Un análisis de la agresividad de las órdenes en el mercado bursátil español

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Resumen

El objetivo de este artículo es estudiar los determinantes de la agresividad de una orden en la bolsa de valores española. Para ello, extendemos la categorización de agresividad propuesta por Biais y otros (1995) y usamos un logit multinomial para encontrar los determinantes de la agresividad. Los resultados obtenidos muestran que una horquilla más ancha favorece la colocación de órdenes limitadas que se sitúan entre los mejores precios, mientras las órdenes de mercado y órdenes limitadas que se sitúan en el mejor nivel existente o por debajo del mismo parecen menos probables. Un aumento de la profundidad hace la colocación de órdenes agresivas más probable en el mismo lado del libro para obtener prioridad en la ejecución. Una mayor volatilidad favorece la colocación de todos los tipos de órdenes. Ante asimetrías de información, la colocación de órdenes en el mismo lado del libro resulta ser menos agresiva mientras que aumenta en el otro lado. Considerado la dinámica del mercado podemos observar que un aumento del número de transacciones en el pasado reciente puede animar la aparición de órdenes de mercado y órdenes limitadas agresivas. En la mayoría de los casos un aumento en el número de órdenes limitadas en los últimos 15 minutos provoca la emisión de órdenes del mismo tipo. Finalmente, observamos que las cancelaciones vienen a menudo seguidas por la colocación de una orden limitada agresiva.

Código JEL: G10, G14

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An Analysis of Order Aggressiveness in the Spanish Stock Exchange

1 Introduction

In limit order markets traders submit orders to a centralized execution system which prioritizes the orders submitted by the price at which they are submitted and the time at which they are introduced. Many stock markets around the world use limit orders. One of the reasons of their popularity is the greater transparency with respect to the dealer system. Typically a limit order book allows its users to view depth at a number of price levels away from the equilibrium market price, while dealer markets usually provide information only about the dealers' best quotes (see e.g. Cao et al. [8]).

Some of the orders placed may be quite aggressive, i.e. a sell order may be placed at a price which is lower than any existing sell order or a buy order can be placed at a price which is higher than any existing buy order. In other cases the prices are far less aggressive. What factors influence the aggressiveness of orders? We try to answer this question using data from the Spanish stock exchange.

Our starting point is the categorization of order aggressiveness made by Biais et al. [6]. We introduce a new category called 'no order' or 'no activity event', and we consider it to be the least aggressive one. We first provide a descriptive analysis of the Spanish stock exchange using the new categorization and then we use a multinomial logit model to estimate the determinants of aggressiveness.

The rest of the paper is organized as follow. The next section contains a brief review of the literature. Section 3 describes the institutional characteristic of SIBE and the database we use, and provides a descriptive analysis of the order flow in the Spanish stock exchange. We estimate the model in section 5, and section 6 contains the conclusions.

2 Literature

The notion of aggressiveness has been initially applied to the choice between market and limit orders, with market orders considered more aggressive. Al-Suhaibani et Kruzanosky [4] use a logit model to explain the choice between limit and market orders in the Saudi market. They find a negative relation between the spread and the placement of market orders. Also, an increase in the order imbalance in favor of the other side of the market increases the probability of placing a market order. When the ratio of trades initiated by the same side of the market increases, the likelihood of the next order being a market order increases. More active traders and traders with small orders are more likely to place market orders. Harris and Hasbrouck [18] analyze the performance of different types of orders on the NYSE. They differentiate orders and trades in terms of their aggressiveness, and they focus on the profitability of the orders. They suggest two measures, one for pre-committed traders and

another for passive traders. The results suggest that limit orders placed at or better than the prevailing quote perform better than do market orders, even after imputing a penalty for unexecuted orders.

Biais et al. [6] proposed a systematic classification of orders according to their level of aggressiveness. The classification has been used by Griffiths et al. [15], Ranaldo [25], Pascual and Veredas. [24], Abad [1], Elull et al. [12], Sasaky [27] , Cao et al. [8], Beber and Caglio[5]. All these studies, with the exception of Elull et al. [12], use an ordered probit model.

Ranaldo [25] analyzes the Swiss Stock Exchange and observes that patient traders become more aggressive when the own (opposite) side book is thicker (thinner), the spread wider and the temporary volatility increases. Buy and sell sides of the book affect the order submission differently.

Griffiths et al. [15] investigates the costs and determinants of order aggressiveness in the Toronto stock exchange. Aggressive orders have larger price impacts but smaller opportunity costs than passive orders. Price impacts are amplified by large orders, firms of small size and stock price volatility. Aggressive buy (sell) orders tend to follow other aggressive buy (sell) orders and occur when the bid-ask spread is narrow and depth on the same (opposite) side of the limit book is large (small). Aggressive buy orders are more likely to be motivated by informational factors than aggressive sell orders.

