The Speed of Limit Order Execution in the Spanish Stock Exchange

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Abstract

We study the factors influencing the speed of limit order execution in the Spanish Stock Exchange. Our dataset includes the orders and transactions of all the assets belonging to IBEX 35 in the period between July and September 2000. 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 in the first hour and the last two hours of the trading session, and it is longer when the inside bid ask spread is larger.

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. 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.

In this paper we analyze the variables affecting the speed of execution and their quantitative impact in the Spanish stock exchange. 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), ensuring a single unified market for each share. The market gives real time information on its screens, so that transparency is fully guaranteed.

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 all the assets belonging to the index IBEX 35, including the shares with

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higher trading volume, in the period between July and September 2000. We will 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). This method is the most appropriate for modeling their evolution and 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 describe the institutional characteristics of the Spanish stock exchange and describe our data. Section 5 discusses the main econometric techniques used in the analysis and presents the model to be estimated. The empirical results appear in section 6, and section 7 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 by the traders, and may therefore influence their decision about whether or not to place a limit order and the price of the order.

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. More in detail, 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.

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 and they try to capture the trade off between the price of the order, probability of execution and the winner's curse risk associated with different order choice. 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 Investment Technology Group (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.

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 expected time to execution 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.

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

In our analysis we consider assets belonging to the IBEX 35, the index of the most traded stocks on 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 in the first hour and the last two hours of the trading session. A relationship is found between expected time of execution and a variable which captures the interaction between the bid ask spread and the trading activity: its coefficient has a negative sign and this relationship is significative only for two assets belonging to the banking sector.

3. 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.

3.1 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 rule. 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[3]. 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 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 which can be executed 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 at 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

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

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. In main trading minimum price variations are: 0.01 euros for prices up to 50 euros; 0.05 euros for prices over 50 euros.

3.2 The Dataset

The data we need to construct the explanatory variables and the execution times are not 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. Contains information about the limit order book as available to market participants. This is given by the five first best orders 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. 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 best 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 five first levels.

Dataset BASA. 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 rigorously the sign of the trade of each transaction and to construct 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. 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.

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) 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[4]. The non—censored observations include all the orders executed, with their time of execution (the time of execution is 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

[4] The time of expiration is computed in the same way in Cho and Nelling (2000).

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. This way 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. The list is provided in the appendix.

3.3 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.

3.3.1 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. According to Biais the most aggressive orders corresponds 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 less 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. 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 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.

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 shows an increase in the aggressiveness, so the more aggressive an order is, the higher will be the value of this variable. If the price aggressiveness takes a negative value it means that the trader has placed the order out of the quote. If we analyze the effect of the price aggressiveness on the order execution times 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.

3.3.2 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 considered. It is expressed in seconds.

The **size of the order** is represented by the number of shares of the order.

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

$$\textit{Relative inside spread}_{t-1} = \frac{askprice_{t-1} - bidprice_{t-1}}{\dfrac{bidprice_{t-1} + askprice_{t-1}}{2}}$$

A wider spread implies a higher transaction cost which provides little incentive for market order traders to execute against the existing limit orders (Suhaibani et al. (2000)). We expect that if the relative bid ask spread increases, the time of execution of the new 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.

We considered two definitions of **volatility.** The firs tone is 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 (**volatility 1**). The second definition is the ratio between the number of transactions of the 30 minutes before the placement of the order and the number of transactions happened one hour before the placement of the order (**volatility 2**) (Lo et al. (2002)). We expect a negative impact of higher 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 expected execution time decreases.

Priority gives the number of shares that have priority on the execution before the new order placed: if the number of shares that have higher priority of execution increases the expected time to execution should also increase.

Another explanatory variable is the one which represents the number of transactions occurred 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 transactions on the buy (sell) side is higher than the number of transactions on the sell (buy) side. Some theoretical models postulate the existence of a diagonal effect: if there is a preponderance of sell (buy) orders the investors tend to place more 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 the execution time of it. For example, Bias et al. (1995) show that 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)). We have also considered the effect of depth on the expected time of execution, considering three possible definitions of the variable:

• **order imbalance**, the proportion of shares on the ask (bid) side with respect to all the limit order book available at the first level;

• **depth1**, the number of shares at the first level;

• **perquant**, the sum of the number of shares outstanding at the five first levels on one side of the market divided by the number of shares outstanding in the five first levels on both sides of the market.

