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THE SPEED OF LIMIT ORDER EXECUTION IN THE SPANISH STOCK EXCHANGE

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Abstract

The objective of this work is to study empirically the factors influencing the execution time in the Spanish Stock Exchange. Our dataset includes the orders and transactions of the assets belonging to IBEX 35 in the period between July and September 2000. We divide the assets into three sub samples according to their trading activity, and we use an econometric model based on survival analysis to analyze the effect of variables such as the relative inside spread, price aggressiveness, asset volatility and depth. We find that limit orders priced at the quotes or within the quotes have a shorter expected time of execution. The same happens when the asset is more volatile and active. Time of execution is shorter at the beginning and at the end of the trading session depending on the group of the assets considered, and it is longer when the inside bid--ask spread is larger. If the trader takes into account the type of the last order introduced before the order placement we can observe that if the previous order was a market order on the opposite (same) side of the book then the expected time of execution of the new limit order is shorter (longer), while if it was a limit order on the same (opposite) side of the book then it is longer (shorter). Finally, we study the effect of the explanatory variables on the expected time of execution over the different periods of the trading session.

JEL Codes: G15, G23.
Keywords: Market Microstructure, Limit Order Book, Order Execution.

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1. Introduction

In many markets investors can use either market or limit orders when they buy and sell shares. The two types of orders tend to play a different role in maintaining market liquidity. According to Biais et al. (1995) limit orders offer liquidity when it is scarce, while market orders consume it when it is plentiful. More in general, the main trade--off appears to be that market orders can be executed more quickly than limit orders, but limit orders allow the trader to obtain a better price. In fact, Cohen, Maier et al. (1981) show that if an investor chooses to trade via limit order, his expected end of period wealth is an increasing function of the order execution probability, which in turn is a decreasing function of the execution time. A crucial issue in the decision between placing a limit order and a market order is therefore the speed at which a limit order can be executed.

This paper studies empirically the determinants of the expected time of execution of a limit order in the Spanish Stock Exchange (SSE). Our objective is to analyze how the variables related to the market and to the order influencing the time of execution in an environment where information processing technology progresses quickly, making information about the market available in real time. We are also interested in finding out whether the effect of the variables on the execution time changes depending on the characteristics of the asset or the time of the trading session.

This type of research has not been developed in the SSE until now for the lack of a suitable limit order dataset. We construct the dataset starting from the limit order book and the list of trades, and applying some algorithms. For this reason the results obtained contain some biases, as we only have the first five levels[1] of the order book. Nevertheless, the results represent the first attempt to study the duration of an order in the SSE, the variables affecting the execution time, and how the SSE works compared to other markets. We also propose a quantitative measure for price aggressiveness, as a determinant of the order duration, different from the qualitative one introduced by Biais et al (1995).

The Spanish market, known by the acronym SIBE, is an order driven market with liquidity providers (specialists) for certain shares. A single trading platform links the four Spanish stock exchanges (Madrid, Barcelona, Bilbao and Valencia), thus ensuring a single unified market for each share. The market gives real time information on its screens, so that transparency is fully guaranteed.

[1] This is explained more in detail in section 3.2.

Our database provides information about the five best bids and offers on the book for each share at each moment, and the transactions occurred. The dataset includes the assets belonging to the index IBEX 35, including the shares with higher trading volume, in the period between July and September 2000. We divide the assets in three sub samples according to their trading activity and we estimate separate models for limit buy and limit sell orders for each stock.

The econometric model for the time of execution is based on survival analysis. This statistical technique is suitable for modeling order duration, since limit order execution times can be interpreted as failure times (they are non-negative, random and temporally ordered). We will estimate the conditional distribution of limit order execution times as a function of economic variables such as limit price, order size and current market conditions. Survival analysis can accommodate censored observations (limit orders that expired or were cancelled before execution), an important feature of limit order execution times. While this technique has been used before (see Lo, McKinlay and Zhang (2002) and Suhaibani and Kryzanowsky (2000)), we are not aware of other applications to the Spanish stock exchange.

The rest of the paper is organized as follows. Section 2 contains a brief review of the literature. In section 3 we explain the hypotheses to be tested. In section 4 we describe the institutional characteristics of the Spanish stock exchange and our data. Section 5 defines the variables included in the model, while sections 6 and 7 discuss the summary statistics and the main empirical features of the Spanish market. In section 8 we introduce the main econometric techniques used in the analysis and present the model to be estimated. The empirical results appear in section 9, and section 10 contains the conclusions.

2. Literature Review

Pre-trade transparency is defined by Madhavan (2000) as 'the wide dissemination of current bid and ask quotations, depths, and possibly also information about limit orders away from the best prices, as well as other pertinent trade related information such as the existence of large order imbalance'. In a transparent market all the variables mentioned above are known to the traders and may therefore influence their decision about whether or not to place a limit order, as well as the price at which the order is placed.

Glosten (1994) provides an analysis of an idealized electronic open limit order book. The analysis suggests that an electronic open limit order book mimics competition among anonymous exchanges. After setting up a general model of investor behavior, the article discusses some characteristics of the equilibrium in an electronic market when there are many limit order submitters. More in detail, if there is a large population of potential liquidity suppliers and the actual

cost of running an exchange is small then, among exchanges that operate continuously and anonymously, the electronic exchange is the only one that does not tend to engender additional competing exchanges.

The limit order decision has been analyzed theoretically by Parlour (1998). She develops a theoretical model of a fully transparent limit order book with symmetric information. She assumes that limit orders have a single limit price and that time priority is strictly enforced. The trader's patience and the state of the limit order book affect the strategy of order placement, and the probability of executing a limit order depends on the placement of the order in the limit order book. Parlour notes that the arrival of a limit buy (sell) order lengthens the queue at the bid (ask) side of the book. This reduces the attractiveness of submitting an additional limit order of the same kind. Therefore, the likelihood of observing a limit order on a given side of the book is inversely (directly) related to the depth on that (opposite) side of the book.

Foucault et al. (2005) model the limit order book as a market for liquidity provision and consumption and they study the optimal order placement decision for liquidity traders who incur waiting cost. They consider the expected waiting time of limit order traders as an endogenous variable and they show that the average time to execution (across limit orders) depends on the tick size, the order arrival rate and the proportion of patient traders relative to the proportion of impatient traders.

Angel (1994) develops an analytical expression for the conditional probability of limit order execution where the conditional element is the investor's information set. His results are applied to batch trading of one round lot of the stock for informed traders who know the entire limit order book. In this context he runs some simulations for continuous trading environments. Hollifield, Miller and Sandas (2003) build a structural model of a pure limit order market where they analyze order placement strategies. Traders submit market and limit orders to the limit order book, taking into account the trade—off between price of the order and probability of execution, as well as the winner's curse risk associated with different order choices. Their optimal order strategy is characterized by a monotone function which maps the liquidity demand of the investors into their subjective execution probabilities. They estimate their model non-parametrically and derive implications for traders' order submission strategies.

A number of papers have analyzed the issue from the empirical point of view. Lo, McKinlay and Zhang (2002) develop an econometric model of limit order execution times using survival analysis, and estimate it with actual limit order data from a brokerage firm specializing in electronic trading. They find that execution times are very sensitive to the limit price and several other explanatory variables such as market volatility, bid ask spread and the size of the limit order.

Al-Suhaibani and Kryzanowsky (2000) study the microstructure of the Saudi Stock Market and analyze the patterns in the order book, the dynamics of order flow, the time of execution and the probability of executing limit orders. They find that liquidity commonly measured by width (spread) and depth is relatively low in this market but it is exceptionally high when measured by immediacy[2]. Furthermore, they find that limit orders that are priced reasonably close to the bid ask spread, on average, have a shorter execution time and have a high probability of subsequent execution.

Cho and Nelling (2000) study the probability of limit order execution and the expected benefit of limit orders for a sample of stocks traded on the NYSE. Their results indicate that the longer a limit order is outstanding, the less likely it is to be executed. The probability of execution is higher for sell orders than for buy orders, lower when the limit price is farther away from the prevailing quote, lower for large trades, higher when spreads are wide and higher in periods of high price volatility.

Biais et al. (1995) analyze the Paris Bourse as an example of a centralized, computerized limit order market particularly appropriate for studying the interaction between the order book and the order flow. They focus on the particular institutional features of the market: existence of a limit order book, strict enforcement of priority rules and treatment of market orders.

Recent investigation on the Spanish market has focused on the estimates of the ex ante cost of liquidity in the limit order book (Martinez et al (2000)), the consequences of the existence of ticks for different market variables like bid ask, depth etc. (Abad et al (2003)), the behavior of hidden orders (Pardo et al (2004)) and the importance of different pieces of limit order book information in characterizing order aggressiveness and the timing of trades, order submissions and cancellations (Pascual et al (2004)).

In our analysis we consider assets belonging to the IBEX 35, the index of the most traded stocks in the Spanish stock exchange. We study the effect of variables such as the bid ask spread, price aggressiveness, asset volatility etc. on the speed of limit order execution. Our results are that limit orders priced at the quotes or within the quotes have a shorter expected time of execution; the expected execution time is also shorter when the asset is more volatile and active, and the time of the placement also affects the duration of the order in a different way depending on the group taken into consideration. We are also interested in finding out the effect of the type of the last order introduced on the expected time of execution of the new order placed, and we find that if the last order introduced is a market order on the opposite

[2] Immediacy refers to how quickly trades of a given size can be executed at a given cost.

(same) side of the book then the expected time of execution of a new order is shorter (longer). If the last order introduced is a limit order on the same (opposite) side of the book then the expected time of execution is longer (shorter). Finally, we analyze time of the day effects.

3. Some Hypotheses

In this section we discuss some hypotheses to be tested in the empirical part.

According to Al-Suhaibani et al (2000), when the spread is wider traders don't have incentive to submit market orders, since the transaction costs are high. Therefore the expected time of execution will be longer, since there are fewer market orders available. Elull et al. (2003) support the same idea; when the spread is wider market orders are less likely to be submitted so the probability of execution of the outstanding limit orders decreases and the expected time of execution increases.

HYPOTHESIS 1: The relative inside spread is positively related to the expected time of execution.

Demsetz (1968) shows that more aggressive limit orders would be submitted to shorten the expected time of execution. This idea is empirically supported by Al- Suhaibani et al. (2000) while Cho et al (2000) find the opposite.

HYPOTHESIS 2: Price aggressiveness affects negatively the expected time of execution.

According to Lo et al. (2002) and Cho et al. (2000) when the market is more active and volatile, trades are executed more quickly.

HYPOTHESIS 3: Market volatility affects negatively the expected time of execution of new limit orders.

Lo et al. (2002) and Al-Suhaibani et al. (2000) show that there is a positive relation between the number of shares which have priority on execution and the expected time of execution. Parlour (1998) predicts that when the number of shares in the queue for execution increases the probability of execution of a new limit order decreases.

HYPOTHESIS 4: When the number of shares which has priority on execution increases the expected time of execution increases.

According to Lo et al. (2002), Al-Suhaibani et al. (2000) and Focault et al. (2005) if the trading activity increases the probability of execution increases and the time of execution is shorter. There will be more traders in the market, so the probability of finding a counterpart increases.

HYPOTHESIS 5: If the trading activity increases the expected time of execution decreases.

The percentage of orders executed on one side of the book one hour before the placement indicates the level of activity on this side of the market and the probability of execution of a limit order on this side. If this percentage increases the probability of execution increases and the expected time of execution should decreases.

HYPOTHESIS 6: If the percentage of limit orders executed on one side of the book increases the expected time of execution of the limit order placed on the same side decreases.

According to Cho et al (2000), Lo et al (2002) and Al-Suhaibani et al. (2000) there is a positive relation between the size of the order and the expected time of execution, suggesting that larger trades take longer to be executed. Al-Suhaibani et al. (2000) point out that the result depends on the side of the book considered.

HYPOTHESIS 7: If the volume of the order is larger then the expected time of execution is longer.

We are interested in finding out the relation (if it exists) between the day of the week at which the order is introduced and its duration.

HYPOTHESIS 8: The day of the week at which the limit order is introduced affects the expected time of execution.

From the existing literature we are aware of the high number of orders placed and executed at the beginning and at the end of the trading session, so we can expect a shorter time of execution in these periods of the day. According to Biais et al. (1995) at the beginning of the trading session traders are more likely to place limit orders than market orders because they are more likely to be executed. Similarly, at the end of the trading session there could be more trades because less patient traders start to adjust their prices as the end of the session approaches in order to induce other traders to execute against them (Niemeyer and Sandas, 1995).

HYPOTHESIS 9: The time of the day at which the order is introduced affects the expected duration of the order. Limit orders placed at the beginning and at the end of the trading session have a shorter expected time of execution.