Abad [1] analyzes the Spanish stock exchange and finds that a wider spread leads to less aggressive orders while more depth on the same side of the book makes the submission of aggressive orders more likely. This finding supports the intuition that traders offer liquidity to the market when it is necessary and demand it when it is plentiful. Transitory volatility affects positively the placement of limit orders and negatively the submission of market orders. In this case we observe asymmetric results between the two sides of the market.

Cao et al. [8] apply their analysis to the Australian stock exchange. They are interested in seeing how traders use the information contained in the open limit order book. They find that traders use not only the first level but also further levels when developing their order submission strategies.

Beber and Caglio [5] examine the order submission strategies on a sample of the ten most transacted stocks on the NYSE, using the TORQ database. They investigate the role of asymmetric information in affecting order submission strategies. Order aggressiveness depends on the state of the order book and on the asset dynamics. The most important determiants are the depth on the same side of the book and the momentum indicator. When they focus on specific situations characterized by higher probability of information based trading, they find that orders are less aggressive, suggesting strategic behavior of informed traders.

Sasaki [27] analyzes the Tokyo stock exchange and finds that the effect of determinants are time varying, reflecting the market environment and intraday variability. They don't find a spread or a diagonal effect. This difference is probably due to the fact that the Tokyo stock exchange is a relatively illiquid market. They do find a depth effect, thus confirming the results of Ranaldo [25] and Griffiths et al. [15].

Pascual and Veredas [24] analyze the impact of the information contained in the whole limit order book in the Spanish Stock Exchange and they find that information beyond the best quote is useful in explaining the aggressiveness of an upcoming liquidity provider. However, higher levels of the book do not affect

the strategic decision of an upcoming liquidity consumer.

Elull et al. [12] use a multinomial logit model to study the determinants of order submission strategy in the NYSE. At first they study the determinants of limit and market orders and they find that wider (narrower) spread increases the probability of limit (market) orders, larger quoted depth favors the submission of market orders and the higher the stock's return in the immediate past, the greater (lower) the likelihood of limit sell (buy) orders for that stock. Higher volatility increases the submission of limit buy orders, marketable limit sell orders and market orders for that stock. These results are confirmed and made richer when the aggressiveness of orders submitted is considered.

Lo and Sapp [21] propose a method which accounts for the fact that traders have to determine the price aggressiveness and quantity simultaneously; they empirically study how investors jointly make these decisions using a simultaneous equations model. An ordered probit model is implemented to account for the discrete nature of price aggressiveness and a censored regression model is implemented to capture the clustering of orders placed at $1 million. They use data on firm quotes submitted to the Reuters D-2000-2 system in the Deutsche Mark-U.S. dollar market. More aggressive orders tend to be smaller in size when submitted or cancelled. Depth on the same (opposite) side of the market leads to less (more) aggressive orders and smaller (larger) size. Orders become more (less) aggressive if there are more aggressive orders submitted on the opposite (same) side of the market.

The objective of this paper is to study the determinants of order aggressiveness in the Spanish stock exchange. We use the categorization made by Biais et al. [6] introducing some changes. First, following Griffiths et al. [15] , Abad [1] and Lo and Sapp [21], we eliminate cancellation as a category. We also introduce a new category, 'no activity'; since no activity is one of the expressions of the patience of the trader who prefers to wait in his participation in the market. Therefore this category is considered as the least aggressive one. The next step is to study the market conditions which affect the aggressiveness of the order submission strategy. We use a multinomial logit model and find that the relative inside spread discourages the placement of market orders and limit orders at or out of the quote, while it makes the placement of aggressive limit orders more likely. An increase in the depth on the same side of the book encourages the placement of market orders and aggressive limit orders and discourages the placement of less aggressive orders. In the case of the depth on the opposite side of the book we observe that more aggressive limit orders become less likely and all the other types of orders become more likely. In very volatile periods the no activity event is less likely. Asymmetry of information among traders makes more likely the placement of less aggressive limit orders on the same side of the book and more aggressive ones on the opposite side. Considering the dynamics of the market we observe that an increase in the number of trades in the recent past may encourage the submission of market orders and aggressive limit orders. In most of the cases an increase in the number of limit orders in the last 15 minutes induces the submission of orders of the same type. With respect to the cancellation of orders at the quotes we can observe that they are followed by the placement of aggressive limit orders.