These definitions of depth are the most common used in the literature. According to the prediction of Handa et al. (1996), depth increases the expected time to execution. We estimate different models introducing the three different definitions of depth and we expect to obtain a positive coefficient for this variable. In many cases the coefficient turns out not to be significant. For example, using perquant we obtain a positive coefficient for 11 assets (only 2 cases are significative, ACS and BKT) on the buy side and for 3 assets (all are significative: BKT, SCH, BBVA) on the sell side. Since the results are weak and contradictory, we have opted for excluding these variables from our final regressions.

3.4 Summary statistics

In this section we present the summary statistics of the limit order book dataset for our assets. We have considered the 35 stocks belonging to the IBEX 35 index 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 and the percentage of orders executed is in parenthesis. On the buy side the percentage of not censored observations is always lower than 50%; the highest percentage is 34.86% (TPI) and the lowest ones are 15.31% (CAN) and 17.69% (ALB). On the sell side the highest percentage is 33.49% (ALT) and the lowest ones are 21.19% (ALB) and 21.62% (CAN).

Table 2 contains summary statistics for the independent variables related to buy and sell orders. Each table provides the mean and the standard deviation of all the variables studied for the pooled assets[5]. We compute the summary statistics

[5] The summary statistics for all the assets are available on request.

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.

Table 1: Number of observations for each of the assets and for the pool of the assets

	BUY	SIDE	SELL	SIDE
	Total Observations	**Uncensored Obs**	**Total Observations**	**Uncensored Obs**
ACE	10712	3482 (32.5)	8757	2607 (29.77)
ACR	11066	4222 (38.15)	10593	2818 (26.60)
ACS	9209	2219 (24.09)	7613	1747 (22.95)
ACX	10054	3213 (31.96)	9003	2350 (26.10)
AGS	7703	1810 (23.50)	6130	1465 (23.90)
ALB	8179	1447 (17.69)	6550	1388 (21.19)
ALT	20747	5802 (27.96)	17268	5784 (33.49)
AMS	26451	8499 (32.13)	23200	6921 (29.83)
ANA	11656	3372 (28.93)	10491	2526 (24.08)
BBVA	40101	11593 (28.91)	39688	10234 (25.78)
BKT	17741	5752 (32.42)	15356	4527 (29.48)
CAN	7346	1125 (15.31)	5406	1169 (21.62)
CTE	8282	2158 (26.05)	6962	1647 (23.66)
CTG	14099	4071 (28.87)	11477	3140 (27.36)
DRC	13410	4053 (30.22)	12489	3890 (31.15)
ELE	31305	9802 (31.31)	26653	8224 (30.86)
FCC	11788	3521 (29.87)	10818	2903 (26.83)
FER	10047	3088 (30.73)	8941	2751 (30.77)
IBE	17467	5278 (30.21)	15305	4847 (31.67)
IDR	14937	4369 (29.25)	12803	3850 (30.07)
NHH	8329	2001 (24.02)	6982	1898 (27.18)
POP	14377	3657 (25.43)	11707	3632 (31.02)
PRY	10980	2648 (24.12)	9207	2607 (28.31)
REE	8622	2754 (31.94)	7102	2238 (31.51)
REP	35706	11361 (31.82)	32438	9570 (29.50)
SCH	50476	13254 (26.26)	61200	14032 (22.93)
SGC	19336	5706 (29.51)	16829	4356 (25.88)
SOL	10451	3268 (31.27)	8795	2440 (27.74)
TEF	153646	42452 (27.63)	130366	33226 (25.48)
TPI	26429	9213 (34.86)	24259	6798 (28.02)
TPZ	18044	5441 (30.15)	15896	4246 (26.71)
TRR	72619	21567 (29.70)	66010	18544 (28.09)
UNF	13432	4583 (34.12)	10646	3199 (30.05)
VAL	8764	2399 (27.37)	7129	2159 (30.28)
ZEL	38824	11415 (29.40)	36081	9916 (27.48)
POOL	792335	230595 (29.10)	710144	193648 (27.57)

The names we use in the table for the variables are: Size of the order (VOL), relative inside spread (BAS), price aggressiveness (PA), volatility 1 and 2 (VOLAT1 and VOLAT2), 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.