Biais et al (1995) define the *diagonal effect*, by which it is meant that the probability that a given type of order or trade occurs is larger after the event has just occurred. There are some possible explanations for this effect. First, the succession of identical types of orders could reflect strategic order splitting[3]. Second, different traders could be imitating each other; imitation arises when certain market participants are known to be informed, so people imitate them. Another possibility is that traders react similarly, but sequentially, to the same event. In our context, if the last order introduced before the placement is a limit order on the same side of the book we have, according to Parlour (1998), lengthened the queue on this side of the book and the probability of execution of this order decreases since it is less attractive and the expected time of execution is longer. If the previous order is a market order on the opposite side of the book it means that a limit order outstanding in the market in the same side of the book of our placement has been executed and it is a signal of the level of activity, and consequently the probability of execution of the new order increases and its duration decreases.

HYPOTHESIS 10: The last order introduced in the market affects the expected time of execution of the new limit order placed: if the last order introduced is a limit order on the same (opposite) side of the book the expected time of execution of the new order may be longer (shorter). If the last order introduced is a market order on the opposite (same) side of the book, the expected time of execution of a new order submitted is shorter (longer).

[3] An example is the case of a trader willing to buy for non--informational reasons and splitting in order to reduce market impact. Another example is the case of an insider with positive information about the value of the stock, who repeatedly buys the stock until his private information is incorporated into the prices.

4. SIBE and the Dataset

In this section we discuss the institutional characteristics of the Spanish stock exchange and the dataset that we are going to use in the empirical analysis.

4.1 SIBE

The current organization of the Spanish Stock Market is regulated by the Stock Market Law 24/1988. Before the reform, the stock market was highly fragmented, as there was no connection among the four stock exchanges (Barcelona, Bilbao, Madrid, and Valencia). Only authorized brokers were allowed to access the markets. All this changed after the reform.

The first electronic trading platform used in Spain connecting the four stock exchanges was the CATS (Computer Assisted Trading System), imported from the Toronto Stock Exchange and in operation since 1989. On 2 November 1995, this system was substituted by the Spanish Stock Exchange Interconnection System (SIBE), on which all the shares then comprising the IBEX 35 index started to trade. SIBE facilitates direct, real time communication among the stock exchanges, allowing for a single price and order book per share. This interconnection has boosted market liquidity and depth. The Spanish market is an order driven market, with liquidity providers (specialists) for certain shares. The market features real time information on its screens and automatic relaying of trading information, so that transparency is fully guaranteed. The market is open on all business days from Monday to Friday, and the trading day is divided in different phases.

Opening Auction. The session begins with the opening auction in which the order book is partially visible. During this time orders can be entered, altered and cancelled, but no trade is executed. The period lasts 30 minutes, opening at 8:30 am, with a 30-second random end period to prevent price manipulation. The opening price is determined by choosing the price at which the largest volume of shares is executed, with some additional tie-breaking rules. After the random end, the allocation period begins, during which the shares included in orders subject to execution at the fixed auction price are traded[4]. Once the shares are allocated, members receive information on the total or partial execution of their orders. All non-executed orders in the allocation period remain in the order book. The market is informed of the

[4] On special occasions, the opening auction may be extended.

opening price, trading volume, time of each trade and the identity of the trading members. After this the market is opened.

Open Market. During this period, running from 9am to 5:30pm, orders can be entered, altered or cancelled, with trading taking place at the price determined according to the open market's matching rules. The order book is open and available to all market members (buying and selling members' codes are shown). Orders with the best price (highest buy and lowest sell) have priority in the book. When prices are the same, orders entered first have priority. Furthermore, market orders entered in the system are executed at the best opposite side price; for example, a buy order will be executed at the price/s of the first order/s on the sell side of the order book. Orders may be fully executed (in one or several steps), partially executed or not executed. Accordingly, each order can generate several trades.

Closing Auction. The session ends with a 5-minute auction, between 5:30pm and 5:35pm, with the same characteristics as the opening auction and a 30-second random end period. The price resulting from this auction shall be the closing price of the session. On special occasions the closing auction may be extended.

The types of orders used in this system are the following.

Market orders: these are orders entered without a specific price limit and traded at the best opposite-side price at the time of entry. If the order is not fully executed against the first opposite--side order, it will continue to be executed as many opposite side prices as are necessary until it is completed. These orders can be introduced both in auctions and on the open market.

Market to limit orders: these are orders without a price which are limited to the best opposite--side price on the order book. If the share is on the open market and there is no order on the opposite side of the order book, the order is rejected.

Limit orders: these are orders to be executed at their limit price or better. These orders can be executed against existing market orders at a price no lower than the limit price, with the rest being left on the market at the limit price, and can be entered both on the open market and during the auctions. Limit orders are executed at the best opposite--side price on the order book (as long as the price is equal to or better than the price of the limit order being entered). A limit order is always executed at its limit price, unless it is included in an auction and the auction price is better than the limit price.

Limit, market and market to limit orders may satisfy one of the following execution conditions: *Minimum volume, Fill or Kill and Execute or Eliminate*. Orders may have hidden volumes, so that only part of the trading volume is displayed in the system. Once the displayed volume has been executed, the rest is considered as newly introduced hidden volume

(iceberg) order. SIBE orders may be valid for the following periods of time: valid for one day; valid until a specific date, valid until cancelled. Orders with a validity of more than one day maintain their priority in the system in accordance with their price and time of entry with respect to orders generated during the session. When a modification to an order impacts priority, a new order number is generated and enters the system as a newly entered order. Trading is carried out in euros to two decimal places. During main trading minimum price variations are: 0.01 euros for prices up to 50 euros; 0.05 euros for prices over 50 euros.

4.2 The Dataset

The data we need to construct the explanatory variables and the execution times are not immediately available, so it is necessary to construct them starting from three datasets provided by Sociedades de Bolsa. We now describe the information available in the three datasets.

Dataset MP. It contains information about the limit order book as available to market participants, given by the five first best levels on the bid and ask side of the book. Each level of the dataset contains the price of the order, the total volume and the number of outstanding limit orders at that price. In the book all events (placement of new orders, cancellations, modifications or executions) are time stamped to the second and lead to a potential order book modification, which is recorded in real time by SIBE. The dataset does not provide the type of event occurred, that is we only observe modifications in the limit order book but not the specific events leading to the change. However, we can combine the information contained in this dataset with the information contained in the other two datasets to obtain such information.

Dataset SM. It contains information on the best orders on the bid and ask sides. We have data about the total volume and the corresponding price of the orders outstanding in the first level of both sides. All the modifications occurred in the first levels are recorded and from its analysis it is possible to find out the event which caused the modification in the book. The cumulated volume transacted is recorded, as well as the price at which the last transaction takes place. From the cumulated volume transacted we can compute the amount of the shares transacted in each negotiation. From the joint analysis of this dataset and the previous one we can classify all the events occurred in the first five levels.

Dataset BASA. It contains information about the transactions occurred during the trading session disaggregated by orders. We have information about the volume, the price and the time. The disadvantage of this dataset consists in not giving any information about the side (buy or sell) from which the trade originated. We have solved this problem by

using the SM and BASA datasets and creating an algorithm which allows us to determine the sign of the trade of each transaction, thus constructing a dataset composed of the transactions occurred on each side of the book.

The different databases can be combined to yield information on events generating changes in the limit order book. That is, combining the information contained in the datasets we obtain for each side of the market the new orders placed, the cancellations with their price, volume and the time of the placement[5]. By using another algorithm, we obtain the transactions occurred during the trading session for each side of the market. In this way we construct a list of all the transactions occurred during the day. We have a set of all the new orders placed in the trading session and a set composed of the executed and cancelled orders. Since we know that, unless specified differently, the orders placed are day orders and in the open session the price priority rule is satisfied, we can program an algorithm which allows us to find out the matching between the new orders placed and the orders executed or cancelled in terms of price and volume. In this way we obtain a set of orders that are executed, another set of orders that are cancelled and another set which contains the non-executed orders. In this dataset it is not possible to distinguish between limit orders executed partially at the best quote on the other side of the book and market to limit orders, since it has to be specified in the dataset and this information is not available.

We can partition the observations in two categories, not censored and censored. Censored observations include cancelled orders with their time of cancellation (the difference between the time at which cancellation occurs and the time of placement), orders going beyond the fifth level and non-executed orders whose time is considered as the difference between the time at which the open session closes and the time of the placement of the order[6]. The non-censored observations include all the orders executed, with their time of execution (the difference between the time at which the transaction occurs and the time of the placement of the order).

In the creation of the limit order dataset we consider only the orders whose development we can follow (they have to be visible all the time in the Limit Order Book we have available). If they go out of the book, for example because they move to the sixth or subsequent levels, we consider them as censored observations with a time equal to the lifetime in the first five levels. We don't take into considerations all the orders coming from the sixth or further levels because we don't know what happens out of the five first levels. They represent 25% of the total order placed. This induces a bias

[5] Other authors investigate empirically the SSE and they need to construct their datasets in order to make their analysis. See Abad (2004) and Pascual (2004).

[6] Cho and Nelling (2000) compute the time of expiration in the same way.

in the result, but it is not possible to approach the problem differently and we use survival analysis in order to accommodate them as censored observations. We emphasize that the majority of orders are placed at the first level (70%) and the executions too, so we can consider the dataset useful in order to approach the problem proposed.

To summarize, we obtain a dataset composed of the new orders placed during the period of analysis, their execution times and the value of the explanatory variables at the placement of the order. The assets considered are the ones belonging to the IBEX 35 except for Zeltia, since in September 2000 the company made a split (3 for 1). The assets are very different among them, so we have decided to divide them into three sub samples according to their trading activity (high, medium and low trading activity samples). The list and the distribution of the assets over the different groups are provided in the appendix.

5. Description of the Variables

In this section we define the variables used in our analysis. We remind the reader that the bid price is the price at which a trader wants to buy a number of shares whereas the ask price is the price at which the trader wants to sell a number of shares.

5.1 Measuring price aggressiveness

In this section we propose a definition of price aggressiveness after having analyzed the state of the literature on the subject. The first contribution on this subject is due to Biais et al. (1995) who propose a categorization of order aggressiveness in 7 categories. The most aggressive orders correspond to buy (sell) orders that demand more volume than is available at the best prevailing ask (bid), and are allowed to go up (down) the book (first category). The other categories are less aggressive, for example in the second one we have orders that demand more volume than is available at the best ask (bid) but are not allowed to go up (down) the book, and the least aggressive category is order cancellation. The first three categories imply total or partial immediate execution of the order, and the remaining ones imply non-immediate execution. Ranaldo (2004) and Griffiths et al. (2000) use this classification in order to study the determinants of price aggressiveness respectively in the Swiss and Toronto Stock exchange[7].

The theoretical models of Focault (1999), Parlour (1998), Handa, Schwartz and Tiwari (2003) and Beber and Caglio (2003) suggest that the limit order book influences the aggressiveness of traders. These models suggest that the state of the limit order book and the trader's place in the limit order queue affect the decision of a trader to submit a market

[7] Abad (2003) provides a similar study applied to the SSE.

order or a limit order, and that the volatility of the asset determines the non-execution risk of a limit order. Harris (1996) measures order aggressiveness as (1-2(A-P)/(A-B)) for buy orders and the negative of this quantity for sell orders, where A(B) denotes the best ask (bid) price, and P is the limit order price. This measure assigns a value of one to market orders and less than one to limit orders. Limit orders placed at the quote have a value of -1, and the difference between the order price and the best quote on the same side increases as this value gets smaller. We are not satisfied with this definition since it does not take into account the variables on the different sides of the market.

Our dataset is composed of limit orders, so we are interested only in the degree of price aggressiveness of limit orders whereas the classification of Biais et al. considers all kind of orders. We will propose a definition of price aggressiveness for both sides. Let *limit price*$_t$ be the price at which the limit order is placed and *bidprice*$_{t-1}$, *askprice*$_{t-1}$ the existing best quotes on both sides at the moment of the order placement.

For the ask side, we define the price aggressiveness of the limit order as:

$$\Pr iceagr_t = \frac{askprice_{t-1} - \lim itprice_t}{\frac{bidprice_{t-1} + askprice_{t-1}}{2}}$$

For the bid side, we define the price aggressiveness of the limit order as:

$$\Pr iceagr_t = \frac{\lim itprice_t - bidprice_{t-1}}{\frac{bidprice_{t-1} + askprice_{t-1}}{2}}$$

When the value of this variable is equal to 0 it means that the placement of the new order occurs at the same price of the best ask (bid) in the limit order book. If the value of this measure is positive it means that the trader is improving the price of the new order with respect to best quote, so the trader has placed a more aggressive order than the one placed at the quote or out of the quote. An increase in the value of this variable corresponds to an increase in aggressiveness. If price aggressiveness takes a negative value it means that the trader has placed the order out of the quote. We expect that an increase in aggressiveness will decrease the order execution time, i.e. we expect a negative sign for the coefficient of price aggressiveness, as stated in hypothesis 2.

