their portfolios. Stock market authorities operate market surveillance departments in order to eliminate closing price manipulation, while the implementation of price auction systems has had some success towards this goal (Comerton-Forde & Putninš, 2011). The many forms that closing price manipulation may take, as well as the sheer volume of transactions, make this a challenging task.

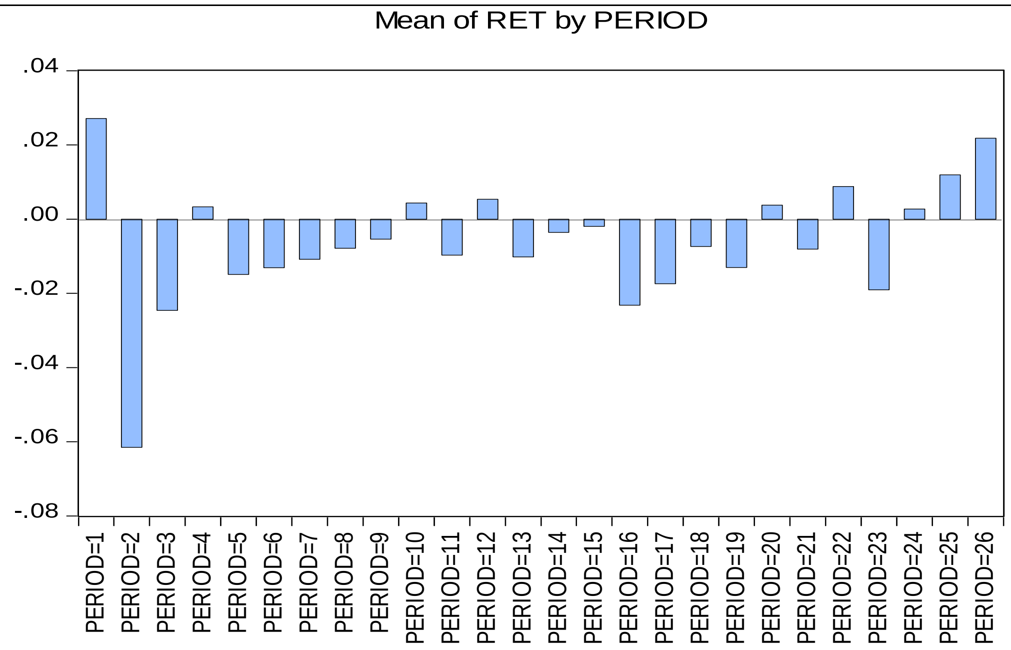
Another important factor is that return anomaly is stronger during the bullish period than in the bearish period consistent with the literature that noise traders' are more aggressive during the high-sentiment periods (Yu and Yuan 2011).

4.3.3 Volatility Seasonality Patterns

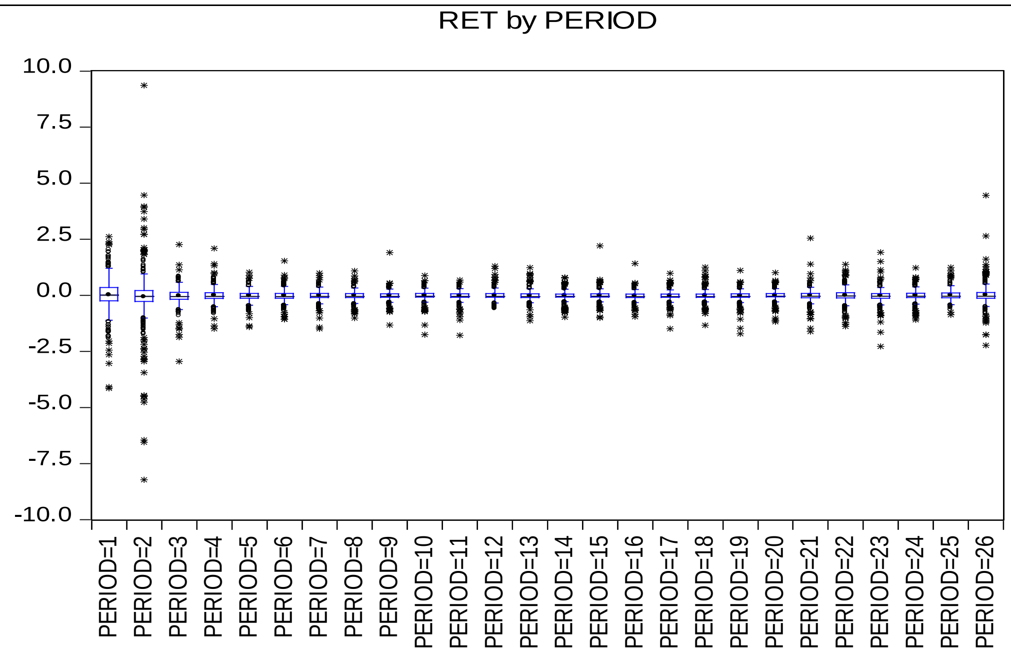
The same "smile" pattern was also observed for the volatility variable for the whole sample period, which was calculated on the basis of the squared returns. The illustration of price volatility plotted against the twenty sixteen 15-minute trading periods is presented in figure 4.2 and table 4.6 with separate models for the full, bull, and bear market periods.

Figure 4.2. Athens General Index 2006-2009 - 15 minutes means

- Panel A: Mean



- Panel B: Box-plot of 15-minute returns



Notes: This figure shows the evolution of intraday returns under the 26 15-minute time intervals for the whole sample period. Period=1 stands for the time interval 10:15-10:30 Period =2 stands for the time interval 10:30-10:45 etc. For the whole period of 29 months, intraday stock returns form a U shape pattern, the well known "smile." During the trading day, more negative mean 15-minute returns are observed than positive mean, but positive returns are observed at the beginning and at the ending of the trading day.

Table 4.5: Intraday variations in relative volatility

Variable: volatility	full sample estimates	"bull" market estimates	"bear" market Estimates
Period $1_{\text{Overnight}}$	0.495***	0.339***	0.674***
Period $2_{10:30-10:45}$	1.022***	0.081***	2.105***
Period $3_{10:45-11:00}$	0.120***	0.032***	0.224***
Period $4_{11:00-11:15}$	0.083**	0.021**	0.154*
Period $5_{11:15-11:30}$	0.053	0.017*	0.093
Period $6_{11:30-11:45}$	0.058	0.018**	0.102
Period $7_{11:45-12:00}$	0.047	0.015	0.084
Period $8_{12:00-12:15}$	0.038	0.014	0.066
Period $9_{12:15-12:30}$	0.038	0.009	0.071
Period $10_{12:30-12:45}$	0.039	0.009	0.073
Period $11_{12:45-13:00}$	0.036	0.011	0.064
Period $12_{13:00-13:15}$	0.036	0.010	0.065
Period $13_{13:15-13:30}$	0.037	0.011	0.068
Period $14_{13:30-13:45}$	0.033	0.008	0.062
Period $15_{13:45-14:00}$	0.038	0.011	0.068
Period $16_{14:00-14:15}$	0.034	0.012	0.058
Period $17_{14:15-14:30}$	0.033	0.008	0.060
Period $18_{14:30-14:45}$	0.040	0.016	0.068
Period $19_{14:45-15:00}$	0.042	0.012	0.076
Period $20_{15:00-15:15}$	0.038	0.012	0.068
Period $21_{15:15-15:30}$	0.063	0.018**	0.114
Period $22_{15:30-15:45}$	0.082**	0.025**	0.146*
Period $23_{15:45-16:00}$	0.072*	0.019**	0.134*
Period $24_{16:00-16:15}$	0.056	0.015*	0.102
Period $25_{16:15-16:30}$	0.044	0.018**	0.072
Period $26_{16:30-16:45}$	0.0159**	0.021**	0.315
AR(1)	0.013**	0.050***	0.003
Adjusted R^2	R^2=0.042	R^2=0.123	R^2=0.078

Notes: The table reports the estimated squared returns of the coefficients of Equation 4.1 where the dependent variables are the 15-minute logarithmic return of the General Index over the period 2/10/2006 – 3/3/2009. Each trading day is divided into 26, 15-minute time periods. The bull market is defined from 02/10/2006 until 02/01/2008, and the bear market is defined from 03/01/2008 to 03/03/2009. "Overnight" spans from 16.45 at day $t-1$ to 10.30 at day t period. *, **, *** denote statistical significance at the 10, 5 and 1% significance level, respectively.

The prices observed at 10:30 am are used as a proxy for opening prices since opening prices are determined exclusively by the call auction method. As shown in this table, the volatility of the 15-minute returns for the whole period exhibits a U-shaped curve, with high volatility at the beginning and at the close of the whole trading session. An exception appears though to be during bull (bear) markets since, on the one hand, the U shape pattern is statistically significant only for the bull market, while on the other hand, the bear market group consistently has greater volatility, especially at the open of the market, than the bull market group.

The statistics presented in Table 4.5 suggest that in all cases, price volatility is high at the very start of the market and lives for a short period. The market remains in a period of high volatility for especially as long as 15 min after the start of the market under the call auction method. For the first two periods that represent prices affected by overnight events and opening call auctions, it seems that there is a volatility shock, which is higher for the bear period, but it lasts longest under the bull period. These tests confirm that there are time dependencies in the intra-day volatility of the ASE, which implies that information is being incorporated slowly into prices, and there is some regularity with which volatility shifts across different levels during a trading day. On average, volatility shifts down to a lower level after Period 4 at 11:00 am and then moves up again after Period 24 at16:30 pm toward the closing auction period.

The fact about the behavior of intra-day volatility at the start of the day is that higher opening market volatility is persistent across all securities. Since this is driven by overnight news and information while the market was closed, this is not unexpected. Given that there will always be overnight news and information that has to be captured into the Athens Exchange market price, it is perhaps inevitable that the opening market price will be far more "volatile" compared to the "closing" price. Traders, after a prolonged period of non-trading like a weekend or overnight, become rather tense at the opening of the market. As a result, during that period, prices do not mirror available information causing great uncertainty to the traders.

What is not expected is that it takes almost half an hour, on average, for prices to adjust. This high "persistence" of volatility is indicative of inefficiency in how slowly market prices adjust to new information. This finding comes in line with the dominant position of Market Makers during the trading after the opening auction as predicted by Abhyankar et al. (1997). Their model illustrated that market makers' opening and closing trades with the aim to manage their portfolio accordingly, could lead to a volatility U-shaped pattern. ASE market exhibits its own empirical regularities since it is an order-driven market with market makers' participation based on the rule book. Most of the stocks of the general index have a market maker associated with them, and they are used as underlings to index and stock derivatives. More specifically, for the period under consideration, the participation of market-making in the stocks that form the general index is described in Table 4.1. It is obvious that the stocks that have market makers assigned to them participate more than 90% in General Index capitalization; thus, the movement of the price of the General Index is very closely connected to the trading of market makers to those stocks. This is strongly supported by the fact that the percentage of market-making participation in the total transaction value of the stocks that constitute the General index fluctuates between 12% to 22%, which shows very active trading participation of market makers to the stocks that they have an obligation to quote. Our findings provide further evidence that the

U-shaped pattern could be attributed to specialist market-making activities. Measuring the effect of market-making we found that immediately after the opening (i.e., Period 2 10:30-10:45), it looks as though the market makers have a dominant position during that quarter of trading session which fluctuates between 25% to 35% to total trading value, thus influencing the stock prices and volatilities accordingly. This is justifiable since market makers are forbidden by ASE Rule Book to enter quotes during the opening Auction; instead, their obligations start immediately after (i.e., from 10:31 onwards). Thus, asymmetric information makes market makers trying to exploit the news at the beginning of the day, so changes in their bid/ask spread and their trades accordingly reflect changes in the level of asymmetric information.

Another important finding is the difference in volatility for bull and bear markets. In line with the sentiment theory developed by Black (1986) and Shen (2017), it seems that a connection of volatility of stocks and noise trading activity is present. In particular, the reasonable assumption that noise traders' participation in the market increases when investor optimism is rising seems to be the case for ASE, given the volatility significance and persistence under the bull market in comparison to the bear market. This finding is consistent with the phenomenon that noise traders' participation in the market increases when investor optimism is rising (Yu and Yuan 2011). However, the pressure of mispricing during the opening of the bear period is much more intense, probably due to the fact that restricted short selling (Up-tick rule) which constrains rational investors from short selling (Hirshleifer et al. 2011). Especially for the period under consideration, short-selling value accounts for 1,66%, 2,75 %, and 1,68% for years 2006, 2007, and 2008 respectively for the stocks comprising the General Index[13].

[13] Source: ASE Monthly Statistical Bulletin.

4.3.4 Day of the week seasonality

Coming now to the analysis of the intraday patterns based on the day of the week, as shown in Table 4.6 and Figure 4.3, we can observe the existence of an intraday variation in each weekday for the ASE General Stock Index.