From the analysis of the summary statistics we observe that the mean of the volume is high and different depending on the type of assets we are considering, and the standard deviation is also high. In the case of the pooled assets the mean of the volume is 2901.77 shares and the standard deviation is 3486.32.

Table2: Summary Statistics for the pool of the assets

POOL	Vol	BAS	PA	Volat1	Volat2	Prior	PMK	TrAc	ExT
BUY	2901.77 (3486.32)	0.00218 (0.00348)	0.00012 (0.00152)	0.6289 (1.4903)	0.4563 (0.26225)	3914.3 (15760.24)	0.5147 (0.1958)	5.2157 (1.4640)	351.43 (1085.2)
SELL	2853.09 (35452.04)	0.002116 (0.002326)	0.000105 (0.0020670)	0.656 (1.5046)	0.4568 (0.2621)	8174.82 (50174.15)	0.48389 (0.1940)	5.3072 (1.4394)	361.25 (1131.9)

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 bidask spread are BBVA, SCH, TEF, TRR and ELE.

Price aggressiveness was defined so that more aggressive orders have a higher value. For orders placed for SCH, TEF and TPZ the mean of this variable is negative and small, indicating that, on average, the traders place orders with a price out of the best quote, but close to it. In the case of BBVA and the pool of the assets the mean value is very small but positive: on average the price of the orders placed is close to the best quote and slightly better. 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 BKT, SGC, TEF, TRR and ZEL. For the first three the value of the standard deviation is very small, but for the remaining two assets the value of the standard deviation is very high. In the case of ZEL the mean of the volatility is high and its standard deviation too; the reason is the increase in the level of activity in the last month. There are also assets with very low volatility like ACE, AGS and NHH.

Consider now trading activity, which measures the level of activity of an asset one hour before the placement of the order. There are 9 assets (AMS, BBVA,ELE,SCH,REP,TEF, TPI, TRR and ZEL) with a high mean of trading activity and a small standard deviation and 3 assets (SCH, TEF, TRR) with a mean higher than 6. The measure of the pooled assets is greater than 5; a value of 6.94 for the trading activity means that an hour before the placement of the order 1033 transactions (on average) have occurred, while a trading activity of 2.8 means that 17 transactions (on average) have occurred. The assets with a high trading activity have a very small bid ask spread, suggesting a 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 number of transactions occurred in the last hour on one side divided by the total number of transactions the hour before the placement). The value of this indicator for the pool of the assets varies from 48.39% on the sell side and 51.47% on the buy side.

Finally, we take a look at the execution times, expressed in seconds. On average, on both sides the assets with the lowest value are TEF, TRR, SCH and BBVA. On the sell side times of execution are higher than the ones on the buy side except for TEF, where we find the opposite effect. For the pooled assets the mean on the buy side is 351.435 seconds and on the sell side is 361.25 seconds.

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.

4. Some Comments about the Market

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

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. We can see that the majority of the orders are concentrated on BBVA, REP, SCH, TEF, TRR and ZEL. 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 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 sell side we can observe that TEF, TRR and ZEL present a higher proportion of transactions on this side with respect to the buy side. ALT, BBVA, ELE, REP and SCH have a higher proportion of transactions on the buy side than on the sell 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).