5.2 The remaining variables

In this section we will analyze all the remaining variables considered in our model.

The **time of execution** is the lifetime of an order and is computed as the difference between the time at which the transaction occurs (order completely filled) and the time of the placement of the order. It is expressed in seconds.

The **size of the order** is represented by the number of shares of the order divided by the median number of shares of the orders introduced for that stock. This way we obtain a normalized measure that can be compared across stocks.

The **relative inside spread** is computed at the time previous to the placement of the order (at the moment the trader makes the decision). The relative inside spread is:

$$Relative\ inside\ spread_{t-1} = \frac{askprice_{t-1} - bidprice_{t-1}}{\frac{bidprice_{t-1} + askprice_{t-1}}{2}}$$

A wider spread implies a higher transaction cost which provides little incentive to place market order (Suhaibani et al. (2000)). We expect that if the relative bid ask spread increases, the time of execution of an order will increase: orders placed when the spread is wide are more difficult to execute unless you take advantage of this difference positioning your price in between.

Volatility is defined as the sum of the absolute value of changes in price in the last 10 minutes before the placement of the order divided by the actual price. Hypothesis 3 states that we expect a negative impact of volatility on execution times.

Trading activity is obtained as the logarithm of the number of transactions occurred one hour before the placement of the order. We expect a negative sign for an active stock, because it is clear that if the trading activity increases the probability of execution of the order increases so the expected execution time decreases.

Priority gives the number of shares that have priority on execution with respect to the new order placed. If the number of shares having higher priority increases then the expected time to execution should also increase.

Another explanatory variable is the number of limit orders executed in the last hour on the buy (sell) side divided by the total number of transactions one hour before the placement; we call it **percmkc(v)**. If this indicator is greater than 50% it means that, on average, the number of executions on the buy (sell) side is higher than the one on the sell (buy)

side. Some theoretical models postulate the existence of a diagonal effect: if there is a preponderance of market sell (buy) orders the investors tend to place more limit buy (sell) orders.

We also insert dummy variables for the **day of the week** and the **time** of the trading session. Time is taken into account by dividing the trading session in 17 intervals of 30 minutes each and using dummy variables. More in detail we will see if the time of the placement of an order is affecting its execution time.

Another set of dummy variable represents the type of the last order introduced before the placement of the new limit order: *lastlb* (*lastls*) is equal to 1 if the last order introduced before the new submission is a limit order to buy (sell) and otherwise is equal to zero; *lastmb* (*lastms*) is equal to 1 if the last order introduced before the new placement is a market order to buy (sell) otherwise is equal to zero.

6. Summary statistics

We now present the summary statistics of the limit order book dataset for our assets. We have considered the stocks belonging to the IBEX 35 index[8] and the three sub samples during the period July—September 2000.

Table 1 shows the information related to the number of orders placed in the period of time analyzed. It contains the total number of orders placed and the number of orders executed (the percentage of orders executed is in parenthesis). On the buy side the percentage of non-censored observations is always lower than 50%; the highest percentage is 38.61% (ACR) and the lowest ones are 15.88% (CAN) and 18.45% (ALB). On the sell side the highest percentage is 33.68% (ALT) and the lowest ones are 21.36% (ALB) and 21.94% (CAN).

Tables 2, 3, 4 and 5 contain summary statistics for the independent variables related to buy and sell orders. Table 2 provides the mean and the standard deviation of all the variables studied for the three sub samples[9].

Tables 3, 4, 5 provide the summary statistics for each variable for the three sub samples for the three periods of the trading session: the beginning of the day (9:00-11:00), intermediate period (11:00-15:30) and the end of the day (15:30-17:30). We compute the summary statistics of all the explanatory variables for all the limit orders placed in the SIBE except for the execution time where we consider only the limit orders executed.

[8] Except Zeltia, as explained in section 4.2.
[9] The summary statistics for all the assets are available on request.

Table 1: Number of observations (total and executed) for each of the assets and for the three sub-samples.

	BUY	SIDE	SELL	SIDE
	Total Observations	**Uncensored Obs**	**Total Observations**	**Uncensored Obs**
ACE	10228	3369 (32.94)	8452	2518 (29.79)
ACR	10539	4069 (38.61)	10205	2730 (26.75)
ACS	8749	2193 (25.07)	7338	1701 (23.18)
ACX	9563	3134 (32.77)	8688	2279 (26.23)
AGS	7271	1756 (24.15)	5867	1428 (24.34)
ALB	7662	1414 (18.45)	6245	1334 (21.36)
ALT	19440	5497 (28.28)	16814	5663 (33.68)
AMS	24710	7993 (32.35)	22488	6729 (29.92)
ANA	11118	3310 (29.77)	10088	2471 (24.49)
BBVA	36995	10552 (28.52)	38801	10029 (25.85)
BKT	16855	5576 (33.08)	14898	4413 (29.62)
CAN	6913	1098 (15.88)	5091	1117 (21.94)
CTE	7809	2095 (26.83)	6739	1611 (23.91)
CTG	13358	3934 (29.45)	11026	3053 (27.69)
DRC	12693	3940 (31.04)	12205	3776 (30.94)
ELE	28931	9341 (32.29)	26085	8074 (30.95)
FCC	11230	3422 (30.47)	10431	2817 (27.01)
FER	9526	2989 (31.38)	8686	2667 (30.70)
IBE	16387	5018 (30.62)	14890	4720 (31.70)
IDR	14085	4271 (30.32)	12418	3733 (30.06)
NHH	7859	1958 (24.91)	6730	1858 (27.61)
POP	13603	3616 (26.58)	11315	3562 (31.48)
PRY	10376	2555 (24.62)	8954	2560 (28.59)
REE	8191	2669 (32.58)	6893	2179 (31.61)
REP	32686	10522 (32.19)	31558	9346 (29.62)
SCH	47139	12228 (25.94)	59706	13685 (22.92)
SGC	18401	5545 (30.13)	16291	4259 (26.14)
SOL	9902	3127 (31.58)	8482	2356 (27.78)
TEF	136137	35743 (26.26)	126200	33266 (25.57)
TPI	24724	8757 (35.42)	23547	6598 (28.02)
TPZ	17017	5122 (30.10)	15325	4085 (26.67)
TRR	65874	19667 (29.86)	63478	17814 (28.06)
UNF	12610	4450 (35.29)	10326	3138 (30.39)
VAL	8332	2312 (27.75)	6924	2103 (30.37)
HIGH	500432	144939 (28.96)	452023	122348 (27.07)
MEDIUM	146716	46030 (31.37)	129921	37372 (28.77)
LOW	107089	28503 (26.62)	90594	23651 (26.11)

The names we use in the tables for the variables are: Size of the order (VOL), relative inside spread (BAS), price aggressiveness (PA), volatility (VOLAT), trading activity (TrAc), priority (Prior), the percentage of market orders (PMK), and execution time (ExT). All the comments we do from now on are valid for both sides of the market unless we specify differently.

Looking at the summary statistics of the volume, defined as the ratio between the number of shares of the order and the median number of shares per order, we observe that the mean is close to 2 (it decreases with trading activity), so it is twice the median value of the orders introduced. At the beginning of the day the volume is, on average, more than 1.5 times the median volume introduced, during the day is twice and at the end of the day it is more than twice the median volume introduced.

Table2: Summary Statistics (mean and standard deviation in parenthesis) for the three sub-samples of assets

Total		Vol	BAS	PA	Volat1	Prior	PMK	TrAc	ExT
BUY	**HIGH**	2.147 (21.7158)	0.0011104 (0.00104)	-0.000195 (0.001068)	0.03249 (0.04106)	9883.33 (28100)	0.51577 (0.1695)	6.2372 (1.010)	147.17 (569.46)
	MEDIUM	1.938 (15.707)	0.002952 (0.00235)	-0.0002798 (0.002259)	0.01392 (0.02035)	2748.08 (9542.8)	0.5184 (0.2098)	4.373 (0.9543)	546.32 (1327.6)
	LOW	1.887 (9.385)	0.00467 (0.00957)	-0.0001644 (0.003074)	0.006967 (0.0129)	993.15 (3006.8)	0.52727 (0.2538)	3.385 (0.894)	836.6 (1790.8)
SELL	**HIGH**	2.4567 (19.633)	0.001078 (0.00091)	-0.00029 (0.001172)	0.03176 (0.0399)	25242.24 (98032)	0.48168 (0.1702)	6.244 (0.966)	165.80 (570.115)
	MEDIUM	1.9622 (19.842)	0.002945 (0.0024)	-0.0002603 (0.00237)	0.01432 (0.0208)	2442.5 (8667.07)	0.4855 (0.2102)	4.393 (0.961)	535.14 (1291.3)
	LOW	2.037 (24.019)	0.004744 (0.00385)	-0.0001859 (0.00464)	0.007406 (0.01334)	1082.55 (3382.55)	0.44908 (0.2475)	3.425 (0.878)	986.013 (2086.2)

Table3: Summary Statistics (mean and standard deviation in parenthesis) for the three sub-samples of assets at the beginning of the day

Opening		Vol	BAS	PA	Volat1	Prior	PMK	TrAc	ExT
BUY	**HIGH**	1.633 (13.284)	0.001278 (0.001136)	-0.00023 (0.001204)	0.0478 (0.0607)	8281.9 (23717)	0.5066 (0.1853)	6.056 (1.3)	164.55 (849.20)
	MEDIUM	1.640 (19.522)	0.00361 (0.00285)	-0.000419 (0.0027)	0.01905 (0.027)	2408.6 (7946.06)	0.5112 (0.2343)	4.1177 (1.2355)	594.5 (1561.29)
	LOW	1.5498 (5.1979)	0.006126 (0.00465)	-0.000473 (0.00397)	0.008199 (0.0130)	921.29 (2549.3)	0.5194 (0.2902)	3.034 (1.087)	957.2 (2197)
SELL	**HIGH**	1.877 (8.1207)	0.001241 (0.001098)	-0.000336 (0.0013)	0.04737 (0.0593)	20626 (85766.7)	0.4897 (0.1861)	6.102 (1.256)	237.08 (948.48)
	MEDIUM	1.647 (7.146)	0.00357 (0.00282)	-0.000392 (0.00279)	0.01956 (0.0273)	2308.33 (8038.24)	0.4784 (0.2345)	4.1365 (1.243)	568.1 (1538.4)
	LOW	1.718 (25.59)	0.00615 (0.004624)	-0.000435 (0.00406)	0.008826 (0.0130)	1068.23 (3186.7)	0.4026 (0.2727)	3.0935 (1.068)	1230.14 (2657.37)

Table4: Summary Statistics (mean and standard deviation in parenthesis) for the three sub-samples of assets in the intermediate period.

Intermediate		Vol	BAS	PA	Volat1	Prior	PMK	TrAc	ExT
BUY	**HIGH**	1.996 (14.66)	0.001034 (0.00108)	-0.000175 (0.001)	0.02608 (0.0297)	10758.36 (28710)	0.5261 (0.176)	6.3446 (0.8565)	176.01 (545.14)
	MEDIUM	1.94 (16.73)	0.002698 (0.00205)	-0.000251 (0.002043)	0.01084 (0.01585)	2928.82 (9765.9)	0.5199 (0.1945)	4.442 (0.7865)	698.7 (1512.7)
	LOW	1.93 (9.95)	0.0041 (0.0139)	-0.000074 (0.00263)	0.00543 (0.011)	1065.04 (3153.09)	0.5361 (0.2347)	3.43 (0.758)	1059.63 (1970)
SELL	**HIGH**	2.229 (14.25)	0.001011 (0.00083)	-0.000301 (0.00113)	0.02556 (0.0287)	31285.8 (104122)	0.4649 (0.1747)	6.349 (0.8132)	211.97 (635)
	MEDIUM	1.94 (21.53)	0.0027 (0.002211)	-0.000218 (0.002146)	0.01108 (0.01608)	2570.83 (9837.3)	0.4848 (0.1953)	4.4659 (0.791)	693.18 (1471.6)
	LOW	1.91 (9.86)	0.004177 (0.00335)	-0.000097 (0.00593)	0.00537 (0.00973)	1154.31 (3779.5)	0.4541 (0.23)	3.4675 (0.740)	1226.6 (2246)

Table5: Summary Statistics (mean and standard deviation in parenthesis) for the three sub-samples of assets in the closing period.