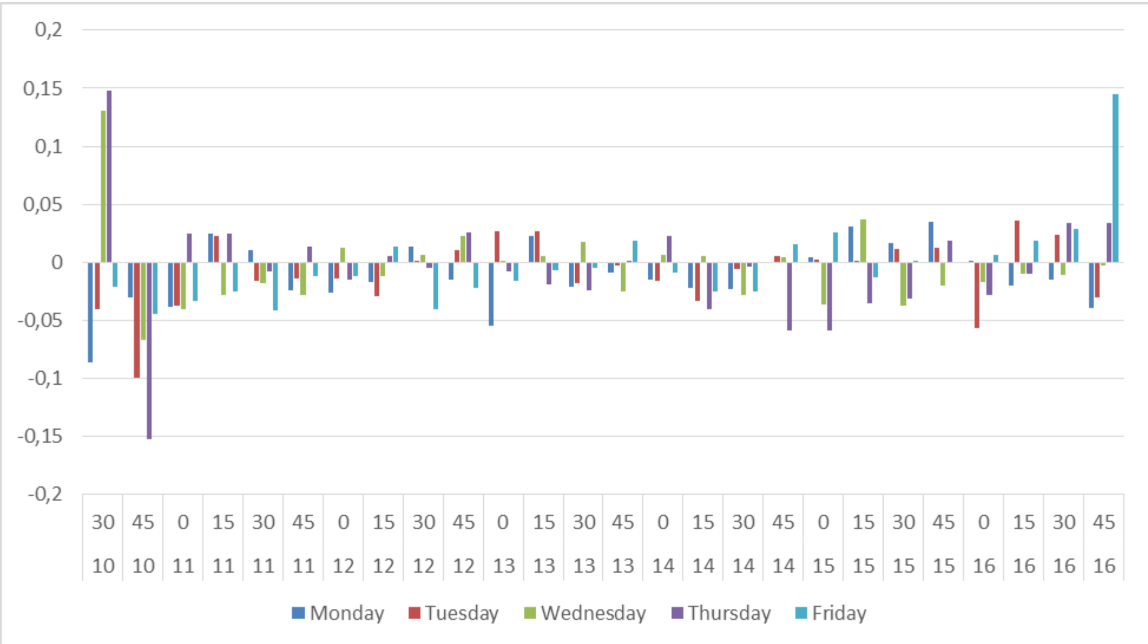
Table 4.6: Intraday variations in relative returns for each day of the week

Variable: return	**Mondays Estimates**	**Tuesdays estimates**	**Wednesdays Estimates**	**Thursdays estimates**	**Fridays estimates**
Period $1_{Overnight}$	-0.088**	-0.032	0.111**	0.015**	0.015
Period $2_{10:30-10:45}$	-0.038	-0.108**	-0.070**	-0.164**	-0.052*
Period $3_{10:45-11:00}$	-0.043	-0.047	-0.035	0.016	-0.015
Period $4_{11:00-11:15}$	0.029	0.015	-0.021	0.024	-0.025
Period $5_{11:15-11:30}$	0.006	-0.031	-0.028	-0.009	-0.037
Period $6_{11:30-11:45}$	-0.025	-0.005	-0.026	0.013	-0.012
Period $7_{11:45-12:00}$	-0.028	-0.022	0.006	-0.014	-0.013
Period $8_{12:00-12:15}$	-0.016	-0.032	-0.018	0.006	0.013
Period $9_{12:15-12:30}$	0.011	0.004	0.003	-0.003	0.036
Period $10_{12:30-12:45}$	-0.015	0.012	0.016	0.027	-0.017
Period $11_{12:45-13:00}$	-0.055*	0.037	0.003	-0.006	-0.016
Period $12_{13:00-13:15}$	0.020	0.027	0.000	-0.017	-0.008
Period $13_{13:15-13:30}$	-0.023	-0.015	0.015	-0.023	-0.009
Period $14_{13:30-13:45}$	-0.009	-0.002	-0.028	0.000	0.016
Period $15_{13:45-14:00}$	-0.016	-0.017	0.007	0.022	-0.006
Period $16_{14:00-14:15}$	-0.022	-0.039	0.006	-0.035	-0.027
Period $17_{14:15-14:30}$	-0.023	0.007	-0.017	-0.003	-0.021
Period $18_{14:30-14:45}$	-0.006	-0.007	0.001	-0.056*	0.008
Period $19_{14:45-15:00}$	0.004	0.001	-0.034	-0.060*	0.015

Period $20_{15:00-15:15}$	0.030	-0.012	0.030	-0.028	-0.015
Period $21_{15:15-15:30}$	0.014	0.009	-0.028	-0.039	-0.002
Period $22_{15:30-15:45}$	0.032	-0.001	-0.012	0.020	-0.002
Period $23_{15:45-16:00}$	0.000	0.063	-0.019	-0.030	0.003
Period $24_{16:00-16:15}$	-0.023	0.043	-0.007	-0.011	0.013
Period $25_{16:15-16:30}$	-0.014	0.026	-0.008	0.029	0.032
Period $26_{16:30-16:45}$	-0.037	-0.027	-0.010	0.034	0.129**
AR(1)	0.028*	0.053**	0.077**	0.046**	0.013***
Adjusted R^2	R^2=0.011	R^2=0.032	R^2=0.021	R^2=0.029	R^2=0.004

Notes: The table reports the estimated coefficients of Equation 4.1 where the dependent variables are the 15-minute logarithmic return of the General Index over the period 2/10/2006 – 3/3/2009 according to the specific day of the week. Each trading day is divided into 26, 15-minute time periods. The bull market is defined from 02/10/2006 until 02/01/2008, and the bear market is defined from 03/01/2008 to 03/03/2009. "Overnight" spans from 16.45 at day $t-1$ to 10.30 at day t period. *, **, *** denote statistical significance at the 10, 5 and 1% significance level, respectively. Single star denotes significance at 95% confidence interval, double at 95% and triple at 99%

Figure 4.3: Intraday variations in relative returns for each day of the week



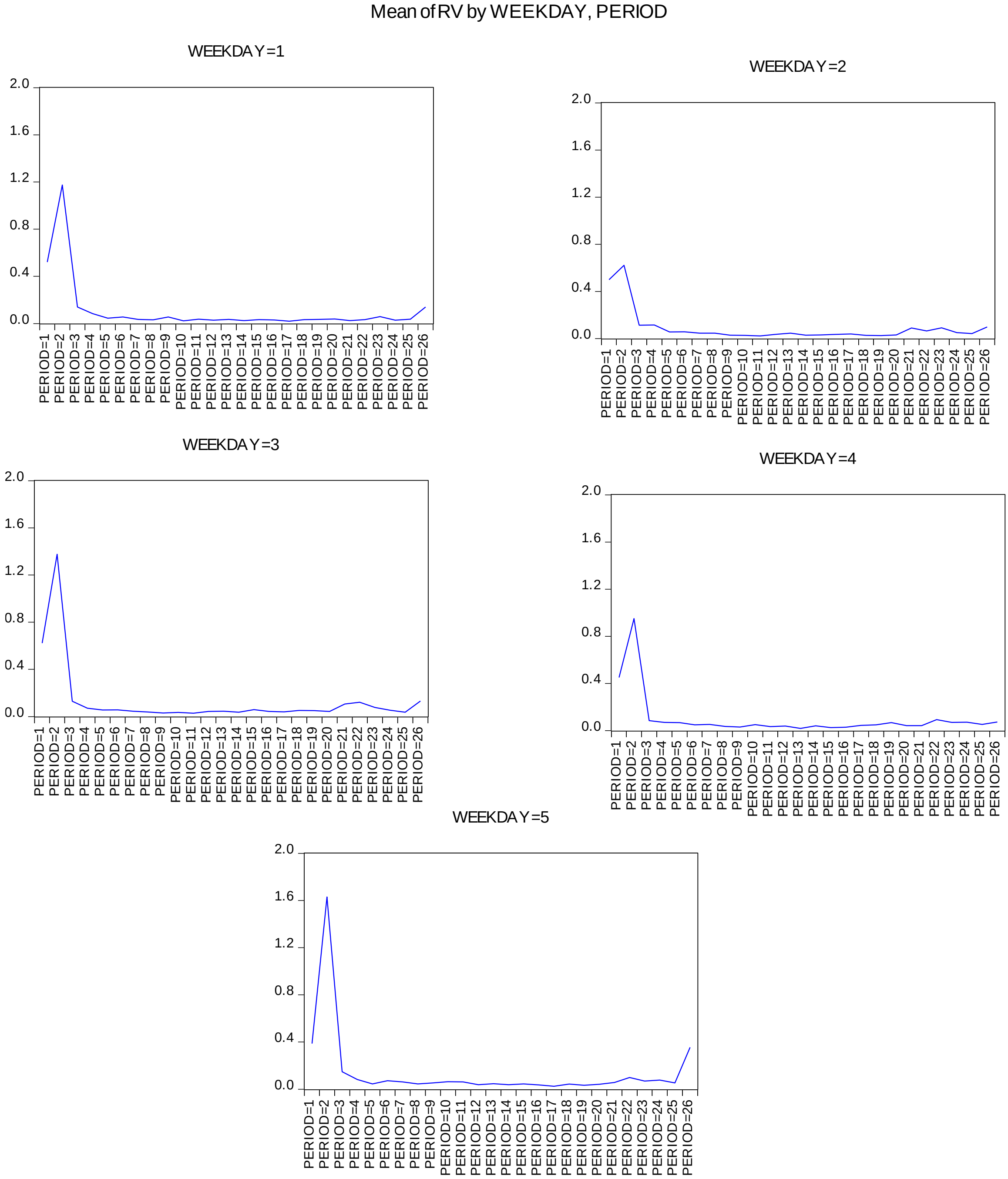
Notes: This figure reports the estimated coefficients of Equation 4.1 where the dependent variables are the 15-minute logarithmic return of the General Index over the period 2/10/2006 – 3/3/2009. Each trading day is divided into 26, 15-minute time periods. Then returns are categorized depending on the day of the week and the time period. "Overnight" spans from 16.45 at day $t-1$ to 10.30 at day t period. *, **, *** denote statistical significance at the 10, 5, and 1% significance level, respectively.

There is significant evidence that the end of the trading period's positive return is very significant for the case on Fridays, where the significant positive closing return is in line with other studies, which produced evidence of the so-called "end of the day" anomaly. Negative opening returns for the index are observed on Monday, which is due to the fact that, the longer the non-trading period, the stronger the impact on stock prices in the opening. Finally, there is a striking difference in the first 15 minutes with positive significant opening returns between Wednesday and Thursday the other weekdays.

These regularities are in line with the literature. Negative Monday returns represent the start of the week effect, while Wednesdays and Thursday's excess return can be attributed to the clearing of the closing (opening) positions of Friday of large portfolio clients, seem to affect the returns on Wednesday and Thursday. As was illustrated earlier, ASE has a rolling T+3 clearing system, which means that the high-density trades of Friday, are settled on Wednesday morning and cleared on Thursday morning.

Regarding the volatility patterns as depicted in figure 4.4, it seems to follow a reverse J shape pattern for all days, while again, the spike in volatility for the time interval that follows the market open is more than obvious.

Figure 4.4: Intraday variations in relative volatility for each day of the week



Notes: The figure reports the squared returns of the estimated coefficients of Equation 4.1 where the dependent variables are the 15-minute logarithmic return of the General Index over the period 2/10/2006 – 3/3/2009 for each day of the week. Each trading day is divided into 26, 15-minute time periods. Weekday 1 refers to Mondays, weekday 2 to Tuesdays and so on. "Overnight" spans from 16.45 at day $t-1$ to 10.30 at day t period. *, **, *** denote statistical significance at the 10, 5, and 1% significance level, respectively.

4.4 Conclusions

The econometric tests performed in this chapter indicated that there are intraday patterns in the Athens Stock Exchange affected by microstructure effect (short-selling, call auction and possible end of day manipulation, settlement cycle, market-making), investors sentiment, and information asymmetry between investors. Stock returns and stock return volatility follow a U shaped pattern during the trading session. Specifically, it is evident that the periodicity of the intraday volatility observed reflects the behavior of traders who adsorbs the overnight change in information and become active at the beginning of the trading session. As the trading day comes to an end, they are changing their positions in anticipation of the close in order to verify any profit that was made during the day. The persistence of the U shape pattern is very characteristic since it was not affected either by the microstructure changes of the ASE trading characteristics such as the introduction of MiFID in 2007 and that of OTC trading in early 2008 nor of Lehman's Brothers crisis (from 2008). During the full sample period and the bull -rising price period, the stock returns and their volatilities are significant accordingly, following a U shaped pattern during the trading session. Specifically, the stock returns were, on average positive and statistically significant at the beginning of the trading day (10:30 a.m.) and the end of it (16:45 p.m.). Also, the significance of the negative returns together with its volatilities at 10:45 a.m. (after the opening auction), and the persistence of the high volatility of another half an hour can be attributed to the dominant position and trading behavior of Market Makers.

The significant positive closing return is in line with other studies that produced evidence of the so-called "end of the day" anomaly. An explanation of this can be based on market manipulation literature. The closing price is a measure of stock performance since it is the price which is reported for the market reports. That is why investors that use this price as benchmark and benefit from it, are particularly interested on how this price is calculated. This finding is going to be further explored in the next chapter, where closing manipulation under different closing methods will be investigated.

At this point, it is essential to note that the high closing price was a characteristic of all cases. Nevertheless, it was not statistically significant in the case of the bear market. Thus, the end of the day anomaly in the Athens exchange characterizes the period with upward movement than the falling prices period. It is true that given the fact that there were obstacles in short selling like the uptick rule, it was easier for the buyers to influence the price upward than it was by the sellers during the falling market.

As far as the day of the week effect is concerned, the negative return of Mondays at the opening is, according to the literature, significant, while for all other days, but Mondays, the returns become significantly negative after the opening of the market due to participation of Market Makers. Also, Wednesday and Thursday's positive significant return for open prices can be attributed to the clearing and settlement effect. Finally, Friday is the only day that returns are positive and significant, signaling the end of week effect for the Greek Market as well. Regarding the volatility patterns, it seems to follow a reverse J shape pattern for all days.

Finally, it seems that the existence of "noise traders" in the market increases when investor optimism is rising since volatility is persistently significant under the bull market in comparison to the bear market (Black, 1986). However, restricted short selling is causing mispricing during the opening of the bear period. The results are in line with most of the previous literature concerning the Greek Market proving high Friday returns and lower equivalent Monday returns, which indicates that investors remained unaffected by the aforementioned exogenous parameters and buying on Fridays and selling on Mondays was their prevalence attitude.

5. Disturbing closing prices during different closing price estimation methods. Evidence and policy implications.

5.1 Introduction

In this chapter, we examine whether the abnormality defined in the closing prices as depicted earlier in chapter 4 is due to efforts from the participants to determine closing prices. In that respect, we investigate the effectiveness of different methods in determining the closing price used in the Athens Stock Exchange (ASE) upon efforts of market participants to adjust closing prices at the desired level. First, we assess the transition from a value-weighted average price (VWAP) method to a plain-vanilla closing call auction method (CCAM). Second, we assess the impact of advanced features introduced within the CCAM (e.g., randomization of the auction time, volatility interrupters) upon closing price determination. We use tick level data for the 15 most active stocks in the ASE and an approach that builds upon the Felixson and Pelli (1999) model. Our analysis provides substantial evidence that efforts of closing price determination persist even after the adoption of the closing call auction method. A full-fledged call auction method does not significantly prevent scheming practices. In addition, investors that trade during the closing price auction, take advantage of key elements of the trading system like the "reference price", which may drive the closing price at the desired level.

Trading venues enable investors to exchange their asset possessions and to handle their financial risks according to their risk appetite. To allow such activities, they offer liquidity services that facilitate transactions as well as trading rules as a framework in which trading orders are conveyed, matched, and executed. These rules should define and protect the rights of market participants, reduce uncertainty, constrain fraud, deter market manipulation, foster liquidity and finally ensure that investors participating in trading venues are creditworthy (O'Hara, 1995).

The trading that takes place is the procedure under which information assessment is transformed into stock prices and is important for the procedure of forming investment portfolios from investors. During a trading session, four prices are usually reported: high, low, open, and close. The closing price, which is the last price that a security traded during the trading session, is the price, which is usually reported in electronic and printed news media. This price is an important signal to market professionals like institutional investors, as well as to private individual investors as it reflects the final valuation assessment during a trading session.