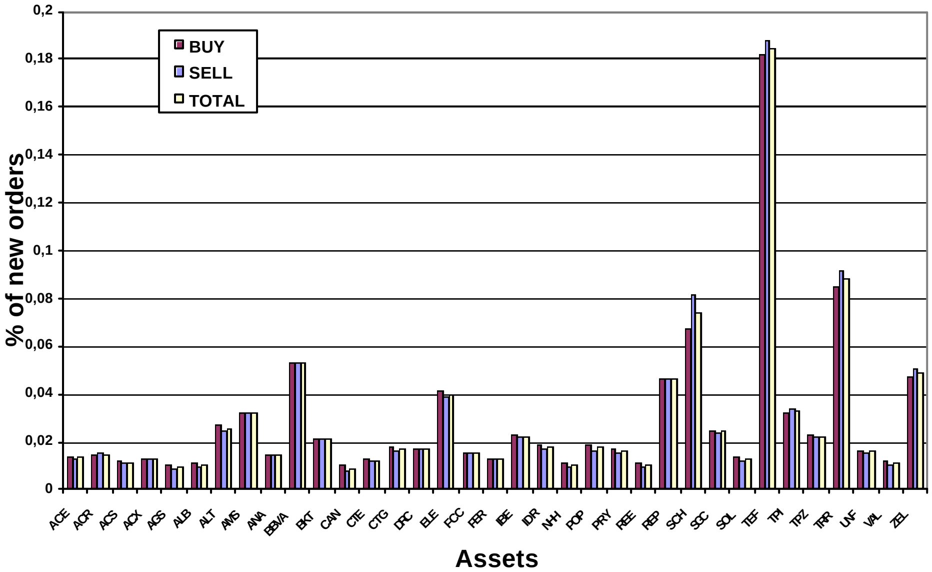

Figure 1: Distribution of the new orders placed among the assets of Ibex 35. The proportion of new orders are computed as the ratio between the number of the new orders placed of an asset divided by the number of new orders placed for all the assets belonging to IBEX.

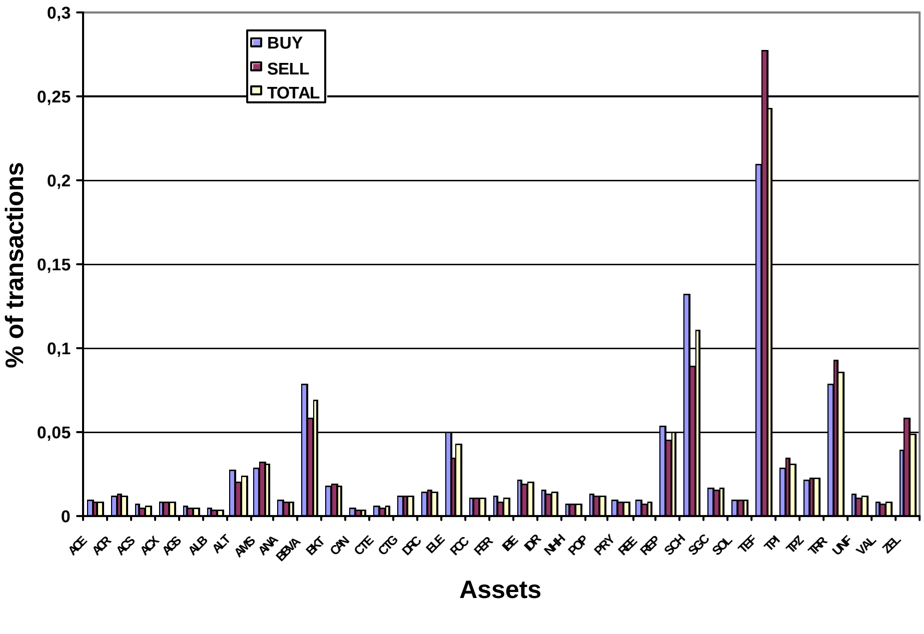

Figure 2: Distribution of the transactions occurred among the assets of Ibex 35. The proportion of transactions are computed as the ratio between the number of the transactions placed of an asset divided by the number of transactions occurred for all the assets belonging to IBEX.