Closing		Vol	BAS	PA	Volat1	Prior	PMK	TrAc	ExT
BUY	**HIGH**	2.869 (33.73)	0.001038 (0.00083)	-0.000182 (0.001021)	0.027108 (0.02478)	10123.5 (30900.3)	0.5093 (0.14)	6.2533 (0.867)	97.23 (231)
	MEDIUM	2.215 (8.552)	0.00269 (0.00212)	-0.000189 (0.00208)	0.01345 (0.0175)	2811.77 (10539.8)	0.5229 (0.206)	4.515 (0.81)	282.93 (536.27)
	LOW	2.137 (11.344)	0.004122 (0.00319)	-6.22e-06 (0.00264)	0.007953 (0.0148)	959.99 (3181.1)	0.5222 (0.243)	3.639 (0.759)	389.15 (665.29)
SELL	**HIGH**	3.3728 (31.26)	0.001022 (0.00081)	-0.000227 (0.001098)	0.02588 (0.0237)	20550.74 (99236.6)	0.4993 (0.1423)	6.2228 (0.8267)	102.87 (240.33)
	MEDIUM	2.2968 (25.029)	0.002675 (0.00208)	-0.000192 (0.00224)	0.01378 (0.01822)	2392.4 (7449.84)	0.4934 (0.2052)	4.538 (0.805)	293.81 (541.12)
	LOW	2.498 (33.72)	0.004178 (0.00328)	-0.000071 (0.002874)	0.00878 (0.0168)	1001.19 (2979.2)	0.4721 (0.2399)	3.677 (0.7418)	417.82 (707.51)

In the case of the relative inside bid—ask spread the mean and the standard deviation are quite small, that is the distance between the bid and the ask price is small. The assets with the lowest mean of the bid ask spread are BBVA, SCH and TEF. The low trading activity sample has the highest values of the relative inside spread on both sides of the market and as the trading activity increases the relative inside spread decreases. From the summary statistics computed according to the different periods of the trading session, we can observe that the relative inside spread is wider at the beginning of the day and then it narrows during the trading session.

Price aggressiveness is defined so that more aggressive orders have a higher value. The value of this variable on average is negative and very close to zero. As the trading activity increases in the sample the orders placed are less

aggressive and the sell side is less aggressive than the buy side (except for the case of the buy medium trading activity sample). During the day the price aggressiveness increases. Orders placed with negative and small price aggressiveness indicate that, on average, the traders place orders with a price out of the best quote, but close to it. The value of the standard deviation in general is small, showing that the mean of this variable is a good indicator.

The assets with the highest volatility values are the ones belonging to the high trading activity sample and when trading activity increases the volatility increases too. We observe the highest volatility at the beginning of the day, and then it decreases during the intermediate period and increases slightly at the end of the trading session (see figure 4). There are also assets with very low volatility belonging to the low trading activity group.

Consider now trading activity, which measures the level of activity of an asset one hour before the placement of the order. There are 6 assets (BBVA, ELE, SCH, REP, TEF and TRR) with a mean of trading activity higher than 5 and a small standard deviation and 3 assets (SCH, TEF, TRR) with a mean higher than 6. A value of 7 (TEF) for the trading activity means that an hour before the placement of the order 1097 transactions (on average) have occurred, while a trading activity of 2.8 (ALB) means that 17 transactions (on average) have occurred. The assets with a high trading activity have a very small bid ask spread, suggesting a negative relationship between these two variables.

Priority seems to be very volatile, with no clear pattern in mean values.

The last explanatory variable is percmkc(v) (the proportion of orders executed on one side of the book the hour before the placement). The value of this indicator is greater than 50% on the buy side for all the samples and it increases slightly as the trading activity decreases at the beginning and at the end of the trading session, the opposite occurs in the intermediate period.

Finally, we take a look at the execution times, expressed in seconds. On average, on both sides the assets with the lowest value are the ones belonging to the high trading activity sample and in particular TEF, TRR, REP and BBVA. We observe an inverse U-shaped curve if we consider the evolution of the execution time along the trading session (fig. 7). On the sell side times of execution are higher than the ones on the buy side, except for TEF and the medium trading activity group, where we find the opposite effect. After the analysis of the stocks belonging to the IBEX 35 we should emphasize that there are big differences between them in terms of immediacy costs, trading activity and depth. Most of the trading activity of this index and the Spanish Market is concentrated on few assets, as we will see more in detail in the next section.

7. Some Comments about the Market

Six assets account for most of the trading activity on the Spanish Market: TEF, SCH, BBVA, REP, TRR, ELE.

Figure 1 shows the distribution of the placement of the new orders over the assets belonging to the IBEX 35 between July and September 2000. The majority of the orders are concentrated on BBVA, REP, SCH, TEF, TRR and ELE. The high trading activity of some assets depends on the period of time we are analyzing: in the case of TRR this is a period of big expansion. If we consider the two sides of the market we can observe that the proportion of new orders is more or less the same. The same thing happens if we take into consideration the number of transactions or market orders occurred in the same period: most of them are concentrated on the same assets (fig 2). In this case there are more differences if we look at the two sides of the market. If we consider the buy side we can observe that TEF and TRR present a higher proportion of transactions on this side with respect to the sell side. ALT, BBVA, ELE, REP and SCH have a higher proportion of transactions on the sell side than on the buy side.

We now consider the evolution of some variables over the trading session. We have divided the trading session into 17 intervals of 30 minutes and we take into consideration the values of the variables at the beginning and at the end of the intervals. The variables we would like to consider are the relative inside spread (computed as the ratio between the bid ask spread and the quote midpoint) and the stock return volatility (computed as the squared midpoint quote returns).

The observed spread pattern for the assets belonging to the IBEX (figure 3) is U-shaped. In the morning the high spread is due to greater uncertainty. As trade progresses and information asymmetry is reduced a decline of the spread is observed. Chan et al. (1995) attribute such pattern to the absence of a specialist market power. The value assumed by the spread is approximately the same in the first and in the last period. Similar results for the SSE but for different periods are achieved by Blanco (1999) and Rubio and Tapia (1996).

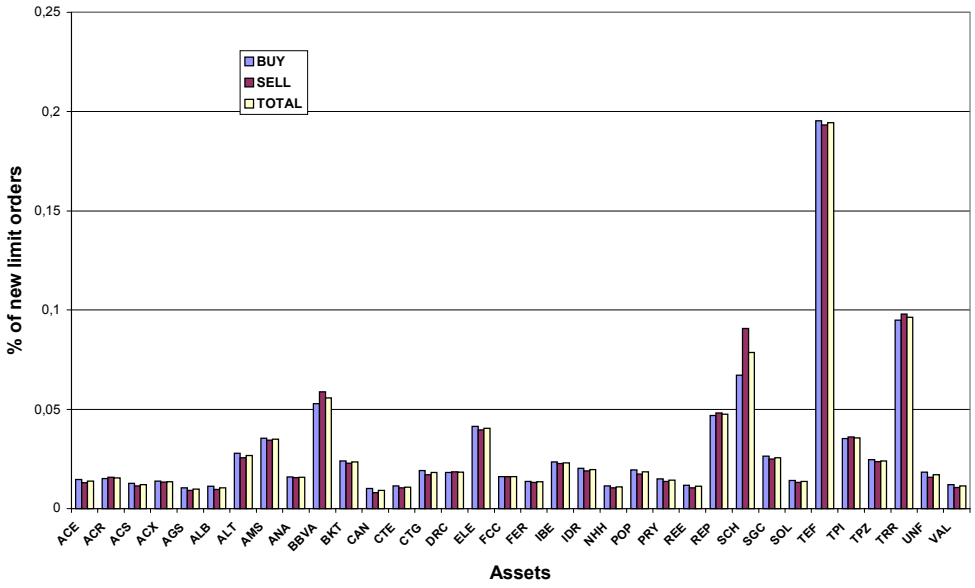

Figure 1: Distribution of the new orders placed among the assets of Ibex 35. The proportion of new orders are computed as the ratio between the number of the new orders placed of an asset divided by the number of new orders placed for all the assets belonging to IBEX.

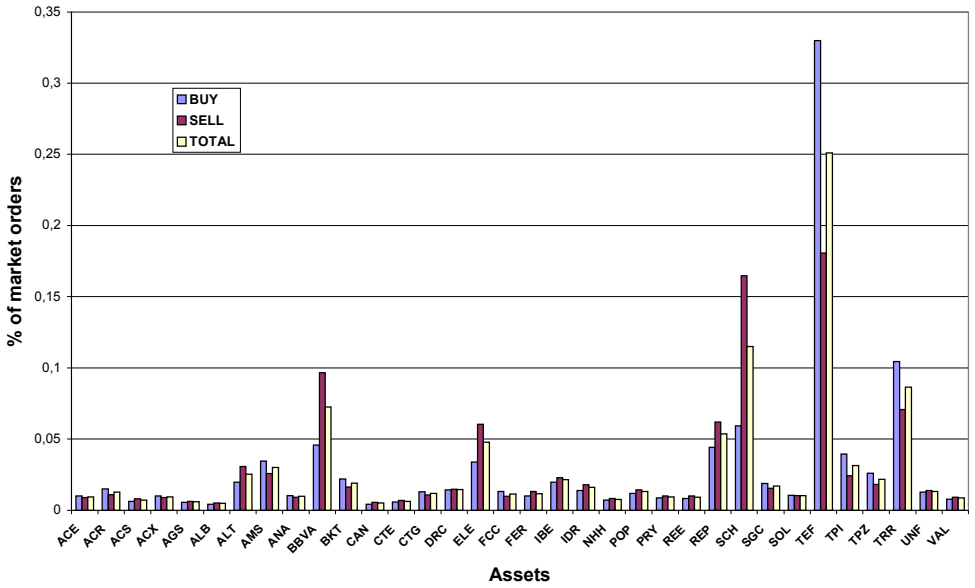

Figure 2: Distribution of the transactions (market orders) occurred among the assets of Ibex 35. The proportion of transactions is computed as the ratio between the number of market orders placed of an asset and the number of transactions occurred for all the assets belonging to IBEX.

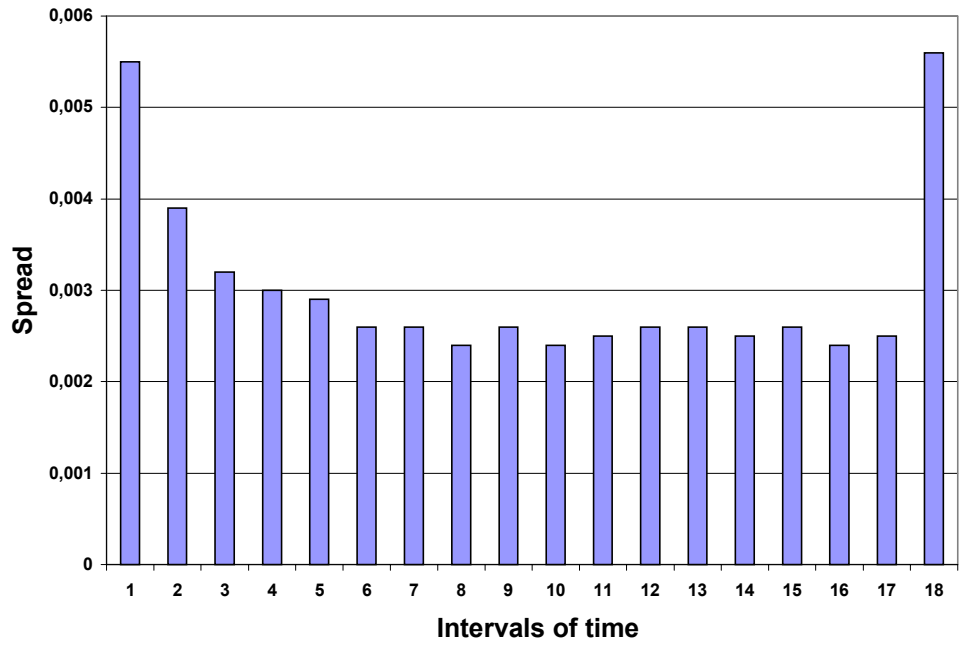

Figure 3: This figure reports the relative inside bid ask spread. The bars are the averages over the 65 days of the sample.