The importance of closing prices to mutual funds evaluation can be found in the computation of their net asset values (NAV) which represents the per share/unit price of the fund on a specific date or time.[14] Since NAV per share is calculated every day, it is determined by the closing prices of the securities in the fund. NAV of funds is the basis for measuring the performance and the remuneration of the fund managers as well as the performance of the fund per se. Fund manager's market is very competitive and underperformance may cost a job more often than in other industries, Porter and Trifts (2014). Consequently, fund managers will strive to report a good performance to the fund's participants. Further, fund performance is important in the funds' competition arena in the efforts of the fund to attract new investors. Research has indicated that investors regard highly the historical performance of a fund and tend to invest in the funds with the best past performance, Chevalier and Ellison (1997), Sirri and Tufano (1998), Cremers et al (2019). In this respect, Carhart et al. (2002) found

[14] The formula for a mutual fund's NAV calculation is:
NAV = Current Portfolio Value Assets - Liabilities / Total number of outstanding units

evidence that fund managers' final-minute transaction was under the purpose of "marking up" the prices of their own stocks thus causing quarter-end and especially year-end prices for mutual fund equities to be abnormally high. On the other hand, there is evidence reported that other professional market participants, like hedge funds, is not easy to correct such mispricing at least instantaneously, Cao et al (2018).

More market professionals may use the closing price of a stock for additional corporate activities. For example, evaluators in their efforts to estimate the value of private or non-traded companies, as these are compared to companies traded on stock exchanges, they use widely multiples like the price to earnings per share ratio (P/E) or enterprise value to EBITDA (EV/EBITDA) ration. In the first ratio, price is usually calculated as an average of closing prices or the closing price of a year wherein the second ratio in order to calculate enterprise value it is necessary to estimate market capitalization as this is defined by the number of shares of the listed company times the market price, as this is again expressed by a closing price or an average of closing prices. Additionally, other corporate actions like bank loans backed by a portfolio of securities are monitored by the value of the pledged portfolio as this is calculated based on the close price of the securities in the portfolio. Even mergers and acquisitions may be based on the closing price when there is an exchange of shares for an M&A deal and a company involved in the deal is a listed one.

Finally, for the derivatives market, many derivatives and structured products like stock options, futures, swaps and equity exchange-traded funds (ETFs) are based on stock prices and consequently, the pricing of the derivatives depends on the closing prices of the underlying stocks. The derivative and underlying markets are connected and closely related. For example, an investor who has purchased ETF shares can hedge its risk by shorting the stocks underlying the ETF or by buying puts on financial stocks instead of shorting them directly. An investor in the options market might sell this put and then delta hedge its risk by shorting the appropriate amount of the underlying stock. Thus, close prices serve as benchmarks for the value of derivative products and are typically used for daily margining and the settlement of derivatives contracts at expiration, Stoll and Whaley (1987, 1991), Chamberlain et al. (1989), Kumar and Seppi (1992), Corredor et al. (2001), Ni et al. (2005).

Therefore, the determination of closing prices is of paramount importance. Given this significance, it would be important to examine the case of effort on possible closing price determination as a tactic for market misuse. Most of the trading venues in the Eurozone use closing auction as the closing price mechanism[15]. The importance of closing auction for the price formation of trading venues across E.U. markets is reflected in recent estimations concerning the turnover in the closing auction in the E.U. as a percentage of total daily turnover.[16]

According to the EU Market Abuse Regulation (596/2014), two signals that may indicate abusive behavior and possible market manipulation are defined as: "Orders to trade given or transactions undertaken which represent a significant proportion of the daily volume of transactions in the relevant financial instrument on the trading venue concerned, in particular when these activities lead to a significant change in the price of the financial instruments", and "Buying or selling of a financial instrument at the reference time of the trading session (e.g. opening, closing, settlement) in an effort to increase, to decrease or to maintain the reference price (e.g. opening price, closing price, settlement

[15] Austria, Belgium, U.K., Italy, Greece, Cyprus Ireland, Netherlands, Norway, Poland, Sweden, Finland and Germany have introduced closing auction mechanism for their exchanges.

[16]See Reuters publication on 18/8/2019 "Last orders: Rise of closing auctions stirs worries in European stock markets"

price) at a specific level – (usually known as marking the close)”. Closing price manipulation occurs when investors who trade large sums of shares may have the incentive to manipulate the closing price of the traded asset. A significant buyer would try to affect the closing price by adding further return to the normal return as this is determined by the normal demand and supply. Conversely, a significant seller would try to impact the closing price by reducing the normal return. The motive behind the big buyers (sellers) influencing the closing price is to enlarge their total capital by the end of the day.

Applied research in this field of efforts to determine closing prices is limited since it requires the use of high-frequency data as well as knowledge of the trading characteristics of the buyers, and the sellers. Most of the researchers evaluate the presence of possible manipulation based on past manipulation cases or changes of securities trading behavior e.g., returns, volatility, and bid-ask spreads (liquidity) during a period when manipulation may have been more likely. According to the best of our knowledge, few studies use data capturing the investor’s unique trading characteristics. In this direction, the study of Felixson and Pelli (1999), examined the Helsinki Stock Exchange and presented statistical results for possible closing price manipulation, while the studies of Kucukkocaoğlu (2008) and Kadioglu, Kucukkocaoğlu and Kılıç (2015) provided evidence that closing call auction sessions have significantly eliminated closing price manipulation in the Istanbul Stock Exchange. The study of Khwaja and Mian (2005) concur for the case of Pakistan.

Cordi, Foley, and Putniņš (2015) argued that closing call auctions design is very important for market efficiency and integrity, and they support the idea of a closing batch mechanism that has randomized closing times and extensions if volatility thresholds are breached. Consistent with this claim, E.U. regulation for capital Markets, MiFID II, addresses the importance of the call auction design. According to Article 19, §1, of the Markets in Financial Instruments Directive (MiFID) II, *"Trading venues shall ensure that appropriate mechanisms to automatically halt or constrain trading are operational at all times during trading hours"* (European Securities and Markets Authority, 2015, p. 268). Thus, all European Union (E.U.) trading venues are required to apply volatility interrupters in their call auctions mechanism after January 2018[17].

In this respect, according to guidelines issued by the European Securities and Markets Authority (ESMA)[18], trading halts include mechanisms that prolong the period of call auctions in case of price deviation with reference to a pre-defined limit. The auction features that are in place from the most E.U. exchanges are: (a) arbitrary closing auction time, (b) limits on the deviation of the closing price by extension of trading time if price exceeds a threshold (i.e., 10% of last traded price) and/or caps on how far auction price can move from last traded price (i.e.,±3%), (c) flexibility, giving the ability to traders to cancel or edit their orders during the whole period of the closing auction and (d) transparency where exchanges continuously disseminate projected (indicative) closing price and the full order book during auctions. Although the Athens Stock Exchange, as a European exchange, has implemented all the above features, no research to date has provided solid evidence of whether such mechanisms do manage to deter investors from determining the closing price. Hence, our study aims to fill this gap, and we believe that our results would be of interest to market practitioners and market regulators.

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[17]Volatility Interrupter is defined as the automatic halt in the trading of specific security and the activation of an interruption in the matching mechanism of a particular security when the price of the trade that is going to be executed exceeds specific price thresholds set by the exchange. These thresholds are usually defined as the percentage deviation of the price of a security with reference to the last price (Reference price) that was executed for the particular security.

[18] Calibration of circuit breakers and publication of trading halts under MiFID II" 06/04/2017, ESMA70-872942901-63,

In this chapter, we investigate for traders' efforts upon influence on the closing price at ASE over two distinct periods that are characterized by a change in the closing price-setting mechanism. In the first period (29/8/2005-28/2/2006), we examine the transition from a value-weighted average price (VWAP) method to a closing call auction method (CCAM). In the second period (31/10/2016-28/4/2017), we compare two variants of a closing call auction method. We focus on a number of investors that represent a significant proportion of the volume of transactions for each of the periods under examination. We base our empirical testing on intraday stock returns of the fifteen (15) stocks with the highest marketability in the ASE. Our methodology is based on the Felixson and Pelli (1999) model of closing price influence, which we expand in two ways. First, we consider investors' behavior based on the whole period under investigation and refer to these as possible "strategic closing price handlers." Second, we introduce in our models an extra variable in order to investigate the possibility that a closing auction may encourage a trading behavior that tends to influence the price just before the closing auction starts, known as the "reference price."

Our results suggest that closing price influence is not completely deterred by the presence of a closing call auction method, either in a plain-vanilla version or a more sophisticated version. In particular, we obtain robust statistical evidence that the big buyers and sellers continue to influence the closing prices. In addition, the reference price is also used to "drive" the closing price. As such, our results match and expand those of Park et al. (2018), for the Hong Kong Stock Exchange.

This thesis offers three main contributions to the literature. First, we assess the impact of a closing call auction method, and how a more elaborate version of it has affected the existence and magnitude of closing price adjustment. Second, we expand our focus and use transactions of the top five (5) and fifteen (15) net buyers or sellers within the whole period under study and not only for one day, as most of the other studies used. We call these traders "strategic closing price handlers" vis-à-vis a daily closing price handler. In this way, we are in a better position to test the propositions of the Market Abuse Regulation directive considering the dominant position of the investors and how they adjust their trading strategy in marking the closing price. Third, we examine the possibility that in a call auction setting, a trader may shift his trading practice just before the closing auction in order to influence the "reference price" to the desired level, which may, in turn, affect the closing price.

The chapter is structured in five sections of which this is the first. Section two (2) presents the data set used and provides a brief description of the microstructure of the ASE related to our results. Section three (3) presents the methodology used, and Section four (4) presents and discusses the empirical results. A final section concludes and provides policy recommendations.

5.2 Data and market microstructure characteristics.

To examine the impact of the auction mechanism on closing price formation, we use two distinct 6-month periods. Our dataset comprises the fifteen (15) most active stocks in the ASE in terms of trading activity (e.g., the value of trades). The data frequency is at the trade by trade level. The sampled stocks account for 67% and 88% of the total ASE trading activity for the first and the second period, respectively. We opt for the most marketable stocks as theoretically, these should be the least susceptible to efforts of closing price determination, Comerton–Forde, and Rydge, (2006), Aggarwal and Wu (2006), Camilleri and Green (2009), and Cordi N. et al. (2018).

The two 6-month sample periods exhibit notable changes in the closing price mechanism used in the ASE. The first period extends from 29/8/2005 to 28/2/2006, the second from 31/10/2016 to 28/4/2017. During the first period, we examine the impact of the introduction of a closing price auction mechanism upon closing price determination. The closing auction was introduced on 28/11/2005, and this date is used to divide the first period into two equally sized sub-periods. During the second period, we examine the change in the closing auction mechanism, which changed from an Enhanced Closing Auction Method to an Alternative Closing Auction without the price tolerance method. The change in the mechanism became effective on the 30/1/2017, which is the date we use to divide the second period into two equally sized sub-periods. In both cases, the use of a sample period of around 130 days before and after the event (i.e., introduction or change in the auction mechanism) is consistent with the relevant literature. Furthermore, it allows us to examine the long-term impact of the change in the closing method, providing sufficient time to examine the behavior of market participants when trying to adjust their trading behavior to a new closing method.

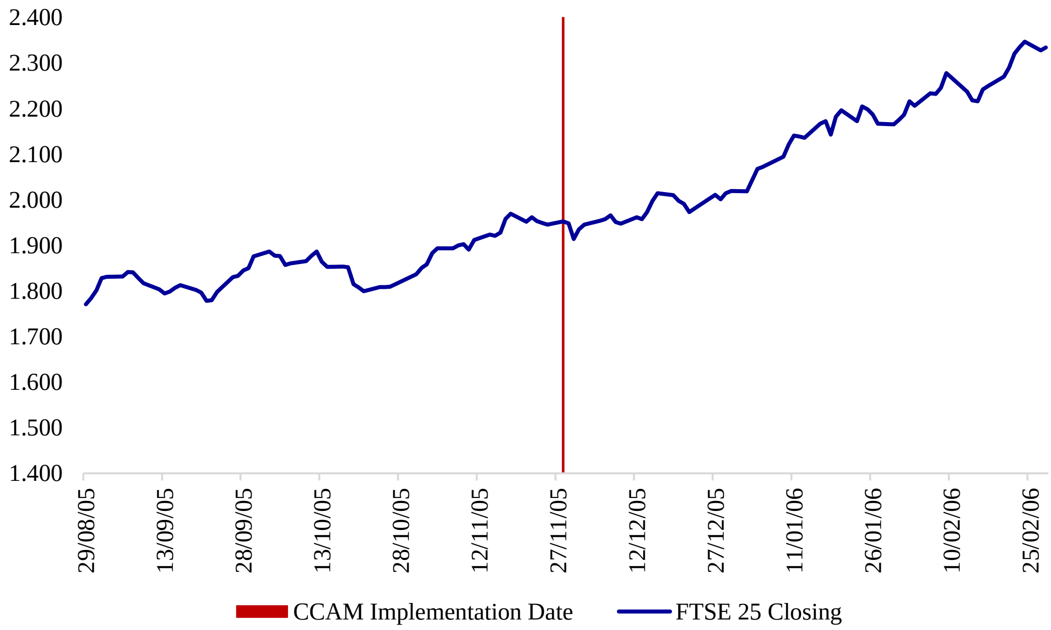
Our dataset is one of the most comprehensive in this line of literature as it contains data of the net participation of each dominant investor (i.e. investor that belonged to the Top 5 or 15 group of the traded volume to each stock for the whole sub-period) that participated during the Continuous phase and the Closing price determination phase at the same day.

A signal of a possible effort to influence the closing price is that the executed trades represent a substantial proportion of the daily volume of trades of a particular stock. This is captured by the fact that we require net buyers/sellers to belong to the top five (5) investors with respect to the volume in each sub-period and refer to these as big buyers/sellers. Hence, the investors selected in this way, command between 7-8% of the total volume across the two periods under investigation. We also check the robustness of our results using the same procedure for the top fifteen (15) investors, which command between 13-14% across the two periods of study.