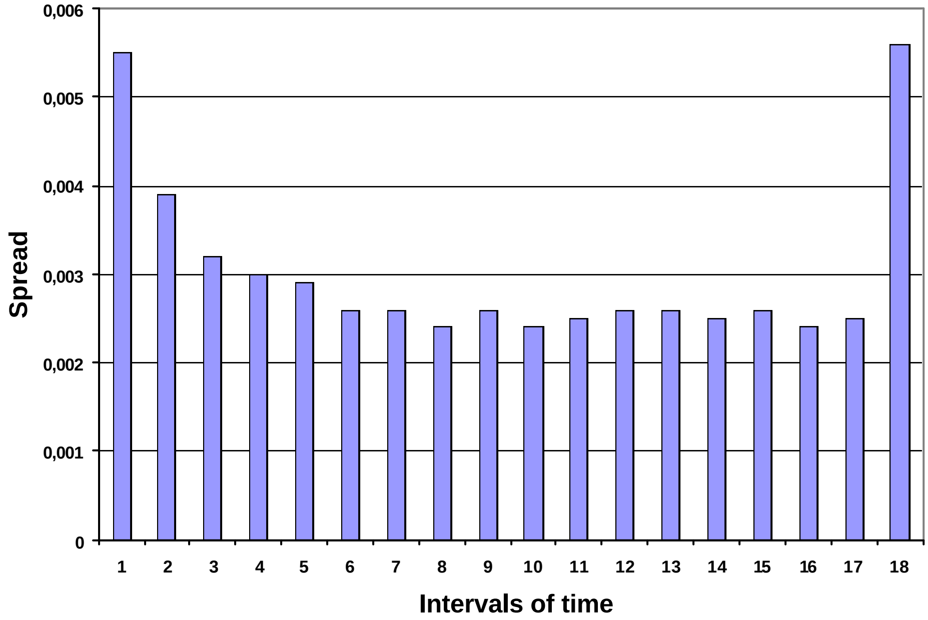

Figure 3: This figure reports the relative inside bid ask spread. The bars are the averages over the 65 days of the sample.

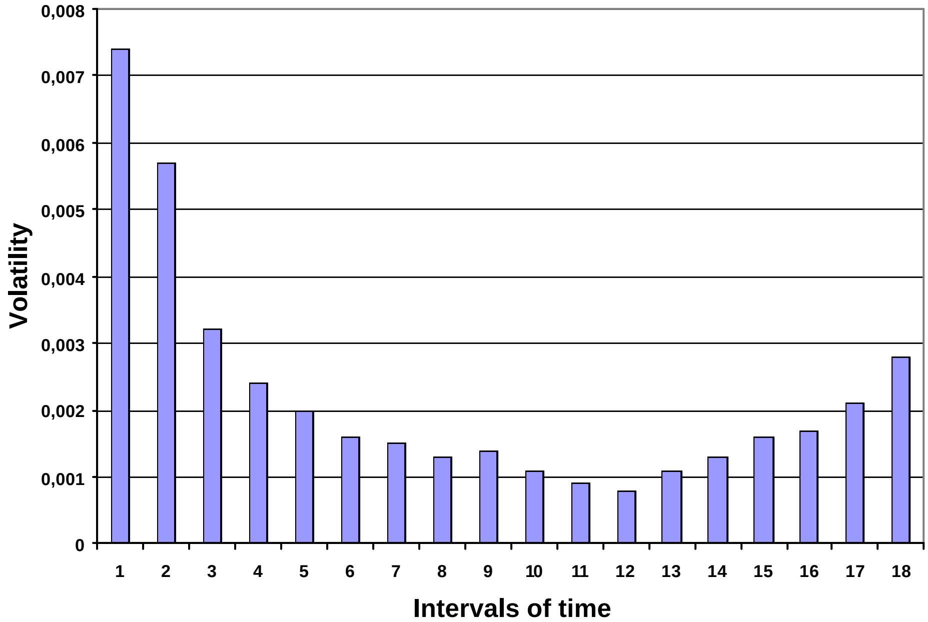

Figure 4: This figure reports the Volatility computed as the squared quote midpoint returns. The quote midpoint return is computed as the log(QMPt)-log(QMPt-1). The bars are the averages over the 65 days of the sample.