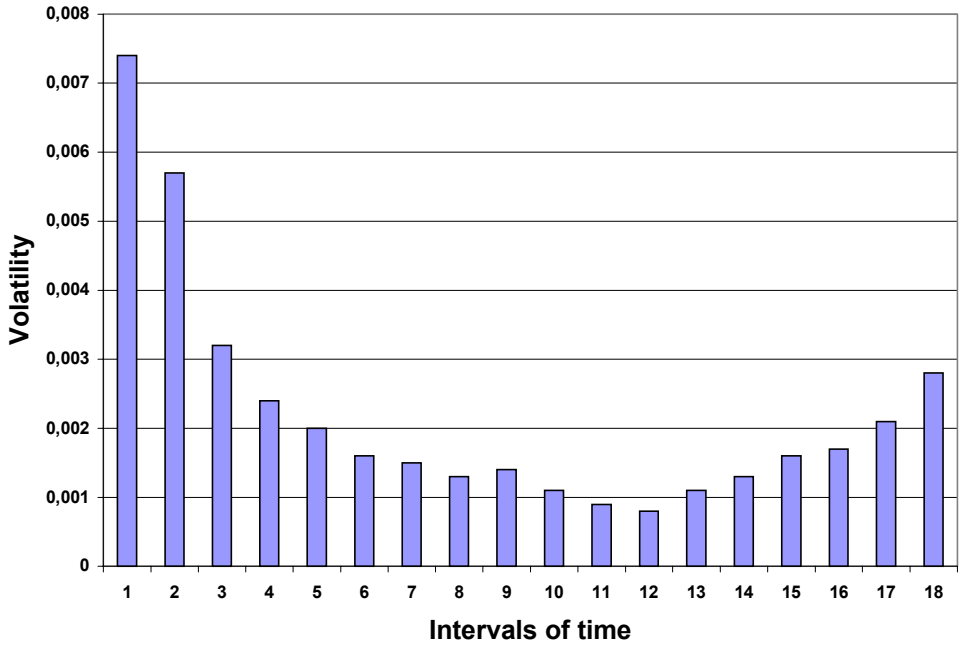

Figure 4: This figure reports the Volatility computed as the squared quote midpoint returns. The quote midpoint return is computed as the log(QMPt)-log(QMPt-1). The bars are the averages over the 65 days of the sample.

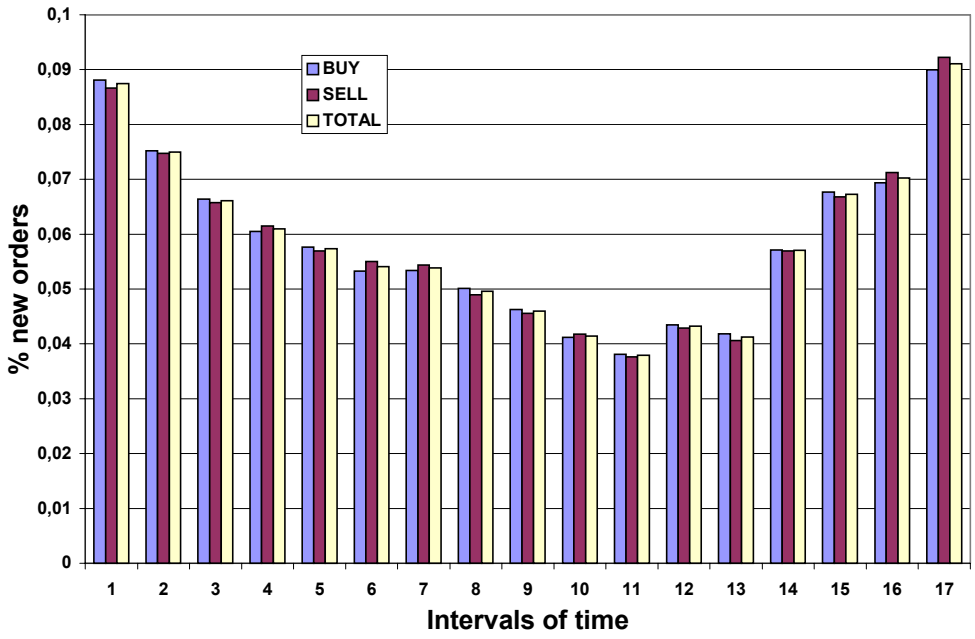

Figure 5: Distribution of the new orders placed over the trading session divided by the side of the market. Each bar is the average proportion across the 65 trading days in the sample.

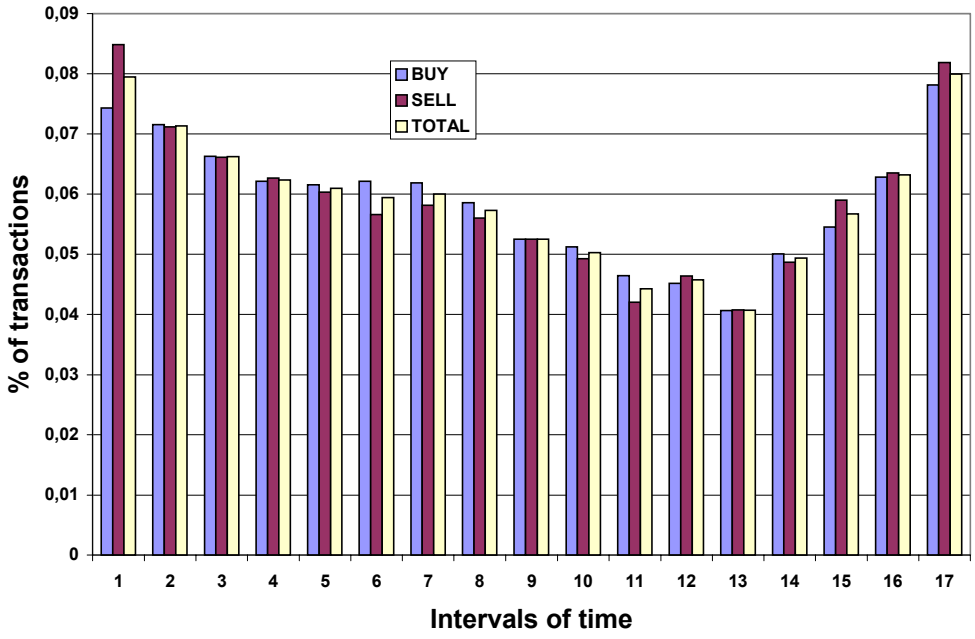

Figure 6: Distribution of the transactions occurred over the trading session divided by the side of the market. Each bar is the average proportion across the 65 trading days in the sample.

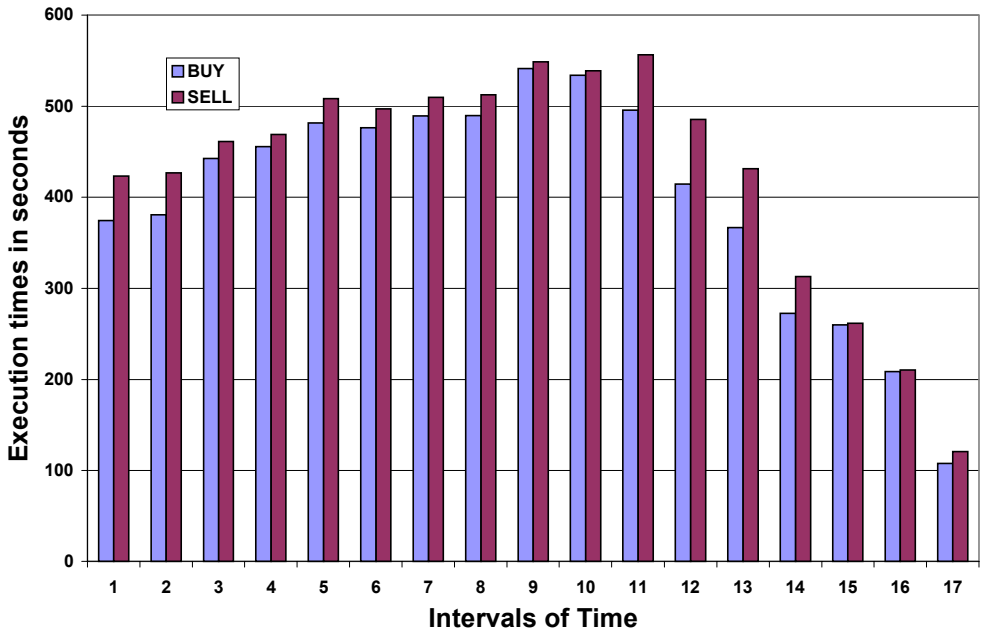

Figure 7: Execution times of the orders placed during the different intervals of the trading session. Each bar represents the mean of the execution times of the orders placed over the different intervals. The execution times are expressed in seconds.

The stock return volatility (figure 4) also exhibits a U-shaped pattern, although the value at the end of the trading session is not as high as the one at the beginning of the session. The highest value is assumed at the beginning of the trading session. This is consistent with the model by Admati and Pfleiderer (1988), which predicts that high volume periods have more informative and hence more volatile prices. This is a situation very typical at the beginning of the day, when there is uncertainty due to information asymmetries and many orders are placed in order to discover the price. In fact, if we look at the distribution of the new orders and the transactions over the trading session (figures 5 and 6) we can observe that they are concentrated mostly at the beginning and at the end of the session, in the same periods in which we observe higher volatility. More in detail, the distribution of the new orders placed during the trading session (figure 5) is U-shaped: the proportion of the new orders placed at the beginning of the day is higher than the proportion of orders placed in other intervals, with the exception of the last 30 minutes when the proportion of the new orders placed is the highest. Probably the traders submit more limit orders in the last half hour because they have enough information to place an order with the 'correct' price, and the risk of no execution related to this submission is not so high since the time left is short and in the last period of the trading session the number of orders executed is high. If we look at the two sides of the book we can observe that the proportion of new orders placed on the buy side is

always approximately the same as the proportion of new orders placed on the sell side. The proportion of transactions occurred during the trading session (figure 6) exhibits a U-shaped pattern, with higher proportions at the beginning and at the end of the day. If we consider the two sides of the book we observe that the proportion of transactions on the sell side is much higher than the one on the buy side in the first 30 minutes. In the following intervals of time the proportion of transactions on both sides is the same.

The execution times of the orders placed in different periods of time of the trading session are represented in figure 7. In the first hour and in the last two hours of the trading session the time of execution for the orders placed is shorter than in the remaining intervals[10] and in most of the cases the orders placed on the buy side have a smaller execution time than the ones on the sell side.

8. Methodology

Our objective is to develop an econometric model of the speed of limit order execution, incorporating all the characteristics of the order and the influence of market conditions. For this purpose the main statistical technique that we are going to use is survival analysis. Survival analysis is a statistical technique[11] which encompasses a wide variety of methods for analyzing the timing of events such as lifetimes, failure times or time to execution. Survival time data have two important characteristics:

• Survival times are non--negative, random and temporally ordered.

• Typically some subjects have censored survival times. Their survival times are not observed, because the event does not take place; if we don't take into account censored data we can produce serious biases in the estimates.

The technique appears to be quite convenient to model the time of execution of limit orders. We try to estimate the following conditional probability, essentially the Cumulative Distribution Function of the execution time T_k of the k^{th} limit order:

$$\Pr(T_k \leq t \mid X_k , P_k , S_k, I_k)$$

[10] We obtain the same results from the estimation of the order execution time model.

[11] See Cox and Oakes (1984), Jenkins (2004) and Kalbfleisch and Prentice (1980).

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where X_k is a vector of explanatory variables that captures market conditions and other information at the time of submission of the k^{th} limit order, and P_k, S_k and I_k are the limit order price, size and side indicator (buy or sell).

We follow Lo et al. (2002) and use a parametric approach. We adopt the generalized gamma distribution because it nests a number of other distributions (Weibull and Exponential) as special cases. Using maximum likelihood techniques, we estimate an accelerated failure time model of the form

$$T = e^{X'\beta} T_{0,}$$

where T is the time to execution, X is a vector of explanatory variables, ß is a parameter vector, and T_0 is called the baseline failure time and its distribution the baseline distribution. The time to execution T is then a scaled transformation of the baseline time T_0, where the explanatory variables and coefficients determine the scaling. After having done the estimation we analyze the estimated parameters of the generalized gamma distribution and we conclude that they are significantly far away from the values of the parameters of the Weibull or the Exponential distribution, so it is appropriate to use the generalized gamma.

9. Empirical Results

We estimate two different models for each asset and for the three sub-samples built taking into consideration the trading activity of the different stocks: one with assets characterized by high trading activity (high TA sample), the second one with assets with medium trading activity (medium TA sample) and the last one with assets with low trading activity (low TA sample). We take this decision in order to emphasize the different characteristics of the stocks belonging to the IBEX 35. We estimate one model for the buy side and one for the sell side, using the program STATA 7.0. The estimated parameters for the three samples, along with their corresponding standard errors, are reported in tables 6-8.

The variables we finally use in this analysis are: **execution times, volume (vol), relative bid ask spread (bidask), price aggressiveness (priceagr), volatility (volat), trading activity (lord60m), priority, percmkc(v),** the time of the day **($hour_i$ for i=1,2…17),** the day of the week **(day_j for j=1,2..5)** and the type of the last order introduced **(lastlb, lastls, lastmb** and **lastms).**

We present, at first, some general results. In the majority of the cases the coefficient of **volume** is negative and significant for both sides, indicating that the higher is the number of shares the trader wants to negotiate the shorter is the expected time of order execution. This result is the opposite of the one predicted by the literature, so it does not

support hypothesis 7. It may be a special feature of the Spanish market, where larger orders are placed mostly by professional traders who have a better knowledge of current market conditions and therefore place their orders when they are more likely to be executed.