3 The Spanish Stock Exchange and the Datasets

In this section we briefly present the institutional characteristics of the Spanish stock market, known as SIBE, and the datasets we use (a more complete description is given in Gava [14]). We also provide a description of the order flow and its composition over the trading day.

3.1 Institutional Characteristics of SIBE

The Spanish market is an order driven market, with liquidity providers for certain shares. The market features real time information on trading activity, so that transparency is fully guaranteed, and it is open from Monday to Friday.

The trading day is divided in different phases. There are two auctions: one at the beginning of the trading session, called **Opening Auction**, and the other at the end, called **Closing Auction**. The first lasts 30 minutes, opening at 8:30 am, with a 30-second random end period to prevent price manipulation. The second lasts between 5:30pm and 5:35pm, with the same characteristics as the opening auction. During the auctions orders are entered, altered and cancelled, but no trade is executed. 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.

Between the two auctions there is the **Open Market** period, running from 9am to 5:30pm. During this period 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 and 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. Orders may be fully executed (in one or several steps), partially executed, cancelled or not executed, so each order can generate several trades.

Orders may have hidden volumes, so that only part of the trading volume is displayed in the system but (differently from the ECN market analyzed in Hasbrouck and Saar [19]) completely hidden orders are not allowed[1]. 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: *for one day*; *until a specific date, 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.

3.2 Datasets

The dataset of the orders submitted, their outcome and their duration are not immediately available, so it is necessary to construct them using three datasets provided by *Sociedad de Bolsas*, the company running the SIBE. We describe briefly the information available in the three datasets and the algorithms we use; for a more complete description see Gava [14].

[1] See Pardo and Pascual [23] for a discussion of the role of hidden orders in the Spanish stock exchange.

Dataset MP contains information about the first five levels of the limit order book as available to market participants.
Dataset SM contains information about volume and price of the first best levels on the bid and ask sides.
Dataset BASA contains information about the transactions in terms of volume, price and time occurred during the trading session disaggregated by orders.

The 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 with their price, volume and time of placement as well as the transactions and cancellations occurred during the trading session.

We use an algorithm proposed by Abad [1] in order to classify the events in the SM dataset, and we construct a set of all the new orders placed in the trading session and another one composed of the executed and cancelled orders. In this way we construct a limit order dataset with the explanatory variables needed. To the limit order dataset we need to add all the market orders, so we have a complete dataset of all the orders submitted.

First, using the definition of aggressiveness given by Biais et al. [6] we define seven categories of events corresponding to decreasing degrees of aggressiveness. The three most aggressive types of orders result in immediate execution. The most aggressive one is a market buy (sell) which cleans the best ask (bid) quote and a part of the following level(s). The second category is composed by market orders which clean the best quote on the opposite side of the book. The third category contains market orders which demand a quantity lower than the one offered at the best quote on the opposite side of the book. The next three categories represent orders of not immediate execution. They are limit orders introduced inside the best quotes so they improve the price with respect to the previous limit orders and they have priority on execution. The fifth category represents limit orders introduced at the best quote and the sixth category is composed of limit orders submitted outside the best quote; the last two categories have not priority on execution. The last category consists in not introducing any order, the least aggressive category. Clearly, for the first six categories we have to consider the buy and sell side.

The event 'no activity' is defined in the following way. First, we compute the average time t_m between successive orders for each asset. Second, whenever the time between orders is higher than the average we introduce a 'no activity' event t_m seconds before the latest order, inserting as many events as the time interval allows.

This definition of 'no activity event' follows closely the one used in Ellul et al. [12]; the only difference is that in their case the no activity time interval is defined as the minimum between the median time between successive order events and five minutes. In our dataset we choose the average time between events in order to take better into account the higher values, which tend to be quite frequent. All the average times between successive events are lower than 5 minutes, so we ignored this part. Easley, Kiefer and O'Hara [11] use a similar definition of no activity event to model and estimate the passage of clock time without activity.

The categories above described are the ones that we will use for the descriptive statistics of the market. When we do our econometric analysis we use slightly different categories; the market orders are divided in only two categories,

large (size above the median size of the sample) and small (size smaller than the median). The reason for using this alternative classification is that we will use the depth of the book as an explanatory variable. Since the previous classification for market orders categorize the market orders in terms of the depth of the book, this might create problems in the regression. We therefore compute the median market order for each asset and for each side of the market and then we define the new categories of market orders by comparing the volume of an order with the volume of the median market order. Thus, in our regression analysis the most aggressive category is composed of market orders with a size larger or equal to the median market order, while the second category is composed of market orders with a volume smaller than the median market order. The remaining categories do not change.

The period considered is July–September 2000, and the assets are all the stocks belonging to the IBEX 35 except ZELTIA, since in September 2000 the company made a split.