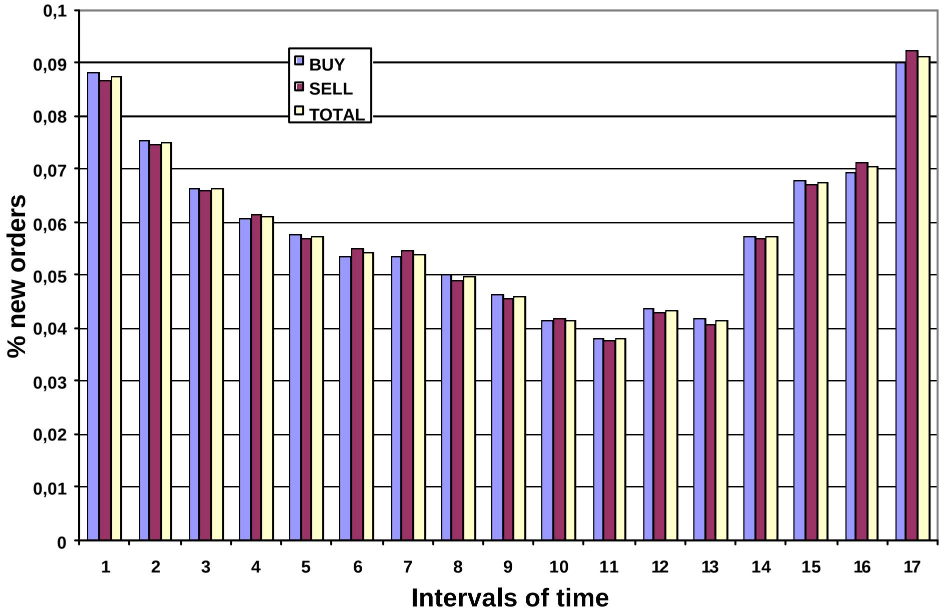

Figure 5: Distribution of the new orders placed over the trading session divided by the side of the market. Each bar is the average proportion across the 65 trading days in the sample.

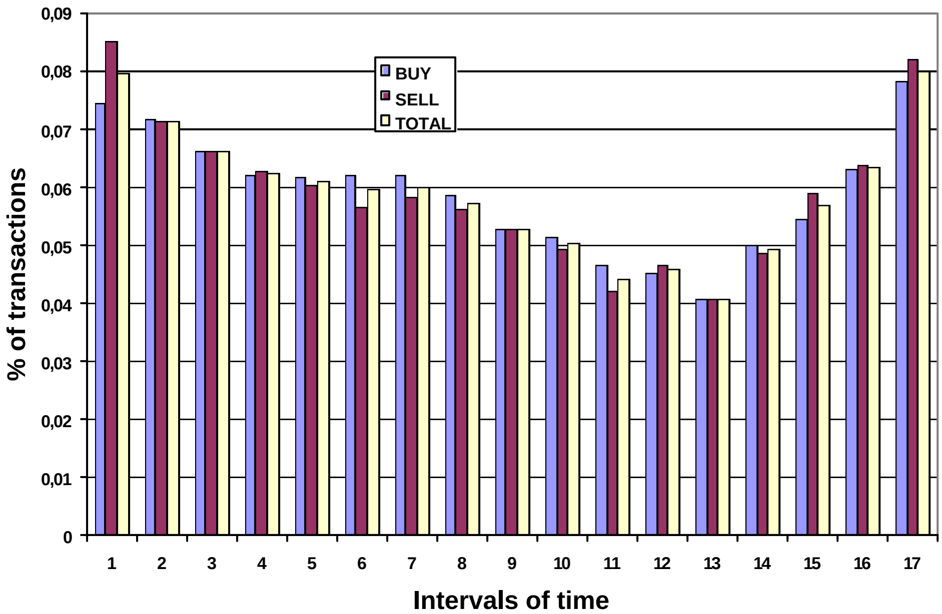

Figure 6: Distribution of the transactions occurred over the trading session divided by the side of the market. Each bar is the average proportion across the 65 trading days in the sample.