The positive sign of the coefficient on **relative bid ask spread** indicates that an increase in the distance between the bid and ask prices causes an increase in the expected time of execution: these results imply that orders placed when the spread is wide are more difficult to execute due to the higher transaction cost related to a wide spread which provides little incentive for market order traders to execute against the existing limit orders (Suhaibani et al. (2000)). In this case the empirical result supports the hypothesis 1. The opposite one is showed by Cho and Nelling (2000) but the correspondent coefficient is not significant: they find out weak evidence that orders placed when spreads are wide take less time to be executed.

The negative sign of **price aggressiveness** shows that, as expected, more aggressive orders are executed faster (Demsetz, 1968). Investors seeking greater price improvement are likely to wait shorter for their trade to be executed; the same result is obtained by Suhaibani et al. (2000) and Lo et al. (2002) (hypothesis 2). The opposite result is obtained by Cho and Nelling (2000): traders placing aggressive orders are likely to wait longer to be executed; this result is a bit counterintuitive, since the effort of the improvement of the price is made in order to shorten the duration of the orders placed. Their analysis is applied to some liquid assets of the NYSE whose activity is very high.

The coefficient of **priority** is positive, as expected: when the number of shares that have higher priority of execution increases, the expected time of execution increases too, as predicted in hypothesis 4 (Lo et al, 2002 have a similar result).

The negative sign of the coefficient of **trading activity** and **volatility** implies that a shorter time to execution is expected when market conditions are more active and volatile as it is predicted in hypotheses 3 and 5.

Another variable considered is the percentage of limit orders executed on one side of the book one hour before the placement of the order **(percmkc(v))**. Its coefficient is usually negative (the only exception is the buy side of the high trade group) implying, for example, that the expected time of execution of a buy order is shorter when there is a preponderance of limit orders transacted on the same side of the book. That is, if the number of limit orders executed on the buy side increases it means that the number of market orders introduced on the sell side has increased, so there is an incentive to place limit orders on the buy side since the trading activity is high and the expected time of execution will be shorter. Hypothesis 6 is therefore confirmed.

We have divided the trading session into 17 intervals of 30 minutes and introduced dummies to study the effect of the time of placement. The results obtained depend on the sample we are taking into consideration and the side of the book. On the buy side orders placed in the first 30 minutes of the session and the last hour have a shorter expected time of execution than the other periods of the trading session for the medium and low trading activity samples, while for the high trading activity group only the last thirty minutes of the trading session have a shorter expected time of execution. On the sell side only the last 90 minutes have a shorter expected time of execution.

In the case of the days of the week we can see that in most of the cases they are significant. Nevertheless they don't show a common pattern for all the assets included in our analysis, it seems that each asset has its own daily path. For the high trading activity group we can observe that Tuesday (day2) shows a shorter expected time of execution than the rest of the days on both sides of the book. For the rest of the groups the daily pattern is different depending on the side of the market.

When a trader is willing to place a limit order he or she can give a look at the type of the last order introduced taking into account its effect on the duration of the new order placed. If the previous order before the placement is a market order on the opposite (same) side of the book, the duration of the new order is shorter (longer). This result is obtained for all the assets and the three groups. Probably if the last limit order is executed on the same (opposite) side there is a higher (lower) level of activity on that side.

If the previous order is a limit order on the same (opposite) side of the book, it means an increase in the depth on the same (opposite) side and consequently the probability of execution of the new limit order decreases (increases) since it is less (more) attractive and the duration is longer (shorter). This is true for all the assets and the three subgroups except the case of the high trading activity sample on the buy side. More in detail, SCH, TEF and TRR have a negative coefficient showing that if the previous order is a limit order to buy the duration of the new limit order to buy is shorter. A possible explanation is given by the fact that these assets are very active and well known, and this is a period of big expansion for them. In these markets there are a lot of traders, some of them informed and others uninformed. The uninformed traders sometimes imitate the actions of traders they believe to be informed, so the succession of limit buys may be explained as a process of imitation (Biais et al,1995).

Table 6: Results for the HIGH trading activity sample.

	BUY			SELL		
Variable	**Coef.**	**Std Error**	**z**	**Coef.**	**Std Error**	**z**
Vol	-0.00704	0.00049	-14.16	-0.00778	0.0006	-12.92
bidask	30.2126	10.9537	2.76	106.4633	15.0772	7.06
priceagr	-804.6113	36.1107	-22.28	-941.1358	26.2353	-35.87
volat	-4.3211	0.6193	-6.98	-7.7637	1.0906	-7.12
priority	2.54e-06	5.68e-07	4.48	4.87e-06	4.35e-07	11.20
lastlb	-0.1833	0.0605	-3.03	-0.4015	0.0553	-7.26
lastls	dropped			dropped		
lastmb	-0.9154	0.0459	-19.93	-0.1642	0.0391	-4.19
lastms	-0.1270	0.0204	-6.23	-0.8565	0.0278	-30.81
Day1	-0.4047	0.0396	-1.02	0.0310	0.0358	0.87
Day2	-0.0799	0.0235	-3.39	-0.0910	0.0281	-3.24
Day3	dropped			dropped		
Day4	0.0254	0.0248	1.02	-0.0283	0.0305	-0.93
Day5	-0.0355	0.0312	-1.14	-0.0304	0.0442	-0.69
Time1	0.2677	0.0515	5.20	0.1524	0.1265	1.20
Time2	0.3225	0.0763	4.23	0.3499	0.0583	6.00
Time3	0.4700	0.0380	12.36	0.2729	0.0771	3.54
Time4	0.4288	0.0967	4.43	0.3135	0.0551	5.69
Time5	0.4085	0.0603	6.77	0.2714	0.0655	4.14
Time6	0.5374	0.0360	14.89	0.3823	0.0689	5.55
Time7	0.5205	0.0376	13.84	0.3830	0.0527	7.26
Time8	0.4917	0.0379	12.96	0.3871	0.0483	8.02
Time9	0.4577	0.0388	11.78	0.3723	0.0492	7.55
Time10	0.5015	0.0391	12.83	0.4936	0.0488	10.11
Time11	0.2047	0.1244	1.65	0.3339	0.0527	6.33
Time12	0.2567	0.0387	6.63	0.2828	0.0671	4.21
Time13	0.1605	0.0388	4.13	0.2009	0.0507	3.96
Time14	dropped			dropped		
Time15	-0.0217	0.0428	-0.51	-0.10255	0.0491	-2.09
Time16	-0.0323	0.0320	-1.01	-0.1863	0.0757	-2.46
Time17	-0.2344	0.0383	-6.12	-0.3122	0.0489	-6.38
percmkc/v	0.2315	0.1047	2.21	-0.5870	0.0809	-7.25
lord60m	-0.1798	0.0188	-9.52	-0.0833	0.0195	-4.27
cons	5.0051	0.1556	32.17	5.0823	0.1092	46.52
/ln sigma	1.29358	0.06382	202.69	1.3464	0.01085	124.10
/kappa	-4.1397	0.04158	-99.55	-4.1387	0.05842	-70.83
sigma	3.6458	0.02327		3.8436	0.04170	

Table 7: Results for the MEDIUM trading activity sample.

	BUY			SELL		
Variable	**Coef.**	**Std Error**	**z**	**Coef.**	**Std Error**	**z**
Vol	-0.039489	0.0028	-13.96	-0.04879	0.0033	-14.70
bidask	88.1490	13.4326	6.56	136.3413	6.5968	20.67
priceagr	-524.86	21.3380	-24.60	-514.8436	15.3133	-33.62
volat	-7.2950	1.1604	-6.29	-13.6713	1.2349	-11.07
priority	0.00004	4.60e-06	8.68	0.00004	5.94e-06	7.69
lastlb	0.0993	0.0374	2.66	-0.2046	0.0461	-4.43
lastls	dropped			dropped		
lastmb	-0.6222	0.0547	-11.37	-0.3206	0.0395	-8.11
lastms	-0.2396	0.0405	-5.91	-0.4705	0.0496	-9.48
Day1	-0.0681	0.0261	-2.62	0.1237	0.0382	3.24
Day2	-0.1185	0.0264	-4.48	0.0533	0.0377	1.42
Day3	dropped			dropped		
Day4	-0.1268	0.0356	-3.57	0.0354	0.0345	1.03
Day5	-0.0853	0.0267	-3.20	-0.0083	0.0398	-0.21
Time1	-0.3944	0.1324	-2.98	0.0288	0.0865	0.33
Time2	0.1874	0.0468	4.00	0.1966	0.0657	2.99
Time3	0.3687	0.0493	7.48	0.1607	0.0652	2.46
Time4	0.4077	0.0479	8.50	0.3315	0.0537	6.17
Time5	0.4069	0.0494	8.22	0.3739	0.0548	6.81
Time6	0.3555	0.0496	7.15	0.2375	0.0608	3.91
Time7	0.2455	0.0522	4.70	0.3492	0.0559	6.25
Time8	0.2749	0.0528	5.20	0.2051	0.0567	3.61
Time9	0.3532	0.0506	6.98	0.2275	0.0589	3.86
Time10	0.2634	0.0521	5.05	0.3418	0.0601	5.69
Time11	0.2545	0.0606	4.20	0.3796	0.0621	6.10
Time12	0.2312	0.0534	4.33	0.3235	0.0640	5.05
Time13	0.1448	0.0518	2.79	0.1489	0.0651	2.29
Time14	dropped			dropped		
Time15	-0.0119	0.0453	-0.26	-0.1096	0.0505	-2.17
Time16	-0.1676	0.0466	-3.60	-0.2031	0.0651	-3.12
Time17	-0.3571	0.0488	-7.31	-0.4020	0.0511	-7.86
percmkc/v	-0.6573	0.0818	-8.04	-0.3504	0.0564	-6.21
lord60m	-0.3320	0.0188	-17.63	-0.1887	0.0188	-10.03
cons	7.9297	0.1881	42.15	7.0190	0.1066	65.86
/ln sigma	1.34026	0.0119	112.57	1.39737	0.00758	184.35
/kappa	-2.09813	0.0644	-32.57	-2.4076	0.0424	-56.79
sigma	3.82002	0.0454		4.0445	0.0306	

Table 8: Results for the LOW trading activity sample.

	BUY			SELL		
Variable	**Coef.**	**Std Error**	**z**	**Coef.**	**Std Error**	**z**
Vol	-0.07691	0.00514	-14.97	-0.05346	0.009299	-5.75
bidask	79.908	13.8562	5.77	132.3964	6.1305	21.60
priceagr	-452.601	11.8744	-38.12	-457.7076	14.4107	-31.76
volat	-10.5047	1.7605	-5.97	-18.5352	1.2462	-14.87
priority	0.00006	7.17e-06	8.76	0.00006	0.00002	3.57
lastlb	0.3123	0.0424	7.37	-0.2167	0.0562	-3.85
lastls	dropped			dropped		
lastmb	-0.5565	0.0768	-7.24	-0.3896	0.0435	-8.94
lastms	-0.2456	0.0434	-5.66	-0.3005	0.1139	-2.64
Day1	0.0952	0.0461	2.06	-0.0873	0.0525	-1.66
Day2	-0.0108	0.0435	-0.25	0.0334	0.0487	0.69
Day3	dropped			dropped		
Day4	0.0463	0.0423	1.09	-0.0798	0.0490	-1.63
Day5	-0.0457	0.0419	-1.09	0.0576	0.0478	1.21
Time1	-0.4763	0.1121	-4.25	0.0661	0.0974	0.68
Time2	0.0653	0.0804	0.81	0.1678	0.08677	1.93
Time3	0.3994	0.0806	4.95	0.2284	0.0860	2.66
Time4	0.3636	0.0824	4.41	0.1940	0.0883	2.20
Time5	0.3535	0.0839	4.21	0.0608	0.1054	0.58
Time6	0.2021	0.0859	2.35	0.3463	0.0929	3.73
Time7	0.0930	0.0830	1.12	0.0083	0.0926	0.09
Time8	0.3628	0.0867	4.18	0.0277	0.0943	0.29
Time9	0.1189	0.0907	1.31	0.1230	0.0971	1.27
Time10	0.1566	0.0895	1.75	0.2217	0.0997	2.22
Time11	0.3274	0.0903	3.63	-0.0507	0.0987	-0.51
Time12	0.1486	0.0885	1.68	0.1822	0.1004	1.81
Time13	-0.4701	0.0883	-0.53	-0.0451	0.0967	-0.47
Time14	dropped			dropped		
Time15	-0.0968	0.0801	-1.21	-0.2591	0.0818	-3.17
Time16	-0.1637	0.0758	-2.16	-0.2083	0.0821	-2.54
Time17	-0.3027	0.0757	-4.00	-0.4994	0.0814	-6.14
percmkc/v	-0.5933	0.0643	-9.23	-0.8699	0.0696	-12.50
lord60m	-0.4923	0.0229	-21.51	-0.1834	0.0232	-7.90
cons	9.0299	0.1405	64.28	8.5058	0.1519	55.98
/ln sigma	1.3984	0.00604	231.41	1.43169	0.00665	215.08
/kappa	-1.8376	0.04857	-37.84	-1.62129	0.081278	-19.95
sigma	4.0486	0.0244		4.18577	0.027863	

Table 9: Results for the HIGH trading activity sample during the period between 9:00-11:00.