4 Descriptive Statistics

In this section we provide a descriptive analysis of the Spanish market in terms of order aggressiveness.

4.1 The Unconditional Probabilities of Orders and Trades

We start dividing events in 13 categories: market orders of large size (1 Buy and 2 Sell); market orders of medium size (3 Buy and 4 Sell); market orders of small size (5 Buy and 6 Sell); limit orders with positive aggressiveness (7 Buy and 8 Sell); limit orders with zero aggressiveness (9 Buy and 10 Sell); limit orders with negative aggressiveness (11 Buy and 12 Sell); and no activity (13).

Tables 1a and 1b show the frequency of the different types of events. Table 1a consider all events. We can observe that the no-activity event is the most frequent. Table 1b shows the frequency of actual orders, i.e. it ignores the no-activity event. When we look at actual orders and trades the majority of orders is concentrated on market orders with a volume smaller than the depth at the best quote on the opposite side of the book.

Figure 1 shows the frequency of different orders depending on the trading activity of the assets. We have divided the stocks into a high trading group, a medium trading group and a low trading group (see Brusco and Gava [7] for details). Small market orders are especially frequent for the assets belonging to the high trading activity group. The next most frequent events are limit orders placed inside or at the quotes for the low and medium trading activity samples[2]. Most of the trading activity is within or at the quotes. According to Biais et al. [6], trades first hit the best quotes in the book thus widening the bid-ask spread and reducing the depth at these quotes. When this occurs new orders at or within the quotes are attracted in order to restore the depth and narrow the spread. We can also observe that the proportion of market orders on the sell side is higher than on the buy side while the limit orders follow the opposite

[2]For the high trading activity group the limit orders placed inside the quotes are not so frequent since the size of the spread is very small and sometimes it is not possible to improve the price.

pattern. This findings show the existence of asymmetry between the two sides of the book and the use of different types of orders.

	Low	Medium	High
MK O. Large vol. Buy (1)	1,19%	1,42%	1,19%
MK O. Large vol. Sell (2)	1,51%	1,65%	1,42%
MK O. Medium vol. Buy (3)	2,81%	2,67%	1,78%
MK O. Medium vol. Sell (4)	3,24%	2,97%	1,85%
MK O. Small vol. Buy (5)	9,18%	12,49%	17,80%
MK O. Small vol. Sell (6)	11,48%	13,57%	18,83%
Limit O. PA>0 Buy (7)	8,56%	5,98%	3,45%
Limit O. PA>0 Sell (8)	7,18%	5,26%	3,24%
Limit O. PA=0 Buy (9)	4,26%	3,89%	3,65%
Limit O. PA=0 Sell (10)	3,51%	3,68%	3,50%
Limit O. PA<0 Buy (11)	3,78%	3,92%	3,25%
Limit O. PA<0 Sell (12)	3,35%	3,40%	3,53%
No activity (13)	39,94%	39,10%	36,50%

Table 1 (a): Proportions of orders, trades and no-activity for the three sub-samples

	Low	Medium	High
MK O. Large vol. Buy (1)	1,99%	2,33%	1,88%
MK O. Large vol. Sell (2)	2,52%	2,71%	2,23%
MK O. Medium vol. Buy (3)	4,67%	4,38%	2,80%
MK O. Medium vol. Sell (4)	5,39%	4,87%	2,92%
MK O. Small vol. Buy (5)	15,29%	20,52%	28,04%
MK O. Small vol. Sell (6)	19,12%	22,28%	29,65%
Limit O. PA>0 Buy (7)	14,25%	9,82%	5,43%
Limit O. PA>0 Sell (8)	11,95%	8,64%	5,10%
Limit O. PA=0 Buy (9)	7,10%	6,39%	5,74%
Limit O. PA=0 Sell (10)	5,84%	6,05%	5,51%
Limit O. PA<0 Buy (11)	6,29%	6,43%	5,12%
Limit O. PA<0 Sell (12)	5,58%	5,58%	5,57%

Table 1 (b): Proportions of orders and trades for the three sub-samples.