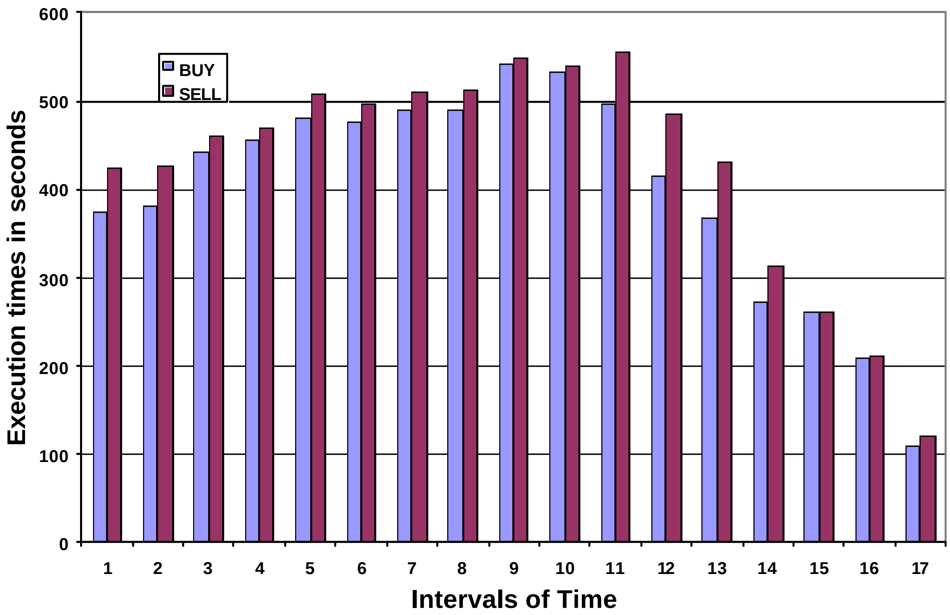

Figure 7: Execution times of the orders placed during the different intervals of the trading session. Each bar represents the mean of the execution times of the orders placed over the different intervals. The execution times are expressed in seconds.

The 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 a spread 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.

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 the other intervals of the trading session with the exception of the last 30 minutes when the proportion of the new orders placed is the highest one. Probably the traders submit more limit orders in the last half hour because they have enough information to place an order with a 'correct' price and the risk of no execution related to this submission is not so high given the fact that 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. Considering now the proportion of transactions occurred during the trading session (figure 6) we can observe 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 can 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. We can observe that in the first hour and in the last two hours of the trading session the time o f execution for the orders placed is shorter than in the remaining intervals [6] 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.

5. 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[7] 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 bias in estimates of the distribution of survival time.

[6] We obtain the same results from the estimation of the order execution time model.
[7] See Cox and Oakes (1984) and Kalbfleisch and Prentice (1980)

.

Due to these characteristics this technique seems to be the most suitable to model the time of execution of limit orders in order to accommodate the censored observations. 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:

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

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), respectively of the k^{th} limit order.

We follow Lo et al. (2002) and use the 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:

$$T = e^{X'ß} T_0$$

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 can 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.

6. Empirical Results

In this section we present the empirical results of the estimation of the order execution time model. We estimate two different models for each asset and for a pool of all the assets: one for the buy side and one for the sell side, using the program STATA 7.0. The estimated parameters for the pooled case, along with their corresponding standard errors, are reported in table 3.

Table 3: Results for the pool of the assets

	BUY			SELL		
Variable	**Coef.**	**Std Error**	**z**	**Coef.**	**Std Error**	**z**
Vol	-0.0000224	1.04e-06	-21.62	-0.0000261	1.42e-06	-21.06
bidask	68.17908	9.873266	6.91	114.6289	6.1654	18.59
priceagr	-515.8255	19.25446	-26.79	-494.8007	17.07502	-28.98
volat	-0.0449235	0.0055565	-8.08	-0.105778	0.0056793	-18.63
priority	6.87e-0.6	1.30e-06	5.27	3.08e-06	1.65e-07	18.70
day1	0.0972408	0.0200442	4.84	dropped		
day2	dropped			-0.047627	0.0283149	-1.68
day3	0.0885031	0.0288268	3.07	0.041213	0.0365038	1.13
day4	0.0496571	0.0339586	1.46	0.0158884	0.0304654	0.52
day5	0.0734558	0.0165252	4.45	0.0163473	0.0373856	0.44
Time1	-0.8184582	0.0651901	-12.55	-0.5276614	0.0640759	-8.23
Time2	0.0064252	0.0364903	0.18	0.0245346	0.0510282	0.48
Time3	0.1677345	0.0373796	4.49	0.1092259	0.0402775	2.71
Time4	0.1662336	0.038287	4.34	0.1404627	0.0380189	3.69
Time5	0.1990947	0.0374546	5.32	0.0278897	0.1166366	0.24
Time6	0.1315948	0.038007	3.46	0.1722037	0.039846	4.32
Time7	0.1037778	0.0379482	2.73	0.1518741	0.0400977	3.79
Time8	0.0997467	0.0386462	2.58	0.0902743	0.0394448	2.29
Time9	0.0639138	0.0396806	1.61	0.0964785	0.041114	2.35
Time10	0.0635197	0.0400541	1.59	0.1521875	0.0416275	3.66
Time11	dropped			0.120878	0.41716	2.90
Time12	-0.0617755	0.0396657	-1.56	0.0828455	0.0418762	1.98
Time13	-0.1793041	0.0409394	-4.38	dropped		
Time14	-0.3345383	0.03829288	-8.74	-0.1888246	0.0382832	-4.93
Time15	-0.3934084	0.0401625	-9.80	-0.3044934	0.0366328	-8.31
Time16	-0.4213289	0.0354018	-11.90	-0.3252989	0.0367505	-8.85
Time17	-0.6181518	0.0353719	-17.48	-0.5988132	0.0416495	-14.38
percmkc/v	-0.5094822	0.0753105	-6.77	-0.6778481	0.068106	-9.95
lord60m	-0.3365165	0.013690	-47.57	-0.2208579	0.0104632	-21.11
cons	7.287584	0.1290471	56.47	6.604259	0.0629621	104.89
/ln sigma	1.409299	0.006515	216.32	1.449651	0.0053558	270.67
/kappa	-2.82994	0.0324357	-87.25	-3.232769	0.0251792	-128.39
sigma	4.093086	0.0266667		4.261627	0.0228243	