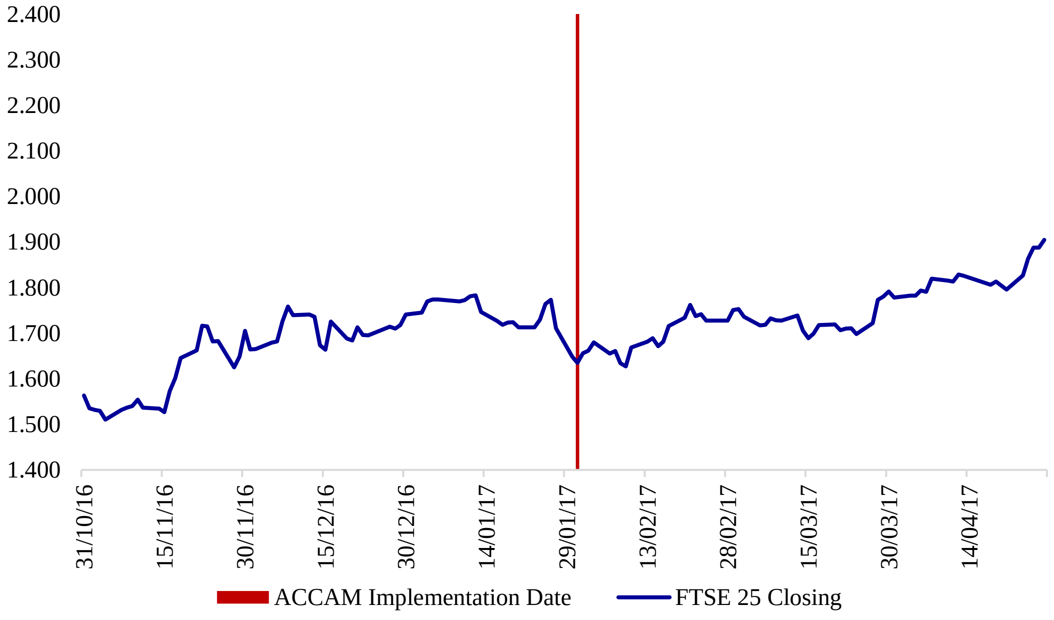
Concerning the information activity for the sample stocks over the two periods of study the value of trades for the 15 most marketable stocks in the first and second periods is around 24.2 and 5.1 billion Euros, respectively while the volume of trades accounts for 1.3 and 7.9 billion shares, respectively. Table 5.1 presents activity information for the sample stocks over the two periods of study. Figure 5.1 plots the evolution of the FTSE Large Capitalization index over the two sample periods in the Athens Stock Exchange, from which our sample is derived. A visual inspection shows a comparable behavior of the index in both periods with a mild upward trend.

Figure 5.1. Evolution of the FTSE 25 Index

Panel A: 29/08/2005 – 28/02/2006



Panel B: 31/10/2016 – 28/04/2017



Notes: The figure plots the evolution of the FTSE 25 Index that features the 25 most active stocks in the Athens Stock Exchange, of which our sample covers the 15 most active over the period 29/08/2005 - 28/2/2006 (Panel A) and 31/10/2016 - 28/4/2017 (Panel B). A first visual inspection verifies an upward trend in both periods. The solid vertical lines represent the change from the VWAP to the CCAM method on the 27/11/2005 (Panel A) and from ECCAM to ACCAM method on the 31/01/2007 (Panel B), see section 3.2 for more details.

Table 5.1. Activity information

	Period 29/8/2005 – 28/2/2006				Period 31/10/2016 – 28/4/2017		
Stock	Number of Trades	Volume of Trades	Value of Trades	Stock	Number of Trades	Volume of Trades	Value of Trades
I	158,969	211,586	3,713	I’	171,446	634,922	1,121
II	200,248	101,696	3,564	II’	234,232	3,478,040	806
III	158,071	114,688	3,207	III’	190,676	2,788,905	520
IV	195,442	95,508	2,512	IV’	232,895	752,522	468
V	165,220	73,116	2,042	V’	102,600	59,452	506
VI	171,236	85,478	1,576	VI’	97,517	63,441	547
VII	131,324	63,011	1,189	VII’	54,850	15,392	212
VIII	75,561	60,982	1,088	VIII’	44,202	15,412	209
IX	59,441	57,149	1,067	IX’	55,660	20,421	127
X	101,723	183,225	928	X’	58,286	7,779	146
XI	162,339	166,383	845	XI’	32,788	8,560	181
XII	99,111	29,130	782	XII’	62,555	33,772	99
XIII	42,865	27,812	676	XIII’	14,815	4,419	96
VIV	112,879	43,778	523	VIV’	46,095	12,630	58
XV	39,955	15,985	503	XV’	30,088	7,772	52
Total	**1,874,384**	**1,329,527**	**24,215**		**1,428,705**	**7,903,439**	**5,148**

Notes: The table presents activity information the sample stocks over the two periods of study. Volume of Trades is measured in thousands and value of trades in million Euros. The stocks are the 15 most liquid in the ASE in each respective period, and are not necessarily the same stocks.

As already mentioned earlier the trading method that is supported for securities closing price determination is the Closing Call Auction Method (CCAM). The CCAM is of particular interest due to its relevance in the closing price formulation. During the two examined periods, the ASE switched two times the processes that are used to calculate the closing price. In particular, ASE switched from the Value Weighted Average Price (VWAP) of a percentage of trades to the Closing Call Auction Method (CCAM) during the first period. In the second period, ASE switched from the Enhanced Closing Auction Method (ECCAM) to the Alternative Closing Call Auction Method (ACCAM). We present in greater detail the closing price calculation methods below.

At the start of our first period, a trading session in the ASE consists of three phases: i) the opening auction phase (10:30 - 11:00); ii) the continuous trading phase (11:00 – 16:00); iii) the close trading phase (16:00 - 16:30). The closing price of each day is calculated at 16:00, i.e., at the start of the last session. The determination of the closing price is governed by the exact method used. Prior to the 27/11/2005 the determination of the closing price was based on the value-weighted average price (VWAP) of the 10% of the daily transactions that occurred before 16:00, starting from the last one before the start of the close trading session and moving backward until the absolute number of transactions that correspond to the 10% of daily transactions has been reached.

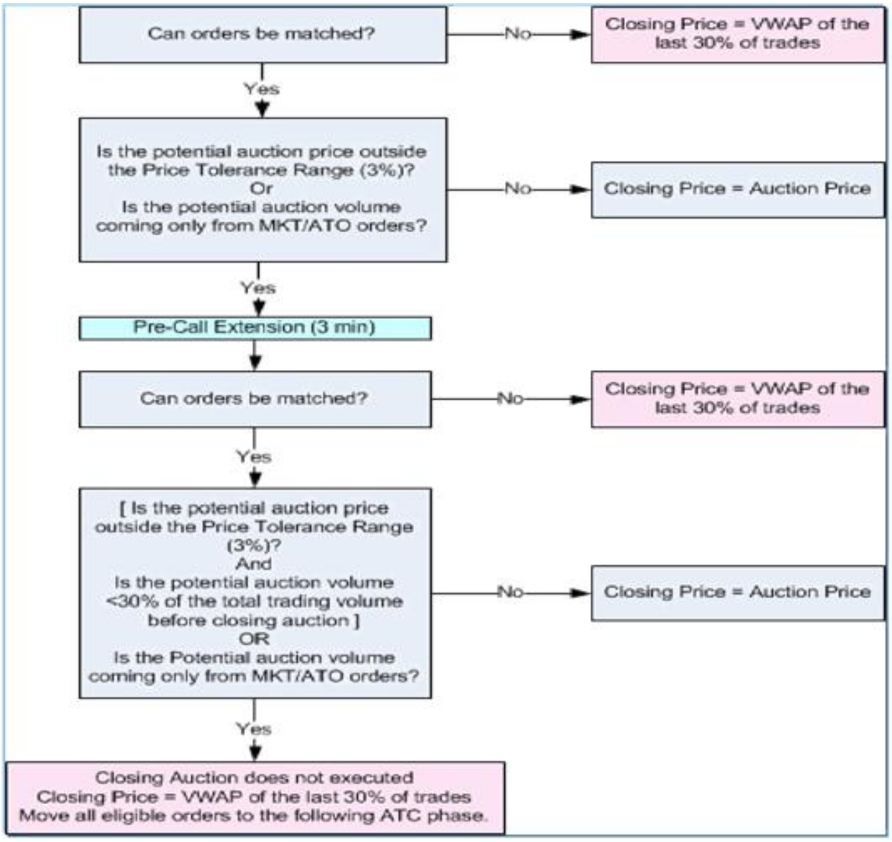
After the 27/11/2005 and to accommodate the introduction of the closing call auction method (CCAM) that replaces the VWAP the trading session consists of four phases: i) the opening auction phase (11:15 – 11:24); ii) the continuous trading phase (11:24 – 16:30); iii) the closing call auction phase (16:30 – 16:39); iv) the close trading phase (16:39 – 17:00). Just before the execution of the auction (i.e., at 16:39) the trading system creates a list of possible auction prices at which the executable volume is maximized. If more than one prices maximize the volume, then the price closest to the reference price is chosen by the system. The reference price is the last recorded price just before the closing auction phase. Thus, the reference price is very crucial, because it is the base price according to which the system will choose to maximize the volume.

The CCAM was operational until the 28/06/2007 when it was enhanced to include features purported to deter market manipulation, such as volatility extensions and interruptions, non-synchronous closing times, increased transparency of projected closing price, full order book, and a price tolerance deviation mechanism[19]. According to this enhanced closing auction mechanism (ECCAM) in case, the closing auction price deviates by more than ±3% (i.e., price tolerance range) or the projected auction volume comes entirely from Market orders (i.e., MKT order rule), then the enhanced closing auction mechanism is overruled in favor of the weighted average price of the 30% of last trades of the daily transactions. Under the ECCAM, it has been possible to extend the closing auction phase under periods of extreme volatility (e.g., projected auction price deviated by more than 3%) and/or the projected auction volume coming entirely from market orders. The extension period was 3 min followed by a random time of 1 min, under which the auction could happen instantaneously. Following this extension period, the system performs additional validations in order to calculate the closing price, namely: i) if the projected auction price continues to deviate by more than ±3%; ii) if the projected auction volume is less than 30% (i.e., volume min rule) of the daily volume; iii) if the total projected volume of the auction comes entirely from Market orders. If these validations are not confirmed, then the VWAP method over the last 30% of the trades is used instead. Diagram 1 shows graphically the ECCAM.

DIAGRAM 1

The different steps that the ECCAM algorithm is using in order to calculate the closing price

[19] The four phases within a trading session during the implementation of the enhanced closing auction mechanism are as follows: i) the opening auction phase (10:15 – 10:30); ii) the continuous trading phase (10:30 – 17:00); iii) the closing auction phase (17:00 – 17:10); iv) the close trading phase (17:10 – 17:20).



The ECCAM has been abolished on the 31/1/2007 by the Alternative Closing Call Auction Method (ACCAM). Compared to its predecessor, the ACCAM abolished the price tolerance range rule but preserved the volatility extensions, the provisions for the dissemination of projected closing price, the full order book, and the non-synchronous closing times. The market schedule remained unchanged.

5.3 Methodology

5.3.1 Panel Data Regression

Panel data models can be used in order to provide information on individual behavior, both across individuals and over time. The data and models have both cross-sectional and time-series dimensions. Panel data can be balanced when all individuals are observed in all time-periods or unbalanced when individuals are not observed in all time-periods. A panel data set is one that monitors a specific sample of individuals along time, and provides several observations on each individual in the sample (Hsiao 2003).

Panel data sets have more than a few advantages as regards to cross-sectional or time-series data sets[20]. If all the cross-sectional units have the same number of time-series observations the panel is balanced, if not it is unbalanced. Below is given a matrix of balanced panel data observations on variable y, N cross-sectional observations, and T time-series observations.

Cross section

Time series

$$\begin{bmatrix} y_{11} & y_{21} & \cdots & y_{i1} & \cdots & y_{N1} \\ y_{12} & y_{22} & \cdots & y_{i2} & \cdots & y_{N2} \\ \vdots & \vdots & \ddots & \vdots & & \vdots \\ y_{1t} & y_{2t} & \cdots & y_{it} & \cdots & y_{Nt} \\ \vdots & \vdots & & \vdots & \ddots & \vdots \\ y_{1T} & y_{2T} & \cdots & y_{iT} & \cdots & y_{NT} \end{bmatrix}$$

Panel data model linear in parameters can be expressed as

$Y_{it} = \beta_1 X_{it1} + \cdots + \beta_\kappa X_{it\kappa} + \alpha_i + u_{it}$ (1) , ι = 1, …, N, t = 1, …, T

Where α_i represents specific fixed effect and u_{it} is the idiosyncratic error. The sum of $\alpha_i + u_{it}$ is known as the composite error. Under the assumptions of the panel data analysis, it is assumed that there exists a random sample from the cross section (assumption 2) and there is no perfect linear relationship between explanatory variables (collinearity-

[20] See Hsiao, C., (2003, 2nd ed), Analysis of Panel Data, second edition, Cambridge University Press. Wooldridge J.M., (2001), Econometric Analysis of Cross Section and Panel Data, The MIT Press. C. Hurlin (University of Orleans)

assumption 3). Also, the idiosyncratic error u_{it} is usually assumed to be exogenous, meaning:

$$E\ (u_{it}|X\text{i}\ ,\ \alpha_i) = 0,\ \text{(assumption 4)}$$

homoskedastic, meaning:

$$\text{var}\ (u_{it}|X\text{i}\ ,\ \alpha_i) = \sigma_u^2,\ \text{(assumption 5)}$$

and lacking of serial correlation, meaning :

$$\text{cov}(\ u_{it}, u_{it}|X\text{i}\ ,\ \alpha_i) = 0.\ \text{(assumption 6)}$$

5.3.1.1 Reasons for using Panel Data

Panel data have advantages[21] such as:

Advantage 1: Panel data estimations can use a large number of data points (N T), increasing the degrees of freedom and reducing the collinearity among explanatory variables. Although this is a way of improving the efficiency of econometric estimates, heterogeneity can arise because of the large number of data.

Advantage 2: Panel data allow economic analyses that cannot be addressed using time-series or cross-sectional data sets.

Advantage 3: Panel data provide a reliable solution for econometric problems that come to surface when there is a presence of unnoticed variables that have a correlation with explanatory variables.

Advantage 4: Although Panel data consist of two dimensions, a cross-sectional dimension N, and a time-series dimension T, thus making the computation of estimators to seem rather complicated, in certain cases the availability of panel data can actually make simpler the computation and inference.

[21] See C. Hurlin (University of Orléans) Advanced Econometrics II February 2018 1 / 61

In order to remove the unobserved variable prior to estimation two methods are used: The Fixed Effect and Random Effect estimators.

A. The fixed-effect (FixEff) estimator can be used in order to analyze the impact of variables that vary over time and it is useful since it eliminates the effect of unobserved variables before the calculation. All explanatory variables that are time-constant are detached together with the unobserved effect. FixEff defines the relationship between predictor and outcome variables within an entity. Since each entity has its own unique features that might have an impact upon the predictor variables, by using FixEff we try to control the impact of the individual on the predictor or outcome variables. This is the explanation behind the assumption as stated above, i.e. the correlation between an individual's error term and predictor variables. In that way, FixEff removes the unique characteristics of the time-invariant variables and it is easy then to examine the remaining effect of the predictors on the outcome variable. Another important assumption of the FixEff model is that those time-invariant features are distinctive to the individual and there should not be any correlation with other individual features. The meaning behind this is that each individual entity is unique, hence the entity's error term and the constant (which captures individual features) should not be correlated with the others. In case where the error terms are correlated, then FixEff should not be used and the model of random-effects should be used instead. This is the main rationale for the Hausman test.