		BUY			SELL	
Variable	Coef.	Std Error	z	Coef.	Std Error	z
Vol	-0.0062063	0.00108	-5.71	-0.007323	0.00098	-7.40
bidask	100.6421	19.5327	5.15	123.9867	17.7248	7.00
priceagr	-561.5492	42.3221	-13.27	-709.4757	39.6876	-17.88
volat	-1.7365	0.3848	-4.51	-4.5676	0.9741	-4.69
priority	0.00002	2.15e-06	8.37	4.68e-06	2.99e-07	15.66
lastlb	-0.09967	0.0635	-1.57	-0.2812	0.0739	-3.80
lastls	dropped			dropped		
lastmb	-0.8752	0.1050	-8.34	-0.1787	0.0608	-2.94
lastms	-0.1663	0.0353	-4.71	-0.7202	0.0499	-14.42
Day1	-0.3228	0.0851	-3.79	-0.0362	0.0689	-0.53
Day2	-0.1556	0.0461	-3.37	-0.1171	0.0487	-2.40
Day3	dropped			dropped		
Day4	-0.2157	0.0423	-5.09	-0.0042	0.0482	-0.09
Day5	-0.1108	0.0440	-5.52	-0.0095	0.0632	-0.15
Time1	-0.0941	0.0556	-1.69	-0.0743	0.095	-0.83
Time2	0.0292	0.0581	0.50	0.0483	0.0428	1.13
Time3	0.1281	0.0597	2.14	-0.0109	0.0583	-0.19
Time4	dropped			dropped		
percmkc/v	0.3011	0.1120	2.69	-1.0500	0.1163	-9.03
lord60m	-0.2364	0.0208	-11.38	-0.0602	0.0242	-2.48
cons	5.3411	0.1570	34.00	4.8441	0.1629	29.74
/ln sigma	1.3418	0.0137	98.12	1.3167	0.0127	103.26
/kappa	-4.919	0.0754	-65.28	-5.1367	0.0746	-68.82
sigma	3.8261	0.0523		3.7308	0.0476	

Table 10: Results for the HIGH trading activity sample during the intermediate period (11:00-15:30).

	BUY			SELL		
Variable	**Coef.**	**Std Error**	**z**	**Coef.**	**Std Error**	**z**
Vol	-0.0099	0.0008	-12.13	-0.0121	0.0010	-11.80
bidask	12.4394	21.6058	0.58	100.4896	23.4618	4.28
priceagr	-930.8218	56.2991	-16.53	-1063.762	43.2077	-24.62
volat	-5.2488	0.8843	-5.94	-12.1974	1.9812	-6.16
priority	7.57e-06	9.81e-06	7.72	5.83e-06	8.23e-07	7.08
lastlb	-0.4005	0.1094	-3.66	-0.5013	0.0830	-6.04
lastls	dropped			dropped		
lastmb	-0.8448	0.0358	-23.55	-0.1359	0.0464	-2.93
lastms	-0.2098	0.0332	-6.32	-0.8536	0.0361	-23.62
Day1	0.0317	0.0359	0.88	0.1607	0.0540	2.97
Day2	-0.1807	0.0306	-5.89	-0.0446	0.0434	-1.03
Day3	dropped			dropped		
Day4	0.0533	0.0446	1.20	0.0077	0.0563	0.14
Day5	-0.1558	0.0465	-3.35	0.1776	0.0446	3.98
Time5	0.1651	0.0682	2.42	-0.0846	0.0689	-1.23
Time6	0.3693	0.0443	8.33	0.1964	0.0465	4.22
Time7	0.3441	0.0459	7.48	0.1670	0.0557	3.00
Time8	0.3153	0.0452	6.97	0.1999	0.0518	3.86
Time9	0.3008	0.0448	6.71	0.1651	0.0454	3.64
Time10	0.3431	0.0457	7.55	0.3322	0.0484	6.85
Time11	-0.0881	0.1106	-0.80	0.1132	0.0512	2.21
Time12	0.0989	0.0457	2.16	0.0876	0.0746	1.17
Time13	dropped			dropped		
percmkc/v	0.7411	0.1641	4.52	-0.7865	0.1119	-7.02
lord60m	-0.0703	0.0337	-2.08	0.0404	0.0317	1.27
cons	4.4285	0.3017	14.68	4.6860	0.1939	24.17
/ln sigma	1.3612	0.0072	188.14	1.4073	0.0098	143.95
/kappa	-4.1983	0.0555	-75.68	-4.2946	0.0689	-62.32
sigma	3.9011	0.0282		4.0847	0.0399	

Table 11: Results for the HIGH trading activity sample during the afternoon (15:30-17:30).

		BUY			SELL	
Variable	Coef.	Std Error	z	Coef.	Std Error	z
Vol	-0.0043	0.0061	-7315	-0.0042	0.0007	-5.85
bidask	165.048	35.1768	4.69	144.299	33.7987	4.27
priceagr	-1043.393	29.3247	-5.58	-1011.268	31.8276	-31.77
volat	-8.5358	0.8065	-10.58	-9.0247	0.8451	-10.68
priority	1.61e-06	6.94e-07	2.32	4.39e-06	8.28e-07	5.30
lastlb	-0.1031	0.0557	-1.85	-0.3226	0.0681	-4.73
lastls	dropped			dropped		
lastmb	-1.0665	0.0367	-29.07	-0.0979	0.0328	-2.99
lastms	0.0738	0.0320	2.31	-0.9163	0.0343	-26.67
Day1	0.1732	0.0381	4.54	0.0176	0.0430	0.41
Day2	0.0584	0.0531	1.10	-0.0391	0.0436	-0.90
Day3	dropped			dropped		
Day4	0.1708	0.0403	4.24	-0.0359	0.0513	-0.70
Day5	0.1308	0.0445	2.94	-0.1250	0.0531	-2.35
Time14	dropped			dropped		
Time15	-0.0090	0.0371	-0.24	-0.1087	0.0433	-2.51
Time16	-0.0206	0.0324	-0.64	-0.1007	0.0443	-2.27
Time17	-0.2714	0.0364	-7.45	-0.3093	0.0438	-7.05
percmkc/v	-0.2524	0.1061	-2.38	0.2239	0.1070	2.09
lord60m	-0.1615	0.0200	-7.95	-0.1754	0.0238	-7.37
cons	5.2068	0.1671	31.16	5.4636	0.1585	34.47
/ln sigma	1.1511	0.0087	132.87	1.2233	0.0091	133.71
/kappa	-3.1258	0.0412	-75.88	-3.2317	0.0447	-72.26
sigma	3.1618	0.0274		3.3985	0.0311	

Table 12: Results for the MEDIUM trading activity sample during the period between 9:00-11:00.

		BUY			SELL	
Variable	Coef.	Std Error	z	Coef.	Std Error	z
Vol	-0.0297	0.00726	-4.09	-0.03686	0.0041	-9.07
bidask	116.1743	12.5271	9.27	125.3162	11.0941	11.30
priceagr	-385.1073	31.2927	-12.31	-410.5632	13.6559	-17.36
volat	-3.8211	1.2828	-2.98	-8.5156	1.9651	-4.33
priority	0.00006	5.68e-06	10.65	0.00004	6.43e-06	5.63
lastlb	0.2185	0.0548	3.99	-0.3487	0.0685	-5.09
lastls	dropped			dropped		
lastmb	-0.4535	0.0730	-6.21	-0.3825	0.0713	-5.37
lastms	-0.2065	0.0573	-3.60	-0.4917	0.0719	-6.84
Day1	-0.0213	0.0516	-0.41	0.1696	0.0736	2.30
Day2	-0.0738	0.0517	-1.43	0.1245	0.0729	1.71
Day3	dropped			dropped		
Day4	-0.1646	0.0598	-2.75	0.1091	0.0654	1.67
Day5	-0.0095	0.0486	-0.20	0.0466	0.0787	0.59
Time1	-0.6674	0.0795	-8.39	-0.2194	0.0789	-2.78
Time2	-0.2345	0.0446	-5.25	-0.0924	0.0549	-1.68
Time3	-0.0206	0.0459	-0.45	-0.1066	0.0533	-2.00
Time4	dropped			dropped		
percmkc/v	-0.9043	0.1021	-8.85	-0.3765	0.0975	-3.86
lord60m	-0.3435	0.0325	-10.55	-0.1795	0.0348	-5.15
cons	7.8004	0.2425	32.18	6.7593	0.1758	38.45
/ln sigma	1.3381	0.0136	98.04	1.4012	0.0095	147.63
/kappa	-2.5797	0.0510	-50.57	-2.9452	0.0455	-64.64
sigma	3.8120	0.052		4.060	0.0385	

Table 13: Results for the MEDIUM trading activity sample during the intermediate period (11:00-15:30).

	BUY			SELL		
Variable	**Coef.**	**Std Error**	**z**	**Coef.**	**Std Error**	**z**
Vol	-0.0425	0.0045	-9.51	-0.0607	0.0059	-10.27
bidask	97.3817	15.4569	6.30	141.9646	10.3823	13.67
priceagr	-663.9295	12.1711	-54.55	-589.1338	16.9997	-34.66
volat	-14.2620	1.7611	-8.10	-15.5335	1.6578	-9.37
priority	0.00003	3.69e-06	9.43	0.00006	7.36e-06	8.26
lastlb	0.0057	0.0479	0.12	-0.2516	0.0837	-3.00
lastls	dropped			dropped		
lastmb	-0.5737	0.0660	-8.69	-0.3520	0.0441	-7.97
lastms	-0.1510	0.0344	-4.39	-0.3510	0.0764	-4.59
Day1	-0.1067	0.0433	-2.46	0.0304	0.0532	0.57
Day2	-0.1636	0.0439	-3.72	0.0509	0.0465	1.09
Day3	dropped			dropped		
Day4	-0.1094	0.0415	-2.63	-0.0079	0.0476	-0.17
Day5	-0.1425	0.0448	-3.18	0.0001	0.0475	0.00
Time5	0.2610	0.0535	4.87	0.2463	0.0717	3.43
Time6	0.2103	0.0553	3.80	0.0840	0.0797	1.05
Time7	0.1011	0.0570	1.77	0.2277	0.0719	3.17
Time8	0.1555	0.0558	2.79	0.0900	0.0729	1.24
Time9	0.2014	0.0551	3.65	0.1050	0.0757	1.39
Time10	0.1357	0.0572	2.37	0.2347	0.0737	3.18
Time11	0.0806	0.0697	1.16	0.2351	0.0761	3.09
Time12	0.1032	0.0595	1.74	0.1712	0.0817	2.10
Time13	dropped			dropped		
percmkc/v	-0.4834	0.0727	-6.65	-0.2053	0.0853	-2.41
lord60m	-0.2806	0.0231	-12.16	-0.2607	0.0286	-9.13
cons	7.7459	0.1237	62.62	7.5030	0.1449	51.78
/ln sigma	1.3616	0.0078	174.47	1.4465	0.0079	181.53
/kappa	-2.2421	0.0430	-52.10	-2.4624	0.0471	-52.22
sigma	3.9025	0.0304		4.2498	0.03387	

Table 14: Results for the MEDIUM trading activity sample during the afternoon (15:30-17:30).

		BUY			SELL	
Variable	Coef.	Std Error	z	Coef.	Std Error	z
Vol	-0.0384	0.0026	-14.61	-0.0402	0.0060	-6.75
bidask	137.9753	9.8276	14.04	161.6444	8.8064	18.36
priceagr	-597.9833	16.4762	-36.29	-579.1382	19.6362	-29.49
volat	-11.7344	1.0637	-10.97	-21.1568	1.2967	-16.32
priority	0.00003	6.38e-06	5.38	0.00005	0.00001	4.03
lastlb	0.0234	0.0445	0.53	-0.0082	0.04806	-0.17
lastls	dropped			dropped		
lastmb	-0.7846	0.0785	-10.01	-0.1378	0.0385	-3.58
lastms	-0.1011	0.0412	-2.45	-0.3447	0.1023	-3.37
day1	-0.0687	0.0423	-1.62	0.1684	0.0497	3.39
day2	-0.0737	0.0416	-1.77	-0.0157	0.0477	-0.33
day3	dropped			dropped		
day4	0.0467	0.0423	1.10	0.0472	0.0465	1.01
day5	-0.0416	0.0441	-0.94	-0.0586	0.0471	-1.24
Time14	dropped			dropped		
Time15	0.0009	0.0435	0.02	-0.1289	0.0497	-2.59
Time16	-0.1472	0.0440	-3.34	-0.2075	0.0505	-4.11
Time17	-0.3361	0.0488	-6.89	-0.4910	0.0543	-9.04
percmkc/v	-0.6464	0.0778	-8.31	-0.5515	0.0781	-7.06
lord60m	-0.3452	0.0223	-15.45	-0.1195	0.0252	-4.74
cons	8.0581	0.1639	49.16	7.1888	0.1545	46.51
/ln sigma	1.2255	0.0091	134.13	1.2870	0.0093	138.47
/kappa	-1.6420	0.0745	-22.04	-1.7352	0.0784	-22.12
sigma	3.4058	0.0311		3.6219	0.0337	

Table 15: Results for the LOW trading activity sample during the period between 9:00-11:00.