The variables we finally use in this analysis are: **execution times, volume (vol), relative bid ask spread (bidask), price aggressiveness (priceagr), volatility1**[8] **(volat), trading activity (lord60m), priority, percmkc(v)**.

We present, at first, some general results and then we consider some particular cases. In the majority of the cases the coefficient of **volume** is negative and significative on 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 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)).

The negative sign of **price aggressiveness** shows that, as expected, more aggressive orders are executed faster.

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.

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.

Another variable considered is the percentage of the transactions occurred in the last hour on one side divided by the total number of transactions occurred one hour before the placement of the order **(percmkc(v))**. Its coefficient is negative, implying for example that the expected time of execution of a buy order is shorter when there is a preponderance of transactions on this side of the book. This is a consequence of the diagonal effect, that is the incentive that traders have to place orders on one side of the market when the conditions appear to be favorable. For example, if the number of transactions on the buy side increases it means that the number of market orders introduced on the sell side increases so there is an incentive to place limit orders on the buy side since the trading activity is high on this side of the book and the expected time of execution is shorter.

[8] We use this definition of volatility because it provides better results.

We have divided the trading session into 17 intervals of 30 minutes and we want to study the effect of the time of placement on the expected time of execution. The result is that there are only few significant intervals. More specifically, orders placed at the first 30 minutes of the session and the last two hours have a shorter expected time of execution than the other periods of the trading session. This is what we observe also in figure 7.

In the case of the days of the week we can see that in most of the cases they are significative. 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. From the analysis of the pooled assets Tuesday (day2) shows a shorter expected time of execution than the rest of the days.

The results for specific stocks are sometimes different from the results of the pooled regressions. For example, two of the most active stocks are BBVA and SCH, and for these two stocks the regression for the buy side shows that the coefficient of the relative bid—ask spread is negative. This means that a wider relative inside spread makes the expected time of execution shorter, the opposite of what happens in the pooled regression. A possible explanation of this difference is that for more active stocks a wider relative bid—ask spread encourages more aggressive orders, something which is instead not observed for less active stocks. We have checked this conjecture by running the regression adding as an independent variable the interaction (product) between the spread and the trading activity. When this is done for the regressions of BBVA and SCH the interaction variable is significative and it has negative coefficient, while the bid—ask spread exhibits a positive coefficient. This corroborates the conjecture that a widening of the bid-ask spread causes a shortening of the execution time only when the level of activity is high. In the regression for the pooled assets the interaction variable is not significative.

7. 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 assets, for the pool of the assets 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 two hours of the trading session the expected execution time is shorter. A relationship is found between expected time of execution and a variable which captures the interaction between the bid ask spread and the trading activity: its coefficient has a negative sign and this relationship is significative only for two assets belonging to the banking sector.

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8. Appendix

8.1List of the assets

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