So, fixed effects model is based on a simple way to eliminate fixed effects term: because it is constant in time, subtracting time-averages from all variables in model (1) above removes α_i completely. Let

$$\overline{y_i} = \frac{1}{T}\sum_{t=1}^{T} y_{it} \qquad \overline{x_{ik}} = \frac{1}{T}\sum_{t=1}^{T} x_{it} \qquad \overline{\alpha_i} = \frac{1}{T}\sum_{t=1}^{T} \alpha_{it} = \alpha_i \quad \overline{u_i} = \frac{1}{T}\sum_{t=1}^{T} u_{it}$$

Then

$$\overline{y_\iota} = \beta_1\overline{x_{\iota 1}} + \cdots + \beta_\kappa\overline{x_{\iota k}} + \alpha_i + \overline{u_\iota} \quad (7)$$

and subtracting (7) from (1) gives

$$(y_{it} - \overline{y_\iota}) = \beta_1(x_{it1} - \overline{x_{\iota 1}}) + \cdots + \beta_\kappa(x_{itk} - \overline{x_{\iota k}}) + (u_{it} - \overline{u_\iota}) \ (8)$$

This model no longer includes fixed effects term (see Woolridge 2009), thus it can be estimated using pooled OLS. This estimator is unbiased under standard assumptions (1) - (4). Adding (5) and (6) makes fixed effects the best linear unbiased estimator. “The key insight is that if the unobserved variable does not change over time, then any changes in the dependent variable must be due to influences other than these fixed characteristics.” (Stock and Watson, 2003).

A disadvantage of the fixed effects estimator is that it does not allow for explanatory variables to be constant in time – such variable would be absorbed in α_i term which is eliminated. Another problem is that the process of subtracting averages causes loss of degrees of freedoms, thus these estimators may not be efficient (variances are overestimated). Both issues are addressed by random effects models, which however require an additional assumption.

B. Random Effects Estimation

Random effects model assumes that fixed effects α_i are uncorrelated with explanatory variables:

cov(x_{it}, α_i) = 0 (9).

Under this assumption, even simple pooled OLS estimation would be unbiased. However, the serial correlation problem is still present, thus pooled OLS would produce invalid variances and other statistics. Fixed effects estimation would provide valid results, but it would be inefficient (thus variations would be overestimated). To get rid of this serial correlation, a 'quasi-demeaning' transformation is used:

$$(y_{it} - \lambda\overline{y_{\iota}}) = \beta_1(x_{it1} - \lambda\overline{x_{\iota 1}}) + \cdots + \beta_{\kappa}(x_{itk} - \lambda\overline{x_{\iota k}}) + (u_{it} - \lambda\overline{u_{\iota}}) \quad (10)$$

where

$$\lambda = 1 - \sqrt{\frac{var\ (u_{it})}{var\ (u_{it}) + T\ var\ (\alpha_i)}} \quad (11)$$

This equation is free of serial correlation and thus can then be estimated using OLS. In practice the coefficient λ is naturally not known, as it is a function of (unknown) variances, thus some estimation is used.

Unlike fixed effects, random effects model allows for explanatory variables which are constant in time. Furthermore, random effect estimator is generally more efficient than fixed effects or first differencing. On the other side, the assumption (9) is very restrictive – in many applications it is invalid. Therefore decision between using fixed effects estimator or either fixed effects or first differencing should be made based on information whether (9) does or does not hold. If (9) is assumed to hold, random effects are consistent and more efficient than fixed effects should be used; otherwise fixed effects is preferable. Commonly used to test (9) is the Hausman test, although its results are only indicative. This thesis analyzes relations between stock price returns and various other variables on panel data.

5.3.2 Methodology Used

Our methodology builds on the work of Felixson and Pelli (1999), upon closing price determination for the Finnish stock market. In particular, we refine their criteria by considering and testing the largest and most active investors in ASE for possible influence of closing price for an extended period of time and not on a daily basis. We may call these investors as "strategic closing price handlers" since their objective for closing price determination is long run and are characterized as net buyers or net sellers over a long period of time and not just for a daily trading session. We follow this direction because we believe that the influence of the stock price determination is not based only on intraday profits but also more importantly, on longer-term financial objectives, as mentioned before.

We measure the dominant net positions that investors have and relate this to closing price movements under the different closing price methods. For each stock the performance of an investor and the effect of that performance upon the closing price is calculated as the sum of the volumes at which the investor buys/sells the shares in his portfolio during the whole sub-period with regard to i) his presence as a buyer/ seller during the sensitive period of closing price calculation and ii) the actual movement of the closing price with respect to the reference price (last trade) just before the auction. If the dominant buyer/seller is active during the closing auction, and that activity leads to a significant increase/decrease of the price, then this investor is taken into account. In other words, using the closing price as a base, the activity of an investor who buys/sell during the trading hours of a specific period and at the same time drives the closing price up/below the price before the calculation of the closing price commences is considered as a "strategic closing price handler". Towards the closing time of trading, the investor observes that if the price is not rising/declining with respect to the reference price, and then tries to input orders and trade during the closing auction to drive the closing price up/down to the level that is profitable for his portfolio. The suspected investors attempt to influence the closing price because of the expense it may incur them if the valuation of their portfolio worseness due to the increase/decline of the closing price. We differentiate our model from the model of Felixson and Pelli (1999), in the sense that we do not account for the effect of the next trading day because we consider the price fluctuation of the next trading day to be affected by other factors like overnight news than manipulation, especially when trading is not characterized as thin. Besides, Felixson and Pelli (1999) found insignificant results concerning the next day effect of the price determination.

Following Felixson and Pelli (1999), we estimate the effectiveness of the closing auction mechanism by using panel regressions with random effects and robust standard errors as depicted by the Hausman test for both periods under consideration.

Table 5.2 Correlated Random Effects - Hausman Test

Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	0.207736	2	0.9013

Correlated Random Effects - Hausman Test
Equation: Untitled
Test period random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Period random	3.474397	2	0.1760

Notes: The table gives the results of the Hausman test suggesting that the random effect method is the most appropriate one for both periods

In particular, we estimate the following regressions:

$$r_{t:t-15} = \beta_0 + \beta_1 Dbuy + \beta_2 Dsell + \beta_3 Dcloseprice + \varepsilon_{it} \quad (12)$$

$$r_{t:t-15} = \beta_0 + \beta_1 Dbuy + \beta_2 Dsell + \beta_3 Dcloseprice + \sum_{i=1}^{N-1} \beta_{0i} + \varepsilon_{it} \quad (13)$$

$$r_{t:t-15} = \sum_{i=1}^{N-1} \beta_{0i} + \sum_{i=1}^{N} \beta_{1i} Dbuy + \sum_{i=1}^{N} \beta_{2i} Dsell + \sum_{i=1}^{N} \beta_{3i} Dcloseprice + \varepsilon_{it} \quad (14)$$

$$r_{t:t-15} = \beta_0 + \sum_{i=1}^{N} \beta_{1i} Dbuy + \sum_{i=1}^{N} \beta_{2i} Dsell + \sum_{i=1}^{N} \beta_{3i} Dcloseprice + \varepsilon_{it} \quad (15)$$

where $r_{t:t-15}$ is the return over the last 15-min; Dbuy takes the value of 1 if the big buyer of a particular stock is active at close, zero otherwise; Dsell takes the value of 1 if the big seller of a particular stock is active at close, zero otherwise; Dcloseprice takes the value of 1 if either the big buyer or the big seller makes the last trade just before the auction trying to influence the closing price by setting up the reference price of the auction, zero otherwise and ε_{it} is the stochastic error term. Equation 13 adds firm fixed effects to account for potential differences in the baseline return across the sample stocks, Equation 14 allows for firm fixed effects and interactions with Dbuy, Dsell and Dcloseprice. Hence, Dbuy and Dsell are stock-specific and allow for possible closing price manipulation in a subset of the stocks as well as different extent of manipulation. Equation 15 has a common intercept (i.e., baseline return) but stock-specific interactions with Dbuy andDsell. Equations 12-15 are estimated over the two sub-periods (i.e., VWAP and CCAM) of the first period to investigate the impact upon closing price manipulation pre and post the transition to a closing auction method. A similar estimation takes place in the second period where the two sub-periods are governed by the ECCAM and ACCAM methods, respectively. The Dcloseprice variable only enters the regressions pertaining to the second period as it is only defined if an auction mechanism exists in both sub-periods.

The intuition behind the 15-minute return is that the exact price before the closing session is used (i.e. the price of the trade just before the trades used for the calculation of the VWAP of 10% for the first sub period and the reference price for the rest sub periods as defined before the closing auction). In this way, we can capture exactly the movement of the price that leads to a significant change driven by the big buyers/sellers of the whole sub-period. Felixson and Pelli (1999) and Kucukkocaoğlu (2008) used the relevant stock price 15-min before closing phase, which could not be used in our case due to the peculiarities of the ASE closing auctions, while Kadioglu, Kucukkocaoğlu and Kiliç (2015) used the price as determined by the VWAP of each investor on the basis of the shares of those trading between 15 min before and close of session on the day under consideration, which again is not appropriate as we do not account for day investors but for strategic ones.

According to the theory, we expect a positive (negative) sign on the coefficient $\beta_1, (\beta_2)$ to reflect that the return before the close is higher (lower) if the big buyer (seller) is active. With regards to the β_3 we would expect a positive sign if the big buyer or big seller attempts to influence the closing price succeeds by increasing (decreasing) it to the desired level and at the same time trying to influence the reference price just before the closing auction. The intercept term in the equations stands for the normal return before the close when there is no attempt to influence the closing price by the buyer/seller. In this sense, the intercept term represents a real demand for security if there is no attempt for influencing the closing price.

5.4 Results

The robustness of four closing price determination methods against possible closing price determination techniques is evaluated next. First, we examine the effect of the change of the closing algorithm from a 10% VWAP to the CCAM, which does not have any special design features. Second, we investigate the impact of the transition from the ECCAM to the ACCAM, with the former comprising of four unique auction characteristics purported to deter closing price manipulation, and the latter excludes one of these unique characteristics, namely the price tolerance rule. Third, we examine the possibility of closing price determination via the reference price.

5.4.1 Transition from VWAP to CCAM

First, we examine the impact of the introduction of the CCAM in the ASE, and table 5.3 (upper part) presents the estimated coefficients and standard errors of Equations 12-15 over the two sub-periods, as well as goodness-of-fit information.

Table 5.3. Estimation results for the first period.

	Upper part: Top 5 Investors							
Variables	Panel A: 29/08/2005 - 26/11/2005				Panel B: 28/11/2005 – 28/02/2006			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Dbuy	0.544***	0.448***	*0.447*	*0.543*	0.247***	0.256***	*0.233*	*0.242*
	(0.118)	(0.101)	*[6]*	*[15]*	(0.027)	(0.028)	*[6]*	*[8]*
Dsell	-0.010	-0.161	*-0.077*	*0.018*	-0.206***	-0.203***	*-0.211*	*-0.203*
	(0.243)	(0.230)	*[13]*	*[0]*	(0.026)	(0.028)	*[9]*	*[8]*
Constant	-0.338***	*-0.256*	*-0.243*	-0.338***	0.006	*0.013*	*0.014*	0.006
	(0.117)	*[2]*	*[5]*	(0.118)	(0.012)	*[6]*	*[7]*	(0.012)
Observations	2,753	2,753	2,753	2,753	2,725	2,725	2,725	2,725
R-squared	0.002	0.029	0.036	0.005	0.028	0.069	0.079	0.036
	Bottom part: Top 15 Investors							
Dbuy	0.459***	0.355***	*0.383*	*0.467*	0.279***	0.274***	*0.264*	*0.268*
	(0.067)	(0.051)	*[13]*	*[15]*	(0.017)	(0.016)	*[12]*	*[13]*

Dsell	-0.163	-0.213	*-0.122*	*-0.038*	-0.260***	-0.245***	*-0.255*	*-0.251*
	(0.169)	(0.164)	*[13]*	*[1]*	(0.029)	(0.028)	*[10]*	*[11]*
Constant	-0.255***	*-0.177*	*-0.172*	-0.255***	0.016**	*0.02*	*0.020*	0.016**
	(0.066)	*[4]*	*[11]*	(0.067)	(0.007)	*[9]*	*[10]*	(0.007)
Observations	6,509	6,509	6,509	6,509	6,986	6,986	6,986	6,986
R-squared	0.002	0.020	0.024	0.006	0.037	0.068	0.073	0.046

NOTES: The table presents estimated coefficients and robust standard errors in parenthesis for Equations 1-4 over the first sub-period where the VWAP is the method for determining the closing price (Panel A) and the second sub-period where the Closing Call Auction Method (CCAM) has been introduced (Panel B). The upper part of the table presents the analysis for the top 5 of investors, the bottom presents the robustness with the top 15 investors, see section 3.1 for details. $r_{t:t-15}$ is the return over the last 15-min; Dbuy takes the value of 1 if the big buyer of a particular stock is active at close, zero otherwise; Dsell takes the value of 1 if the big seller of a particular stock is active at close, zero otherwise, see section 4 for more details. Coefficients in italics in models 2-4 are the average estimated coefficients of the statistically significant stocks and the value in square brackets represents the number of statistically significant stocks at the 1% significance level. Statistical significance is marked at the 1% (***), 5% (**) and 10% (*) levels.

A cursory inspection of the results reveals a positive and significant coefficient on the Dbuy across both periods. This suggests that net buyers with a dominant position during this period participate in the closing price formation period and drive the price up more effective during the VWAP period than during the Auction. A diminishing positive and significant coefficient on the Dbuy across both periods show that Auction has improved price formation. A negative and significant coefficient on the Dsell is evidenced only for the second sub-period, where the CCAM is in place. The finding here shows that net sellers may influence the closing price more easily compared to the VWAP. Nevertheless, this result is in line with Park et al. (2018) concerning the limited effectiveness of the plain vanilla auction mechanism. The bottom part of Table 5.3 presents the robustness analysis, where the top 15 investors are used in testing for possible closing price determination. Overall, the results here are consistent with the earlier part and suggest that evidence of an effort to influence the closing price is still present. In addition, the intercept term is positive as expected from theory and captures the well-documented fact that share prices tend to rise before the close (U-shape pattern). Overall, it appears that the introduction of the CCAM did not manage to constrain dominant investors completely from influencing the closing price.