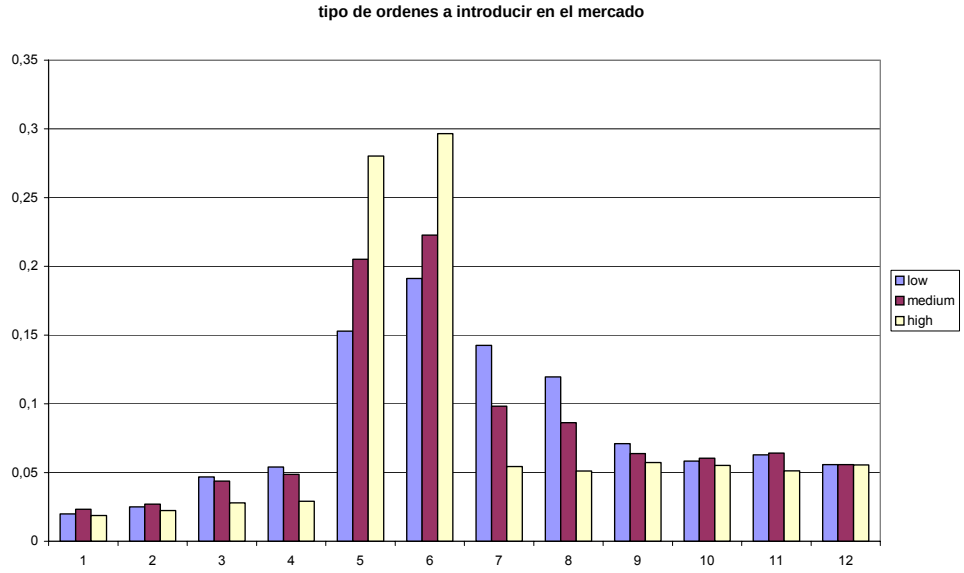

Figure 1: Proportion of trades and orders for the three sub samples.

4.2 Orders and Trades over the Day

The evolution of orders tends to follow a U-shaped pattern over the trading day for all the categories of limit orders. The U-shaped pattern is particularly clear for the high trading activity stocks, while for other samples the proportion of market orders is lower at the beginning of the day and decreases when the trading activity decreases. In all the subsamples the proportion of large market orders is very high at the end of the trading day, followed by the other types of market orders. This may be a consequence of the deadline effect: a great majority of agreements are concluded near the end of the bargaining horizon (Roth et al. [26]). Probably for these assets traders are waiting until the end of the day in order to make transactions.