		BUY			SELL	
Variable	Coef.	Std Error	z	Coef.	Std Error	z
Vol	-0.0471	0.0065	-7.23	-0.0357	0.0235	-1.52
bidask	107.5601	9.9746	10.78	113.8763	11.02	10.34
priceagr	-365.9916	19.5721	-18.70	-358.7272	13.8708	-25.86
volat	-8.2497	3.1183	-2.65	-8.3738	2.8751	-2.91
priority	0.00015	0.00003	6.16	0.0002	0.00003	8.75
lastlb	0.2775	0.0806	3.44	-0.1063	0.1004	-1.06
lastls	dropped			dropped		
lastmb	-0.5444	0.1258	-4.33	-0.4314	0.0851	-5.07
lastms	-0.2980	0.0776	-3.84	-0.6644	0.1794	-3.70
day1	0.1717	0.0856	2.00	0.0955	0.1008	0.95
day2	-0.0133	0.0873	-0.15	0.1698	0.1015	1.67
day3	dropped			dropped		
day4	0.1877	0.0861	2.18	0.0271	0.0999	0.27
day5	-0.0898	0.0866	-1.04	0.2109	0.0976	2.16
Time1	-0.7334	0.1067	-6.88	-0.2020	0.1080	-1.87
Time2	-0.2293	0.0744	-3.08	-0.0458	0.0867	-0.53
Time3	0.0759	0.0856	1.02	0.0754	0.0837	0.90
Time4	dropped			dropped		
percmkc/v	-0.8392	0.1225	-6.85	-0.8579	0.1274	-6.70
lord60m	-0.4114	0.0429	-9.58	-0.2613	0.0469	5.56
cons	8.437	0.219	38.51	8.2439	0.2353	35.04
/ln sigma	1.40007	0.013	107.39	1.4315	0.0130	109.90
/kappa	-2.2867	0.0638	-35.83	-2.017	0.07235	-27.88
sigma	4.0555	0.0528		4.1848	0.0545	

Table 16: Results for the LOW trading activity sample during the intermediate period (11:00-15:30).

	BUY			SELL		
Variable	**Coef.**	**Std Error**	**z**	**Coef.**	**Std Error**	**z**
Vol	-0.07189	0.0070	-10.22	-0.08310	0.0092	-9.07
bidask	67.5155	17.8327	3.79	127.4024	9.9561	12.80
priceagr	-513.5178	17.7066	-29.00	-504.6234	35.4254	-14.24
volat	-12.0115	4.3129	-2.79	-22.4021	3.1970	-7.01
priority	0.00011	0.00002	5.74	0.00004	0.00002	2.61
lastlb	0.3722	0.0656	5.67	-0.1317	0.0901	-1.46
lastls	dropped			dropped		
lastmb	-0.3863	0.1337	-2.89	-0.4646	0.0801	-5.80
lastms	-0.2258	0.0623	-3.63	-0.0443	0.2264	-0.20
day1	0.1069	0.0685	1.56	-0.2329	0.0862	-2.70
day2	-0.0239	0.0676	-0.35	-0.1825	0.0776	-2.35
day3	dropped			dropped		
day4	0.04028	0.0654	0.62	-0.1355	0.0752	-1.80
day5	-0.1289	0.0664	-1.94	-0.0141	0.0758	-0.19
Time5	0.3969	0.0914	4.34	0.0785	0.1085	0.72
Time6	0.2681	0.0928	2.89	0.3838	0.1033	3.72
Time7	0.1391	0.0901	1.54	0.0401	0.1021	0.39
Time8	0.4198	0.0942	4.46	0.1187	0.1024	1.16
Time9	0.2280	0.0964	2.37	0.1611	0.1046	1.54
Time10	0.2087	0.0957	2.18	0.2677	0.1080	2.48
Time11	0.3843	0.0964	3.99	-0.0371	0.1075	-0.34
Time12	0.2198	0.966	2.27	0.2157	0.1086	1.99
Time13	dropped			dropped		
percmkc/v	-0.3577	0.0986	-3.63	-0.8762	0.1130	-7.76
lord60m	-0.5486	0.0367	-15.39	-0.2278	0.0377	-6.05
cons	9.2330	0.1815	50.88	9.0115	0.2885	31.24
/ln sigma	1.4307	0.008192	174.65	1.4629	0.01095	133.56
/kappa	-1.7649	0.074	-23.85	-1.5527	0.168	-9.24
sigma	4.1826	0.034256		4.3183	0.04729	

Table 17: Results for the LOW trading activity sample during the afternoon (15:30-17:30).

		BUY			SELL	
Variable	Coef.	Std Error	z	Coef.	Std Error	z
Vol	-0.0561	0.0082	-6.81	-0.028	0.01225	-2.29
bidask	166.0775	9.8670	16.83	159.5387	10.4082	15.33
priceagr	-488.5414	21.8607	-22.35	-466.1792	18.4601	-25.25
volat	-11.5175	1.7858	-6.45	-20.5726	1.4815	-13.89
priority	0.000046	0.00001	4.49	0.00019	0.000024	8.11
lastlb	0.3216	0.0664	4.85	-0.3098	0.0895	-3.46
lastls	dropped			dropped		
lastmb	-0.4434	0.1508	-2.94	-0.2187	0.0656	-3.33
lastms	-0.0269	0.0636	-0.42	-0.0141	0.169	-0.08
day1	0.0679	0.0743	0.92	-0.0988	0.0836	-1.18
day2	0.0386	0.0717	0.54	0.131	0.0819	1.60
day3	dropped			dropped		
day4	-0.0346	0.0706	-0.49	-0.0797	0.0832	-0.96
day5	0.0153	0.0689	0.22	-0.006	0.0802	-0.08
Time14	dropped			dropped		
Time15	-0.1208	0.0758	-1.59	-0.3018	0.0828	-3.64
Time16	-0.2289	0.0767	-2.98	-0.2759	0.0842	-3.28
Time17	-0.3883	0.0772	-5.03	-0.6239	0.0871	-7.16
percmkc/v	-0.73	0.1037	-7.04	-0.9124	0.1138	-8.01
lord60m	-0.5187	0.0393	-13.20	-0.0879	0.04	-2.19
cons	-.3410	0.2376	9.32	8.3624	0.2207	37.89
/ln sigma	1.2995	0.0090	143.56	1.3329	0.0122	108.98
/kappa	-1.2052	0.1068	-11.28	-1.0787	0.1205	-8.95
sigma	3.6676	0.0332		3.7919	0.04638	

We also analyze the different effect of the explanatory variables over the different periods of the trading session. The results are reported in tables 9-17. We have divided the trading session into three periods by looking at figures 3 and 4: morning or opening period (9:00-11:00), intermediate period (11:00-15:30) and afternoon or closing period (15:30-17:30).

As observed before, volume has a negative coefficient. This is true for all the periods of the trading session but the effect is the highest in the intermediate period (when uncertainty is reduced) and it gets weaker in the closing period and in the opening period for all the groups on both sides of the market.

About price aggressiveness we can remind that an increase of the order aggressiveness makes the expected time of execution shorter, and also in this case the strongest effect is obtained in the intermediate period (except for the high trading sample, where the effect is stronger in the afternoon). The weakest effect is observed in the morning, probably because price improvements are used as an instrument for price discovery rather than as a way to speed up execution time.

The relative inside spread shows a positive coefficient. This is true for all the periods of the trading session, but the strongest effect is obtained at the beginning and at the end of the trading session when there is more uncertainty. This is true for all the groups on the buy side and for the high one on the sell side; in the rest of the cases (low and medium trading activity samples on the sell side) the effect achieves the smallest value in the morning and then it becomes bigger and bigger[12].

Volatility has a negative coefficient and it takes the biggest value in the intermediate period, a bit lower in the afternoon and still lower in the opening period. It can be observed that the strongest effect is obtained when, on average, the volatility in the market is small and vice-versa (figure 4). The only exception is given by the medium (on the sell side) and the high (on the buy side) which follow an increasing pattern.

If the priority increases, the expected time of execution increases too. On the buy side the effect seems to be more intense in the opening period when the market is trying to discover the price and a lot of orders are placed, while in the following periods the effect is decreasing over the trading session. On the sell side this effect is the highest on the intermediate period, a bit lower in the morning and it reaches the lowest point in the closing period. This is true for the high and medium trading activity samples, while the low trading activity group has the opposite pattern.

[12] Probably it is an outcome of the trading activity.

The percentage of orders executed on one side of the book one hour before the placement has a negative coefficient. For the low and medium trading activity group this effect is the highest one at the beginning and at the end of the trading session, when there are a lot of orders placed and executed. For the high group there is no clear pattern.

If the last order introduced is a market order on the opposite side of the book the coefficient is negative and its effect has an increasing pattern over the trading session. The highest effect is achieved in the afternoon.

If the last order introduced is a market order on the same side of the book, the effect on the expected time of execution is negative and in general it is decreasing over the trading session. If the last order introduced is a limit order there is no special pattern and many coefficients are not significant.

10. Conclusions

In this paper we have analyzed the microstructure of the Spanish Stock Exchange. Our objective was to study the effect of microstructure variables on the speed of limit order execution. We have estimated the model separately for each asset, for the three sub samples classified according to the trading activity and for each side of the market; the results are similar for all the assets. We used the method of survival analysis which takes into account the problem of censored observations of our dataset. We find that execution times are sensitive to some explanatory variables such as the bid—ask spread, price aggressiveness, volatility and trading activity. Limit orders priced at the quotes or within the quotes have a shorter expected time to execution. Also, execution time is shorter when the asset is more volatile and active. The time of the day affects the expected execution time; for orders placed during the first 30 minutes and the last hour of the trading session the expected execution time is shorter on the buy side, while on the sell side only the orders placed during the last 90 minutes have a shorter expected time of execution. The type of the last order introduced before the placement also affects the duration of the new limit order. For example, if the previous order is a market order on the opposite side of the book the expected time of execution of a new limit order is shorter because in this side of the market there is a lot of activity and the probability of execution is higher.

We have also divided the trading session into three periods in order to study how the explanatory variables affect differently the expected time of execution over the trading session.

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8. Appendix

8.1List and distribution of the assets over the three sub samples

We divide the assets in three sub samples according to the trading activity computed as the logarithm of the number of transactions occurred one before the placement. All the assets with a median trading activity lower than 3.8 belong to the low trading activity sample (L). If the assets present a median trading activity included between 3.8 and 5 they belong to the medium trading activity sample (M) and, finally, if the assets have a median trading activity higher than 5 they are assigned to the high trading activity group (H).

Acesa	ACE	**L**	Ferrovial	FER	**M**
Aceralia	ACR	**M**	Iberdrola	IBE	**M**
Actividades Construcción Servicios	ACS	**L**	Indra	IDR	**M**
Acerinox	ACX	**L**	NH Hoteles	NHH	**L**
Aguas de Barcelona	AGS	**L**	Banco Popular	POP	**M**
Corporación Financiera Alba	ALB	**L**	Pryca	PRY	**L**
Altadis	ALT	**M**	Red Eléctrica de España	REE	**L**
Amadeus A Privilegiadas	AMS	**M**	Repsol	REP	**H**
Acciona	ANA	**L**	(Banco)Santander Central Hispano	SCH	**H**
Banco Bilbao Vizcaya Argentaria	BBVA	**H**	Sogecable	SGC	**M**
Bankinter	BKT	**M**	Sol Meliá	SOL	**M**
Hidrocantábrico	CAN	**L**	Telefónica	TEF	**H**
Continente	CTE	**L**	Telefónica Publicidad e Información	TPI	**M**
Gas Natural	CTG	**L**	Telepizza	TPZ	**M**
Grupo Dragados	DRC	**M**	Terra	TRR	**H**
Endesa	ELE	**H**	Unión Fenosa	UNF	**M**
Fomento de Construcción Contratas	FCC	**M**	Grupo Vallehermoso	VAL	**L**