5.4.2 Transition from ECCAM to ACCAM

The second examination relates to the transition from the ECCAM to the ACCAM in the ASE. Both methods are closing auction, but the former also includes the price tolerance rule; see section 3.2 for more details. Table 5.4 (upper part) presents the estimated coefficients and standard errors of Equations 12-15 over the two sub-periods, as well as goodness-of-fit information.

Table 5.4. Estimation results for the second period.

	Upper part: Top 5 Investors							
Variables	Panel A: 31/10/2016 - 31/01/2017				Panel B: 01/02/2017 - 28/04/2017			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Dbuy	0.532***	0.460***	*0.4574*	*0.498*	0.459***	0.365***	*0.359*	*0.429*
	(0.033)	(0.035)	*[11]*	*[12]*	(0.025)	(0.028)	*[12]*	*[13]*
Dsell	-0.411***	-0.477***	*-0.441*	*-0.401*	-0.268***	-0.347***	*-0.326*	*-0.254*
	(0.028)	(0.032)	*[12]*	*[11]*	(0.023)	(0.028)	*[7]*	*[9]*
Dcloseprice	0.061	0.062	*0.065*	*0.085*	0.085***	0.057*	*0.032*	*0.075*
	(0.042)	(0.044)	*[1]*	*[1]*	(0.033)	(0.033)	*[1]*	*[1]*
Constant	-0.050***	*-0.012*	*-0.019*	-0.050***	-0.057***	*0.011*	*0.015*	-0.057***
	(0.005)	*[9]*	*[9]*	(0.005)	(0.003)	*[8]*	*[9]*	(0.003)
Observations	47,884	47,884	47,884	47,884	51,186	51,186	51,186	51,186
R-squared	0.003	0.028	0.029	0.004	0.003	0.013	0.014	0.004
	Bottom part: Top 15 Investors							
Dbuy	0.515***	0.466***	*0.464*	*0.491*	0.477***	0.380***	*0.377*	*0.443*
	(0.022)	(0.024)	*[15]*	*[15]*	(0.018)	(0.019)	*[15]*	*[15]*
Dsell	-0.427***	-0.456***	*-0.449*	*-0.424*	-0.307***	-0.375***	*-0.358*	*-0.291*
	(0.020)	(0.022)	*[14]*	*[15]*	(0.016)	(0.018)	*[13]*	*[13]*
Dcloseprice	0.029	0.014	*0.026*	*0.044*	0.076***	0.045*	*0.033*	*0.075*
	(0.029)	(0.030)	*[2]*	*[1]*	(0.025)	(0.025)	*[0]*	*[0]*
Constant	-0.031***	*0.001*	*-0.002*	-0.031***	-0.050***	*0.017*	*0.022*	-0.049***
	(0.004)	*[12]*	*[12]*	(0.004)	(0.003)	*[13]*	*[12]*	(0.003)
Observations	61,546	61,546	61,546	61,546	64,321	64,321	64,321	64,321
R-squared	0.007	0.032	0.033	0.008	0.008	0.018	0.019	0.009

NOTES: The table presents estimated coefficients and robust standard errors in parenthesis for Equations 1-4 over the first sub-period where the ECCAM is the method for determining the closing price (Panel A) and the second sub-period where the ACCAM is used

(Panel B). The upper part of the table presents the analysis for the top 5 of investors, the bottom presents the robustness with the top 15 investors, see section 3.1 for details. $r_{t:t-15}$ is the return over the last 15-min; Dbuy takes the value of 1 if the big buyer of a particular stock is active at close, zero otherwise; Dsell takes the value of 1 if the big seller of a particular stock is active at close, zero otherwise, see section 4 for more details. Dcloseprice takes the value of 1 if either the big buyer or the big seller makes the last trade just before the auction trying to influence the closing price by setting up the reference price of the auction, zero otherwise. Coefficients in italics in models 2-4 are the average estimated coefficients of the statistically significant stocks and the value in square brackets represents the number of statistically significant stocks at the 1% significance level. Statistical significance is marked at the 1% (***), 5% (**) and 10% (*) levels.

An inspection of the results shows a positive and significant coefficient on the Dbuy and a negative and significant coefficient on theDsell. No significant change is detected between the two sub-periods, which suggests that dominant investors influence the closing price under both closing call auction methods. Indeed, even with the more complex ECCAM in place, it has not been possible to eliminate their effort to influence the closing price, which generalizes the finding of Park et al. (2018). The Dcloseprice variable provides interesting reading. In the first sub-period with the ECCAM in place, it fails to reach conventional significance levels, but during the second sub-period with the ACCAM Dcloseprice becomes significantly positive. This may suggest that a small change in the characteristics of the closing call auction method made influence of the closing price more severe, as it is now easier for dominant investors to affect the reference price and drive the closing price at their desired level. A closer investigation of the individual stock marginal effects reveals that the influence of the reference price is particularly strong for certain stocks, and may be affected by firm-specific factors and/or investor expectations and information. The bottom part of Table 5.4 presents the robustness analysis with the top 15 investors included in the analysis. Overall, the results here are consistent with the earlier part and suggest that evidence of influencing of the closing price is still present under both closing call auction methods. Furthermore, closing price determination is enhanced when the price tolerance rule is abolished as perspective dominant investors may target the reference price.

5.5 Conclusions and policy implications

The closing price manipulation might affect market participants in many ways. For example, it may affect the unit price of the Open end Mutual Funds; technical analysts reports which are based on the closing price; automated trading based on programming which uses an input the closing price, as well company valuation as this may be used in mergers deals or loan agreements backed by securities.

Auction mechanisms reduce the possibility of manipulation since market participants attempting to manipulate closing prices would need to submit larger trade orders and spend more capital. The closing call auction mechanism adopted by the Athens Stock Exchange (ASE) in 2005 was a step forward into the effort of acquiring a trading methodology for a more efficient price formation. In this thesis, we provide the first assessment of two markedly different techniques for determining the closing price upon stock market manipulation, namely the value-weighted average price (VWAP) and the closing call auction method (CCAM), that took place in the ASE during the 29/8/2005-28/2/2006 period. In a similar fashion, we examine the transition between two variants of the closing call auction method over the 31/10/2016-28/4/2017 period to assess the impact of the additional restrictions imposed on the closing call auction method upon determination of the closing price. We use trade by trade data of the top investors regarding their trading activity, on the fifteen most active stocks in the ASE and expand on the Felixson and Pelli (1999) model of closing price manipulation. In particular, we consider investors' behavior based on the whole period under investigation and refer to these as possible "strategic closing price handlers". In addition, we introduce an extra variable in order to investigate the possibility that a closing auction may encourage a trading behavior that tends to affect the price just before the closing auction starts, known as the “reference price”.

Our results strongly indicate that closing call auction in the ASE did not manage to eliminate efforts of the dominant investors to determine closing price. Notably, during the periods that the ASE introduced the closing call auction mechanism with procedures including precautions against price manipulation, like volatility interrupters, non-synchronous closing times, dissemination of projected closing price and full order book, and a price tolerance deviation method, the statistical results obtained do not support closing price manipulation deterrence. The findings of our study further support that small details in the closing call auction design, like the price tolerance deviation rule, can affect the effectiveness of the mechanism against efforts for forming the closing price.

Focusing on the characteristics of a possible effort on closing price determination environment, this may depend on aspects such as the marketability of the stock in question, or the specific design of the auction mechanism. Many studies suggest that price manipulation typically occurs among illiquid and less tradable stocks, and as noted by Camilleri and Green (2009), opening and closing call auctions may not necessarily improve share trading in a less liquid emerging market. Our results suggest that closing price determination can arise even for liquid and active in terms of trading stocks. In addition, possible price determination tends to persist since it seems to adapt to different closing methods; even if these are supposed to be sophisticated.

Trading venues have introduced a vast number of mechanisms by vigorous enforcement of the Law and trading rules, which include direct supervision, inspection, reporting, product design requirements, position limits settlement price rules, market halts, and closing auction methods in order to sustain stock price manipulation. The reason why most of the

E.U.'s stock exchanges use call auction mechanism for determining closing prices of listed companies is because closing auctions theoretically contribute to making listed companies more visible and traceable at large quantities of shares, with a high degree of execution probability and reliable prices. The outcomes of the current analysis support that call auction mechanism should be a dynamic process and should be redesigned at relatively short periods of time, not giving time to possible manipulators to adapt and take advantage of the weaknesses of a current auction system. In this direction, trading venues should readjust volatility interrupters parameters on a regular basis according to recent metrics every time.

6. CONCLUSION

This thesis focuses on market microstructure issues in the Greek stock market in two main themes: market efficiency in conjunction with the seasonality of stock pricing and closing price determination. The ultimate aim of this thesis is to present an analysis of these two issues, the connection between them, and to provide empirical evidence to researchers, trading venues, and government regulators on designing trading matching mechanisms. Although studies based on intraday stock market indices and individual stock data are well-documented for the stock market in Greece, there is not any exploration of the microstructure effect upon the seasonality and closing price determination of the stock prices in Greece.

In general, the studies that examine the effect of market microstructures take into account the effects of market design on efficiency by examining factors like the open and close price calculation. One of the microstructure's applications is to facilitate the advancement of trading strategies and algorithms for market participants. The significance of this application is apparent in the recent evolution of algorithmic trading. Trading algorithms are built based on the depth of the order book, the exact market schedule that the order will be placed upon like opening, continues or closing, and the selection of the matching algorithm like: a pure call auction mechanism; a continuous limit order book market; a quote driven dealer market; a block trading matching mechanism, or combinations of the above. Equity markets usually facilitate trading using two order-matching mechanisms, namely a call auction and a continuous matching method. In a call auction market, investors' orders are gathered for execution at a specific point in time. The active orders entered during the call auction method form a single price, which enables those orders that maximize the volume at that price to be executed.

In contrast, a continuous market facilitates the immediate execution of buy and sell orders as they arrive in the market (assuming they are matched), leading to a sequence of trades occurring at different prices. Nowadays, numerous international stock exchange such as the Nasdaq, the Euronext Paris, the Deutsche Borse, the London Stock Exchange, the Australian Stock Exchange, etc., have adopted their trading mechanism to include the call auction to open and close the trading day. In contrast, the remainder of the day's trading activities continued to rely on the continuous trading method. The objective of using the call auction, as part of the trading mechanism, is to promote a liquid and efficient market, through minimal trading costs and market frictions. Consequently, participants face further decisions when operating in a call plus continuous, mixed market: how to submit an order to a call auction which is followed by continuous trading (e.g., an opening call), and how to submit an order to a continuous trading environment that is followed by a call auction (e.g., a closing call). Taking these tactical decisions into account is part of the complexity of microstructure analysis. In this regard, volatilities were examined between call auction and continuous matching mechanism in order to identify the nature of the systemic pattern in return volatilities.

This thesis examines the behavior of intraday return and return volatility. The statistical properties and systematic characteristics of intraday returns and return volatility are explored using 15-minute data of the General Composite Index of Athens Exchange. Contrary to EMH, stock returns and stock return volatility in the Athens Stock Exchange follow a U shaped pattern. This intraday pattern is so persistent that it was not affected either by the introduction of MiFID I in 2007 and that of OTC trading in early 2008 or the Lehman’s Brothers crisis in 2008. Furthermore, this analysis emphasizes the significance of the negative returns together with its volatilities at 10:45 a.m. (after the opening auction), and the persistence of the high volatility of another half an hour attributable to the dominant position and trading behavior of Market Makers. In addition, significant negative returns of Mondays opening prices, and Wednesday and Thursday's positive significant return for open prices can be attributed to the clearing and settlement effect. Finally, Friday is the only day that return is positive and significant indicating the end of week effect for the Greek Market as well.

Also, this thesis did not depart from the findings of other studies that produced evidence of the so-called "end of the day" anomaly which actually lead us to observe high closing prices during the whole sample period. An explanation of this can be based on market manipulation literature. Due to the possible harmful effect of market manipulation to price formation, MiFID II explicitly imposes the obligation to trading venues to maintain systems and rules against possible manipulation and to be able to investigate and impose fines to members that break these rules.

Confidence in the fairness of markets improves their efficiency and liquidity. Market manipulation, misleading conduct, insider trading, and other fraudulent or deceptive conduct, may distort the price discovery system, distort prices and unfairly disadvantage investors. Therefore, stock markets regulators need to be able through well-established systems and mechanisms to expose, examine, and sue market manipulation. This is quite important given the fact that manipulative technics continuously evolve and take advantage of the arbitrage mechanism existing in different trading venues.

It is a general belief that auction mechanisms reduce the possibility of manipulation since market participants attempting to manipulate closing prices would need to submit larger orders. Besides reducing the influence of manipulative orders, the consolidation of liquidity also reduces the profitability of manipulative strategies by increasing the execution cost and risk for traders trying to manipulate the auction. Closing call auction sessions were one of the measures proposed to improve price efficiency in ASE. They entered into force on December 12, 2005, to reduce extraordinary price movements and to ensure more efficient price formation in ASE. Our study aims to test the existence of efforts to determine the closing price and the effect of closing call auction sessions on the deterrence of this effort by analyzing the most liquid 15 shares of ASE. The method developed by Felixson and Pelli (1999) is utilized in this work to test whether or not closing prices were handled and to test the effectiveness of closing auction. Within this model of Felixson and Pelli, it is statistically possible to discuss the existence of closing price determination in ASE prior to the implementation of closing call auction sessions.

Contrary to the general belief, our results strongly indicate that closing call auction in ASE managed to diminish the efforts for closing price determination, but not to eliminate them. Notably, during the periods that ASE introduced call auction mechanism with procedures including precautions against price handling like volatility extensions, non-synchronous closing times, dissemination of projected closing price, and a price tolerance deviation method, the statistical results obtained do not support complete closing price manipulation deterrence. The findings of our study also support the conclusion that seemingly minor details in call auction design like the abundance of the price tolerance deviation method can meaningfully affect the call auction’s performance as it is measured through the effort to determine the closing price.

Going into a more in-depth analysis of the indications of the possibility to affect closing prices, this is highly dependent on aspects such as the liquidity of the stock, or the specific design of the auction mechanism. This is why we chose the liquid stocks for our sample, and we validated the importance of the reference price just before the auction commences. However, liquidity, a change in the closing mechanism, and the impact of the dominant investors upon the reference price that "drives" closing prices led us to conclude that they are not enough to completely deter price closing determination in the case of ASE.