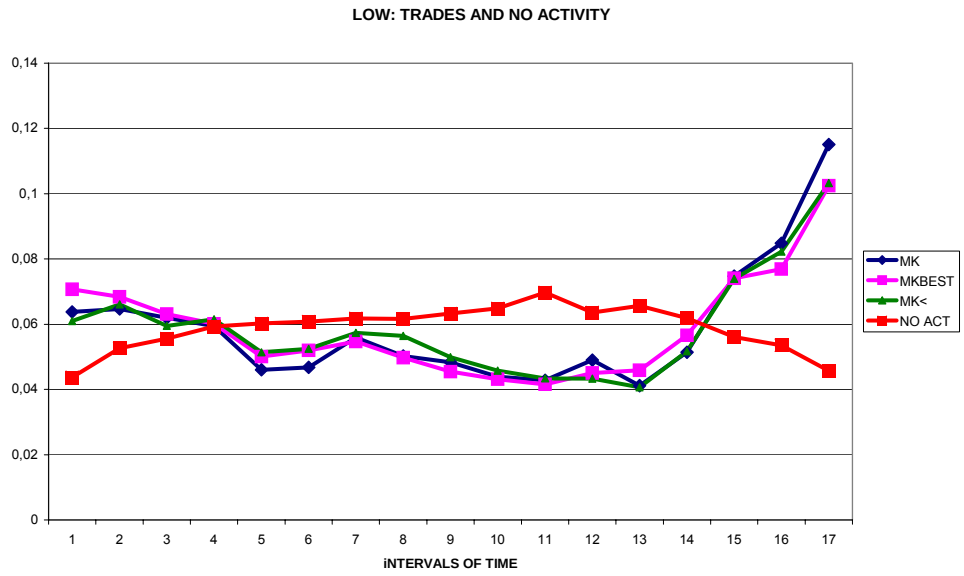

Figure 2

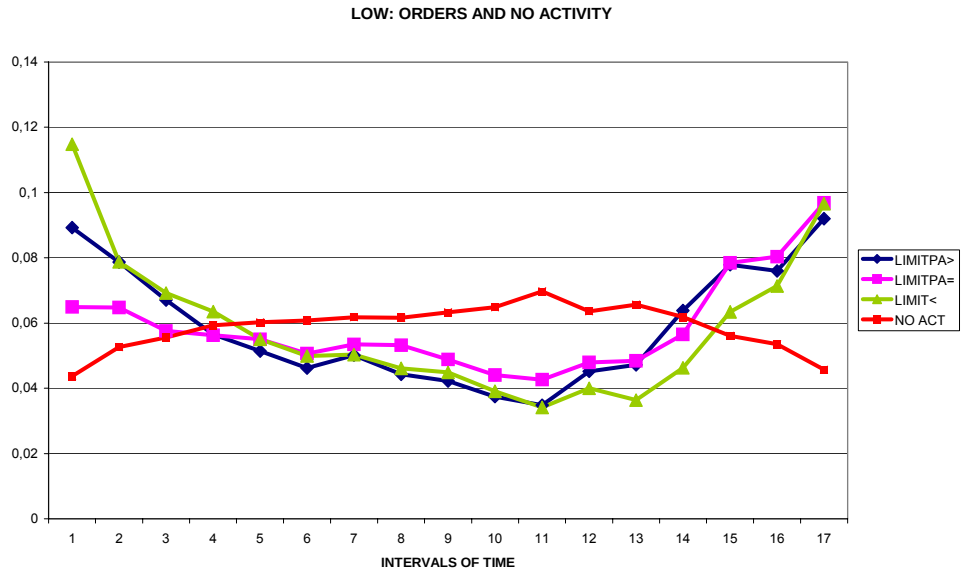

Figure 3

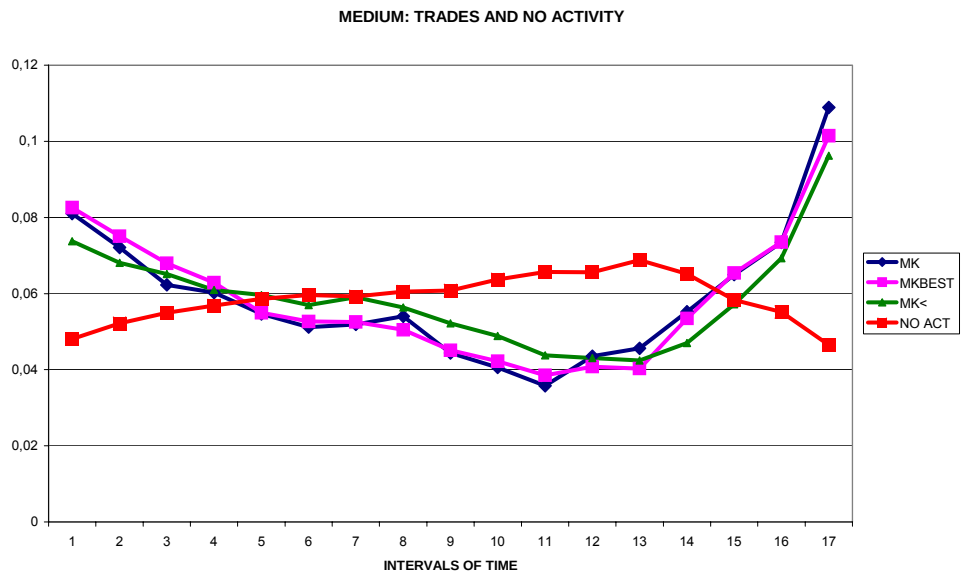

Figure 4

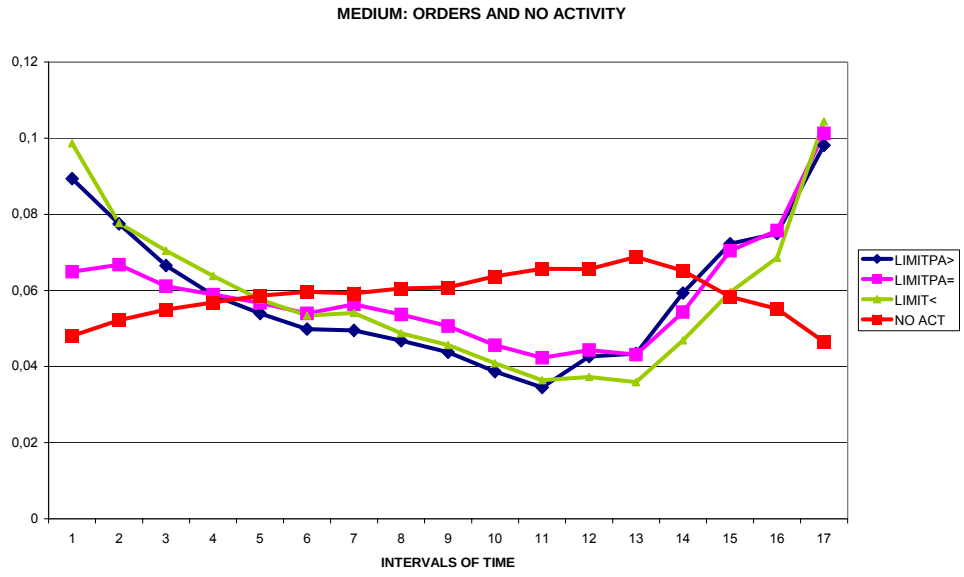

Figure 5

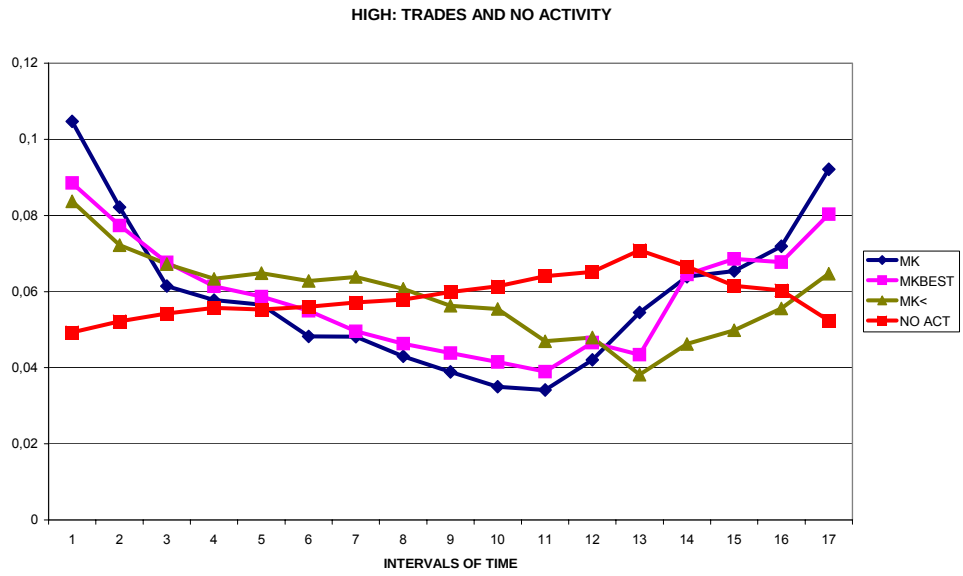

Figure 6

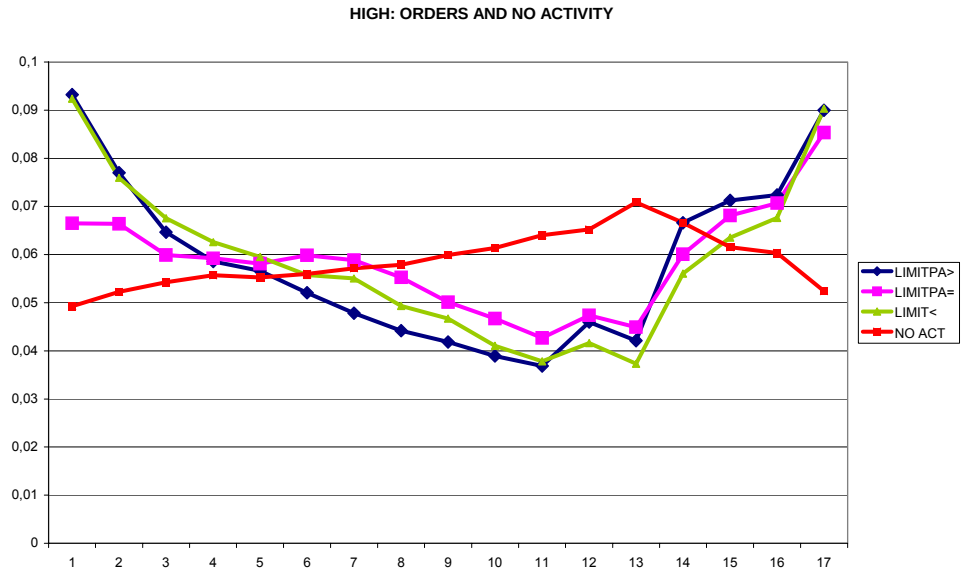

Figure 7

4.3 Orders and Trades Conditional on the Last Order or Trade

Consider now the frequency of each of the 13 categories conditional upon the type of the previous event. The results are presented in the tables 2-4 for the

three subsamples high, medium and low trading activity group. Tables 2-4 are contingency tables (i.e. transition probability matrices) in which each row is a probability vector summing up to one. For example, the first entry in Table 2 days that, for stocks in the low trading activity group, after a category 1 event (a large buy market order) the probability that the next event is another large buy market order is 24.41%, while the probability of a no event (i.e., more than the average time between orders will pass before a new order is placed), denoted by category 13, is 5.09%