These findings indicate that regulators and trading venues, when building the specific characteristics of an auction mechanism as the closing price identifier, they should take into account parameters like liquidity and volatility behavior of the concerned stocks. Trading venues should adjust their volatility interrupters by taking into account the liquidity and volatility profile and the quotation level of the financial instruments. Another important aspect to be taken into account by trading venues is the frequent recalculation of the volatility interrupters characteristics that must be done by trading venues.

ASE, after the recent change in the closing algorithm (30/1/2017), introduced liquidity classes to all stocks and assigned different volatility parameters and closing calculation methods. More specifically, regarding the Closing Price of the Securities for the most liquid stocks, the closing price is calculated only by Auction as it was mentioned. For the stocks, with no liquidity, the closing price is calculated, taking into consideration more parameters, such as the value of the trades at the auction period compared with the security Capitalization, in order to avoid the determination of a closing price by low valued trades[22]. It remains to validate and check the effectiveness of this categorization, especially concerning less liquid stocks.

[22] For a brief description of the structure of ASE regarding liquidity classes see Appendix V.

Given these weaknesses, there is a need for ongoing research is concerned, using intraday transaction data. As far as market microstructure, further research on (1) the trading mechanism of the call auction and continuous trading, (2) the effects of converting calculation of closing price mechanism to a call auction method, and (3) the effect of changing the thresholds defined for the price restrictions, under volatility shocks are directions for further research.

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Appendix I – Orders' Data

Every order of a specific stock that is transmitted by the members to OASIS, is entered as a record which includes the following information:

Buy or Sell – The possible marks received are:

B for buy

S for sell

OASIS Symbol – Determines the security (stock, right or bond), to which the order is referred. Each security, entered in the system, receives a unique code name of five keys, named OASIS symbol and determines the security.

Total Number of Units – Determines the total number of offered or requested units of the specific security. Only integer numbers are accepted.

Disclosed Number of Units – Determines the disclosed number of offered or requested units of the security, which can be equal to or less than the total number of units.

Price – Determines the price of order. The prices that may get are:

> **Price Limit**, into the limits, determined by ASE: For the bid orders, the buyer declares that he is interested in making a trade with price less than or equal to the written price. For ask orders, the seller declares that he is interested in making a trade with price higher than or equal to the declared one.
>
> **MKT:** The order is called "Market" and the system automatically records, that the buyer/seller is interested to realize a trade in any price that an opposite order will appear in the order book. If no order from the opposite side exists, then MKT order is cancelled.
>
> **ATO –** At the open (only in call auction phases): The buyer/seller is interested to realize a trade at the call auction price, wherever it will be determined.
>
> **ATC –** At the close: The order will be matched, if possible, only at the close price, that will be calculated after the determination of the closing price.

Client's Account: Determines, through a 12 key string code, the identity of client of the member. This code is obligatory and it is used for clearing purposes.

Account's Type: The account's type is determined. The marks that it can take are:

C for a client (final investor)

M for member interest

Internal client's Code: Determines, through an 11 key string code, the internal code that the Member assigns to the order. This code is optional and it is used for the member's internal use.

Code of Clearing member: Determines, through a code, the identity of the member which is responsible for the clearing of trades. This code is obligatory; it is filled automatically by the system and is, by definition, the same with the ID of the member who entered the order.

Special Conditions: The possible marks received are:

> **STOP:** The STOP orders remain inactive in the system, until the satisfaction of the activation criterion. For buy orders, the criterion is activated when a trade is executed, to a price equal to or higher than the STOP price. For sell orders the criterion is activated when a trade is executed, to a price equal to or less than the STOP price. STOP orders may be either Limit STOP or MKT STOP. By the entry of the special STOP condition the relevant fields must be completed, which declare, the STOP activating symbol and the price in which the stock condition will be activated. The STOP symbol may be either a stock, to which the order is referred, or another stock or an index.
>
> **Immediate or Cancel (IOC):** The condition IOC defines if the order will be executed immediately or it will be cancelled. If the order is partially executed, the unexecuted number of shares is cancelled by the system.
>
> **Fill or Kill (FOK)**: The condition FOK defines whether the order will be executed immediately and totally or it will be cancelled.
>
> **Duration:** It defines the lifetime of the order which can be:
>
> **Day order (DAY):** which lasts only for the current trading session.

Good Till Date (GTD): which lasts up to the date, which must also be defined.

Good Till Cancel (GTC): which lasts until it will be cancelled.

If the price of a duration order, in the course of sessions, is out of the daily price boundaries, the order becomes inactive.

Remarks: Space for optional use by the member.

Inactive Order: Defines if the order will be entered in the system, as inactive. Inactive orders get time stamp, as soon as they activate.

Appendix II – Orders' Examples

Orders without Conditions

Example 1 – Limit Orders

Let, the book of orders during the CAMM phase looks as follows:

Stock CD	
Buy	**Sell**
100 @ 2,74	
300 @ 2,60	
1.000 @ 2,52	
500 @ 2,50	

Orders are classified by price/time priority. Suppose that an order of sell 500 @ 2,40 is entered. Orders are executed from upwards to downwards with the following trades to be executed "100 @ 2,74", "300 @ 2,60" and "100 @ 2,52". The order book includes, after the executed trades, the following orders:

Stock CD	
Buy	**Sell**
900 @ 2,52	
500 @ 2,50	

Example 2 – Market Orders (MKT)

The order book for CD stock includes the following orders, by the time the order "Sell 600 CD MKT" is entered:

Stock CD	
Buy	**Sell**
100 @ 2,30	30 @ 2,42
100 @ 2,30	10 @ 2,48
200 @ 2,30	200 @ 2,58

Stock CD	
Buy	**Sell**
100 @ 2,20	100 @ 3,02
200 @ 2,20	100 @ 3,12
100 @ 2,08	
100 @ 2,04	

The following trades will be executed: “100 @ 2,30”, “100 @ 2,30”, “200 @ 2,30”, “100 @ 2,20” and “100 @ 2,20”.

The MKT order was fully executed. After the implementation of order, the order book will look like this:

Stock CD	
Buy	**Sale**
100 @ 2,20	30 @ 2,42
100 @ 2,08	10 @ 2,48
100 @ 2,04	200 @ 2,58
	100 @ 3,02
	100 @ 3,12

Example 3 – At The Open Orders (ATO)

Supposing, in the phase of determination of opening auction price, the order book includes the following orders according to price/time priority:

Stock CD	Reference Price = 2,52
Buy	**Sell**
500 @ MKT	1.000 @ MKT
300 @ ATO	2.000 @ ATO

500 @ 2,74	500 @ 2,52
100 @ 2,60	
200 @ 2,52	
1.000 @ 2,40	

Observe that orders with ATO price have priority over limit orders and the orders with MKT price have priority over ATO due to time priority and limit orders due to price priority.

Auction price, after the calculation of the auction price, will be 2.52 for the way of calculation ATO price). The executed trades are the following:

Order " Sell 1.000 @ MKT" will be matched with buy orders " 500 @ MKT", "300 @ ATO" and partially (200 stocks) with "500 @ 2,74".

Order "Sell 2,000 @ ATO" will be matched with buy orders "300 @ 2,74", (the unexecuted number of shares after the first trade), " 100 @ 2,60", and " 200 @ 2,52".

After the end of the above trades, the order book will be:

Stock CD	Opening Price (Last Price) = 2,52
Buy	**Sell**
1.000 @ 2,40	500 @ 2,52

The 1.400 units of the order "Sell 2,000 @ ATO" which were not executed, are cancelled by the system.

Example 4 – At The Close Orders (ATC)

Let's suppose, that after the closing auction the system has entered into the "At the close" (ATC) trading phase and the order book looks like the following:

Stock CD	Closing Auction Price: 5,00

Buy	Sell
1.000 @ 5,26	1.000 @ 5,36
1.000 @ 5,22	1.000 @ 5,42
300 @ 5,12	
200 @ 4,90	
300 @ ATC	

If an order "sell 3,000 CD @ ATC" is entered during the "At the close" phase then:

At the price of 5,00 the following trades will be executed, with the following sequence: First the " 1,000 @ 5,26", then " 1,000 @ 5,22", " 300 @ 5.12" and at the end "300 @ ATC".

Observe that the buy order " 200 @ 4.90" is not executed, because orders may be executed at the ATC price, only if their price is equal to or greater than ATC (which means, for buy orders, that their price is ≥ than ATC price and for sell orders ≤ than ATC price.

After the execution of trades, the order book includes the following orders:

Stock CD	Closing Auction Price: 5,00
Buy	**Sell**
200 @ 4,90	400 @ ATC

Conditional Orders

Example 5 – STOP Limit

The order book is, as follows:

Stock AB	Last trade 10,44
Buy	**Sell**
100 @ 10,70	200 @ 11,70
300 @ 10,86	200 @ 11,84
STOP AB 10,70 1.000 @ 11,84	

A trade "10 @ 10,70" is executed and then automatically STOP order is activated (released).

Then the order book will be as follows:

Stock AB	Last trade 10,70
Buy	**Sell**
1000 @ 11,84	200 @ 11,70
90 @ 10,70	200 @ 11,84
300 @ 10,86	

After the matching of orders, the order book will be as follows:

OTE Stock	Last trade 11,84
Buy	**Sell**
600 @ 11,84	
90 @ 10,70	
300 @ 10,86	

Example 6 –STOP Index Limit

Let's imagine that the index FTSE is at 1,350 units and the order book is as follows:

Stock CD	Last price: 11,70
Buy	**Sell**
1000 @ 11,40	100 @ 11,70
200 @ 11,02	500 @ 12,32
STOP FTSE 1,360 A CD 1,000 @ MKT	

As a result of aggressive buy orders to stocks comprising the FTSE index, FTSE rises to 1,360 and then automatically STOP order is activated. After the execution of trades, the order book will look like this:

Stock CD	Last price: 12,32
Buy	**Sell**
400 @ 12,32	
1000 @ 11,40	
200 @ 11,02	

The activation of STOP order, had the effect of a trade at 11.70 with "100 @ 11.70" at first and then with "500 @ 12,32". After that the remaining volume of 400 of the MKT order was changed to a limit order at the last trade price ie 400 @ 12,32.

Example 7 – Immediate Or Cancel (IOC)

The order book is, as follows:

CD Stock	
Buy	**Sell**
100 @ 2,84	2.000 @ 2,20 IOC
300 @ 2,70	
1.000 @ 2,56	
500 @ 2,40	

The following trades will be executed: "100 @ 2,84", "300 @ 2.70", "1,000 @ 2.56" and "500 @ 2.40". The rest of 100 stocks will be cancelled due to IOC condition.

Example 8 – Fill Or Kill (FOK)

The order book is as follows:

AB Stock	

Buy	Sell
100 @ 2,84	2.000 @ 2,20 FOK
300 @ 2,70	
1.000 @ 2,56	
500 @ 2,40	

There will be no execution and FOK order will be cancelled due to the fact that not all of the 2,000 units of the order, are eligible for execution.

Example 9 – Bonds, Hit & Take Method

The order book in the Special Terms Board for a bond looks like this:

AD Bond	
Buy	**Sell**
100 @ 101.418 MO10	100 @ 101.408 MO20
50 @ 101.416 AON	40 @ 101.418 AON
25 @ 101.384 MF5	100 @ 101.626 MF15

With the Hit & Take method, user may choose any of the 6 above orders in order to realize a trade.

Buy orders

The buy order "100 @ 101,418 MO10" may be executed with one or more opposite orders, with volume multiple of 10.

The buy order "50 @ 101,416 AON" may be executed with an opposite order, only in its total.

The buy order "25 @ 101,384 MF5" may be chosen with one or more opposite orders, with volume equal to or higher than 5.

Sell orders

The sell order "100 @ 101,408 MO20" may be executed with one or more opposite orders, with volume multiple of 20.

The sell order “40 @ 101,418 AON” may be executed with an opposite order, only on its total.

The sell order “100 @ 101,626 MF15” may be chosen by one or more opposite orders, with volume equal to or higher than 15.

Appendix III –Algorithms

Example of Closing Auction Price Calculation Algorithm

Let's suppose that the order book, during the determination phase of closing auction price is, as follows:

Stocks: XYZ	Reference price: 22,28
Buy	**Sell**
1.000 @ 19,34	3.000 @ 13,48
1.000 @ 19,34	1.000 @ 16,40
2.000 @ 19,34	2.000 @ 19,34
2.000 @ 16,40	3.000 @ 19,34
2.000 @ 16,40	1.000 @ 22,28
1.000 @ 13,48	
3.000 @ 10,54	

The system creates the following table in order to find the prices where the volume is maximized:

Aggregated Buy Vol	Buy Vol	Projected Auction Price	Sell Vol	Aggregated Sell Vol	Projected Auction Vol
12.000	3.000	10,54		0	0
9.000	1.000	13,48	3.000	3.000	3.000
5.000	4.000	16,40	1.000	4.000	4.000
4.000	4.000	19,34	5.000	9.000	4.000
0		22,28	1.000	10.000	0

There are two possible closing auction prices, in which the trading volume is maximized, among sell and buy orders: at 16,40 and at 19,34. Since the reference price (ie the last trade before the auction) is at 22,28, the system will calculate the closing auction price at 19,34, which is closer to 22,28 than the price of 16,40.

After the closing auction, the order book will have the following orders:

Stock: XYZ	Last trade (closing) price: 19,34
Buy	**Sell**
2000 @ 16,40	2000 @ 19,34
2000 @ 16,40	3000 @ 19,34
1000 @ 13,48	1000 @ 22,28

Appendix IV – Bonds in ASE

Supported types of Fixed Income Securities

ASE supports the following types of Fixed Income securities:

Issuer	Coupon	Rate	Cash Flows	Cash flow timing	Maturity date
International Organizations	Regular	Fixed	Normal	Periodical	Specific
Government	Zero Coupon	Floating		Non periodical	Without Expiration Date
Listing Companies					

At the same time securities trading certificates are also supported:

1. Rights of premature settlement from the issuer of bond-holder
2. Rights of conversion
3. Bonds that have been issued in foreign currency
4. Bonds for which Coupons and the nominal price trading separately (STRIPs)

Traded Value and Accrued interest

The value determination of one transaction in Bonds market is calculating according to the next equation:

Bond Trade Value = Price * Quantity * Face Value + Accrued Interest

Where:

- Price: The trade price of bond expressed as percentage on the hundred of face value.(ex 102.2341%).
- Quantity: Quantity of bond trade expressed in units

- Face Value: Bond Face Value.
- Accrued Interest

The accrued interest is calculated as follows:

$$\text{Accrued Interest} = \text{Quantity} * \text{Face Value} * \text{Coupon Rate} * \text{Day's Basis}$$

Where:

- Quantity: Quantity of action of bond expressed in units
- Face Value: Bond Face Value
- Current Coupon Rate
- Day’s Basis: Is the number of Day’s Count divided by base year. The day’s Count (in calendar days) is calculated as follows:
- Day’s Count = Settlement Date – Previous Coupon Date

Clearing & Settlement

According to the current models in the European markets, it is assumed that the owner of bond during clearing is the seller of bond. Hence, the seller of bond receives the accrued interest until the date of clearing.

If the date of clearing is equal to the day of payment of coupon, the seller receives coupon from the issuer of bond and the accrued interest are zero. Moreover, if the date of clearing is after the day of payment of coupon, the issuer pays the value of coupon to the seller and the buyer pays to the seller the accrued interest of the new coupon period proportional to the number of days that intervenes from the date of payment of forth mentioned coupon and date of clearing.

So, the settlement Date is included in the calculation of Day’s Count (inclusive) while the holder of bond is assumed to be the seller, while Previous Coupon Date is not included (exclusive) as it is the last day of previous interest period.

It is reminded that the Packets of Settlement are cleared in time T+0 and as a result the accrued interest for these packets will not be zero, with the exception of the payment day of the coupon.

Appendix V- General Information on trading procedure

Market	Segment	Trading Rules	Trading system	CCP	Members	Settlement Cycle	Trading Unit	Trading session	Duration of the session		Trading Details/Methods
									From	To	
Securities Market	Main Market	According to Athens Stock Exchange Rulebook, EU regulations and texts with institutional content	Automated Integrated Trading System (OASIS)	Athens Exchange Clearing House SA (ATHEXClear)	The Trading Members who participate in the trading services are distinguished based on their headquarters and the place of their activities into: 1. Trading Members based in Greece 2. Trading Members based in Cyprus 3. Trading Members based outside Greece and Cyprus (Remote Members	T+2 T+3 T+4	All the transferable securities listed in ATHEX, are traded with a trading unit of one (1) share. The trading unit for all derivatives products of the derivatives market of ATHEX is one (1) contract.	Pre-Call	10:15	RTP: between 10:29 and 10:30	«Method 2»
								PAP/V	Throughout the preceding period		
								Trading Session	Expiry of the preceding period	17:00	«Method 1»
								Call Auction	13:45	RTP: between 13:59 and 14:00	«Method 2» - Conducted only on the 3rd Friday of each month to calculate clearing prices in the Derivatives Market. If the day in question is a holiday, it is conducted on the immediately preceding business day.
								PAP/V	Throughout the preceding period		
								At-The-Close Trades	Expiry of the preceding	17:20	«Method 3» - Trades are concluded at the closing price
								Forced Sales	10:16	10:26	«Method 5-1»
								Pre-Agreed Trades cleared by ATHEXCLEAR	10:30	5:20	«Method 6-1» - Simple Block Trades
									10:30	5:20	«Method 6-1» - Simple block trades with special fee which involve the transfer of stock of companies limited by shares, the majority of whose shares belong directly or indirectly to the Greek State (total value of over €150,000,000) or whose total assets exceed €1,500,000,000, from the shareholders to

											the underwriters of the placement.
									10:30	5:10	«Method 6-1» Simple block trades with same day settlement, with or without special fee
									Conducted from 10:30 to 17:20 up to and including the fourth (4th) day following the transaction covered by the bilateral lending or borrowing (T+4)		«Method 6-3» Restitution Block Trades
								Pre-Agreed Trades not cleared by ATHEXCLEAR	Conducted during a special period from 10:30 to 17:10		«Method 6-2» Spot 1 Settlement Block Trades
									Conducted during a special period from 10:15 to 10:30		«Method 6-2» Spot 2 Settlement Block Trades
								Force sale of certificated registered shares	Entry of buy orders from 10:20 to 17:10 Entry of sell orders from 17:10 to 17:20		«Method 4» Special Terms Board
	Surveillance Segment							Pre-Call	10:15	RTP: between 11:58 and 12:00	«Method 2»
								PAP/V	Throughout the preceding period		
								Call Auction	Expiry of the preceding period	RTP: between 13:43 and 13:45	«Method 2»
								PAP/V	Throughout the preceding period		
								Call Auction	Expiry of the preceding period	RTP: between 15:28 and 15:30	«Method 2»
								PAP/V	Throughout the preceding period		
								Call Auction	Expiry of the preceding period	RTP: between 17:08 and 17:10	«Method 2»
								PAP/V	Throughout the preceding period		
								At-The-Close trades	Expiry of the preceding period	17:20	«Method 3» Trades are concluded at the closing price
								Forced Sales	10:16	10:26	«Method 5-1»
								Pre-Agreed Trades cleared by ATHEXCLEAR	10:30	17:20	«Method 6-1» - Simple block trades
									10:30	17:20	«Method 6-1» - Simple block trades with

											special fee which involve the transfer of stock of companies limited by shares, the majority of whose shares belong directly or indirectly to the Greek State (total value of over €150,000,000) or whose total assets exceed €1,500,000,000, from the shareholders to the underwriters of the placement
									10:30	16:45	«Method 6-1» Simple block trades with same day settlement, with or without special fee
									Conducted from 10:30 to 17:20 up to and including the fourth (4th) day following the transaction covered by the bilateral lending or borrowing (T+4)		«Method 6-3» Restitution Block Trades
								Pre-Agreed Trades not cleared by ATHEXCLEAR	Conducted during a special period from 10:30 to 16:45		«Method 6-2» Spot 1 Settlement Block Trades
									Conducted during a special period from 10:15 to 10:30		«Method 6-2» Spot 2 Settlement Block Trades
								Forced sale of certificated registered shares	Entry of buy orders from 10:20 to 17:10 Entry of sell orders from 17:10 to 17:20		«Method 4» Special Terms Board»
	Fixed Income Securities Segment							Trading Session	10:30	17:00	«Method 1»
								Hit & Take	10:30	17:00	«Method 4»
								Forced Sales	10:16	10:26	«Method 5-1»
								Pre-Agreed Trades cleared by ATHEXCLEAR	10:30	17:00	«Method 6-1» - Simple block trades Minimum Value of Trade: 200.000 €
									10:30	17:00	«Method 6-1» Simple block trades with special fee which involve the transfer of stock

											of companies limited by shares, the majority of whose shares belong directly or indirectly to the Greek State (total value of over €150,000,000) or whose total assets exceed €1,500,000,000, from the shareholders to the underwriters of the placement
									10:30	17:00	«Method 6-1» Simple block trades with same day settlement, with or without special fee
									Conducted from 10:30 to 17:00 up to and including the fourth (4th) day following the transaction covered by the bilateral lending or borrowing (T+4)		«Method 6-3» Restitution Block Trades
								Pre-Agreed Trades not cleared by ATHEXCLEAR	Conducted during a special period from 10:30 to 16:45		«Method 6-2» Spot 1 Settlement Block Trades
									Conducted during a special period from 10:15 to 10:30		«Method 6-2» Spot 2 Settlement Block Trades
	Exchange - Traded Fund Segment							Pre-Call	10:15	RTP: between 10:29 and 10:30	«Method 2»
								PAP/V	Throughout the preceding period		
								Trading Session	expiry of the preceding period	17:10	«Method 1»
								At-The-Close trades	17:10	17:20	«Method 3 » Trades are concluded at the closing price
								Forced Sales	10:16	10:26	«Method 5-1»
								Pre-Agreed Trades cleared by ATHEXCLEAR	10:30	17:20	«Method 6-1» - Simple block trades Minimum Value of Trade: 1.000.000 €
									10:30	17:20	«Method 6-1» Simple block trades with

											special fee which involve the transfer of stock of companies limited by shares, the majority of whose shares belong directly or indirectly to the Greek State (total value of over €150,000,000) or whose total assets exceed €1,500,000,000, from the shareholders to the underwriters of the placement
									10:30	17:10	«Method 6-1» Simple block trades with same day settlement, with or without special fee
									Conducted from 10:30 to 17:00 up to and including the fourth (4th) day following the transaction covered by the bilateral lending or borrowing (T+4)		«Method 6-3» Restitution Block Trades
								Pre-Agreed Trades not cleared by ATHEXCLEAR	Conducted during a special period from 10:30 to 17:10		«Method 6-2» Spot 1 Settlement Block Trades
									Conducted during a special period from 10:15 to 10:30:		«Method 6-2» Spot 2 Settlement Block Trades
	Warrants Segment							Trading Session	10:15	17:20	«Method 1»
								Forced Sales	10:16	10:26	«Method 5-1»
								Pre-Agreed Trades cleared by ATHEXCLEAR	10:30	17:20	«Method 6-1» - Simple block trades Minimum Value of Trade: 60.000 €
									10:30	17:20	«Method 6-1» Simple block trades with special fee which involve the transfer of stock of companies limited by shares, the majority of whose shares belong directly

											or indirectly to the Greek State (total value of over €150,000,000) or whose total assets exceed €1,500,000,000, from the shareholders to the underwriters of the placement
									10:30	17:10	«Method 6-1» Simple block trades with same day settlement, with or without special fee
									Conducted from 10:30 to 17:20 up to and including the fourth (4th) day following the transaction covered by the bilateral lending or borrowing (T+4)		«Method 6-3» Restitution Block Trades
								Pre-Agreed Trades not cleared by ATHEXCLEAR	Conducted during a special period from 10:30 to 17:10		«Method 6-2» Spot 1 Settlement Block Trades
									Conducted during a special period from 10:15 to 10:30		«Method 6-2» Spot 2 Settlement Block Trades
Multilateral Trading Facility / Alternative Market	Shares and Pre-Emptive Rights				Trading in Alternative Market (EN.A.) becomes only via the Members of the MTF / EN.A. ATHEX Members are automatically members of the MTF / EN.A..			Pre-Call	10:15	RTP: between 10:58 and 11:00	«Method 2»
								PAP/V	Throughout the preceding period		
								Trading Session	Expiry of the preceding period	17:00	«Method 1»
								At-The-Close Trades	17:00	17:20	«Method 3» Trades are concluded at the closing price
								Forced Sales	10:16	10:26	«Method 5-1»
								Pre-Agreed Trades cleared by ATHEXCLEAR	11:00	17:20	«Method 6-1» - Simple block trades
									11:00	17:20	«Method 6-1» Simple block trades with special fee which involve the transfer of stock of companies limited by shares, the majority of whose shares belong directly

											or indirectly to the Greek State (total value of over €150,000,000) or whose total assets exceed €1,500,000,000, from the shareholders to the underwriters of the placement
									11:00	17:10	«Method 6-1» Simple block trades with same day settlement, with or without special fee
									Conducted from 11:00 to 17:20 up to and including the fourth (4th) day following the transaction covered by the bilateral lending or borrowing (T+4)		«Method 6-3» Restitution Block Trades
								Pre-Agreed Trades not cleared by ATHEXCLEAR	Conducted during a special period from 11:00 to 17:10		«Method 6-2» Spot 1 Settlement Block Trades
									Conducted during a special period from 10:15 to 10:30		«Method 6-2» Spot 2 Settlement Block Trades
	Bonds & Other Fixed Income Securities							Trading Session	10:30	17:00	«Method 1»
								Hit & Take	10:30	17:00	«Method 4»
								Forced Sales	10:16	10:26	«Method 5-1»
								Pre-Agreed Trades cleared by ATHEXCLEAR	10:30	17:00	«Method 6-1» - Simple block trades
									10:30	17:00	«Method 6-1» Simple block trades with special fee which involve the transfer of stock of companies limited by shares, the majority of whose shares belong directly or indirectly to the Greek State (total value of over €150,000,000) or whose total assets exceed €1,500,000,000, from the shareholders to the

											underwriters of the placement
									10:30	17:00	«Method 6-1» Simple block trades with same day settlement, with or without special fee
									Conducted from 10:30 to 17:00 up to and including the fourth (4th) day following the transaction covered by the bilateral lending or borrowing (T+4)		«Method 6-3» Restitution Block Trades
								Pre-Agreed Trades not cleared by ATHEXCLEAR	Conducted during a special period from 10:30 to 17:00		«Method 6-2» Spot 1 Settlement Block Trades
									Conducted during a special period from 10:15 to 10:30		«Method 6-2» Spot 2 Settlement Block Trades
Derivatives	Index Derivatives				The members participating in the ATHEX derivatives market are the ATHEX members, as far as concerns the execution of trades, and the ATHEXClear members as far as concerns the conducting of the clearing process of the aforementioned	T+1		Trading Session	10:10	17:20	«Method 1»
								Pre-Agreed Trades	10:10	17:20	«Method 7-1»
	Sto ck							Trading Session	10:11	17:20	«Method 1»

					realized transactions. ATHEX members according to the ability of conducting transactions in the derivatives market are distinguished to the following categories: **Trading members**, which can realize transactions on behalf of their clients or for their own account. **Market Makers** where through an Own Account the members are committed to enter quotes on one or more products that are traded in the Derivatives Market of ATHEX, aiming to reinforce the liquidity and the depth of the market.			Pre-Agreed Trades	10:11	17:20	«Method 7-1»

Special trading requirements

Market	Market making	Closing Price	Spread			Volatility Interrupters		Closing algorithm	
			From	To	Max range	Static limit	Dynamic limit	Main	Alternative
Main market - High Liquidity Class	Yes	≥ 0,05	-30%	30%	60%	10%	3%	Auction	VWAP of trades in predefined time period before the end of the trading session
	No					10%	3%		
	Yes	< 0,05				15%	N/A		
	No					15%	N/A		
Main market – Middle Liquidity Class	Yes	≥ 0,05	-30%	30%	60%	10%	3%	Auction	VWAP of trades in predefined time period before the end of the trading session
	No					10%	3%		
	Yes	< 0,05				15%	N/A		
	No					15%	N/A		
Main market – Low Liquidity Class	Yes	≥ 0,05	-30%	30%	60%	10%	3%	Auction and Significant auction value	VWAP of a percentage of daily volume or the start of day
	No		-10%	10%	20%	N/A	3%		
	Yes	< 0,05	-30%	30%	60%	15%	N/A		
	No		-10%	10%	20%	N/A			
Bonds	Yes	N/A	Unlimited			10%	3%	VWAP of last 30 minutes' trades of trading session	VWAP of last 60 minutes' trades of trading session
Surveillance Market	N/A	N/A	-20%	20%	40%	N/A		VWAP of 100%of daily volume	Start of day price
ETFs	Yes	N/A	-30%	30%	60%			Last trade	Start of day price

Warrants	Yes	N/A	±50% adjusted to ±100%,to +200% and to +400%		Last trade	Start of day price
Alternative Shares Market	N/A	N/A	±10% adjusted to ±20%		VWAP of 30% of last trades	Start of day price
Alternative Bonds Market	N/A	N/A	Unlimited		VWAP of last 30 minutes' trades of trading session	VWAP of last 60 minutes' trades of trading session