Low	t												
t-1	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
1	**24,41%**	0,17%	**23,60%**	0,43%	**19,21%**	1,82%	10,33%	7,49%	1,65%	3,21%	1,30%	1,30%	5,09%
2	0,15%	**26,15%**	0,53%	**23,14%**	1,70%	**18,29%**	8,72%	**9,42%**	3,05%	1,41%	1,01%	1,07%	5,37%
3	**9,56%**	0,32%	2,16%	1,02%	10,97%	3,11%	**51,00%**	4,32%	2,38%	2,14%	2,28%	2,02%	8,72%
4	0,21%	**11,11%**	0,96%	2,25%	2,87%	14,00%	4,95%	**45,11%**	2,22%	2,34%	2,03%	2,01%	9,94%
5	**2,73%**	0,38%	**5,40%**	1,84%	**33,64%**	5,66%	10,31%	3,67%	3,62%	**5,85%**	3,46%	2,89%	20,55%
6	0,30%	**2,64%**	1,44%	**5,79%**	4,44%	**35,28%**	4,60%	8,43%	**6,02%**	2,97%	2,95%	2,95%	22,20%
7	0,70%	0,97%	4,01%	**5,92%**	9,51%	7,69%	**13,69%**	6,34%	**9,25%**	3,50%	**7,89%**	3,59%	26,92%
8	0,81%	0,91%	**5,89%**	4,73%	6,79%	11,26%	8,05%	**12,64%**	3,83%	**7,09%**	4,22%	**7,23%**	26,54%
9	0,51%	0,56%	2,59%	1,18%	8,35%	**17,65%**	**11,38%**	5,91%	**8,56%**	3,61%	**5,12%**	3,55%	31,04%
10	0,55%	0,63%	1,23%	2,87%	**15,81%**	9,52%	8,45%	8,69%	4,39%	**7,07%**	4,40%	**4,70%**	31,70%
11	0,60%	0,74%	2,49%	4,00%	8,86%	9,17%	9,52%	6,59%	5,24%	3,96%	**12,10%**	4,51%	**32,21%**
12	0,64%	0,70%	3,80%	2,97%	7,56%	10,42%	8,41%	7,58%	4,38%	4,62%	4,96%	**9,78%**	**34,17%**
13	0,34%	0,41%	1,56%	1,75%	5,34%	7,08%	5,16%	3,87%	2,76%	2,30%	2,43%	2,36%	**64,65%**
Uncondtional frequency	*1,19%*	*1,51%*	*2,81%*	*3,24%*	*9,18%*	*11,48%*	*8,56%*	*7,18%*	*4,26%*	*3,51%*	*3,78%*	*3,35%*	*39,94%*

Table 2: Contingency table for the low trading activity group.

Medium	t												
t-1	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
1	**27,89%**	0,16%	**19,09%**	0,59%	**23,91%**	2,46%	**7,63%**	5,33%	1,50%	3,10%	1,65%	1,26%	5,44%
2	0,16%	**28,85%**	0,53%	**20,04%**	2,31%	**22,39%**	6,08%	**7,47%**	2,66%	1,33%	1,20%	1,37%	5,60%
3	**10,62%**	0,37%	1,79%	1,02%	12,05%	4,23%	**49,05%**	3,22%	2,42%	1,86%	2,59%	1,95%	8,82%
4	0,38%	**11,49%**	0,93%	1,99%	4,27%	14,25%	3,70%	**43,99%**	2,10%	2,22%	2,13%	2,24%	10,31%
5	**2,80%**	0,39%	4,04%	1,72%	**38,58%**	6,73%	6,73%	2,79%	3,35%	**5,23%**	4,04%	2,85%	20,76%
6	0,31%	**2,92%**	1,50%	4,42%	6,18%	**40,30%**	3,34%	6,26%	4,66%	2,85%	2,90%	3,01%	21,35%
7	0,84%	1,15%	**4,44%**	**6,50%**	12,08%	9,79%	**7,85%**	5,22%	**8,16%**	3,94%	**8,60%**	4,15%	27,27%
8	1,14%	0,95%	**6,51%**	**4,78%**	9,33%	13,14%	6,16%	**6,97%**	3,99%	**7,05%**	4,65%	**7,92%**	27,41%
9	0,60%	0,56%	2,84%	0,91%	11,28%	**17,86%**	7,48%	4,63%	**7,55%**	4,59%	**5,62%**	4,20%	**31,88%**
10	0,57%	0,66%	0,98%	2,81%	**19,08%**	10,98%	5,62%	5,58%	4,79%	**7,40%**	5,31%	**4,99%**	31,23%
11	0,62%	0,79%	2,83%	3,78%	13,20%	10,30%	6,53%	4,76%	**5,43%**	4,78%	**10,54%**	4,73%	31,70%
12	0,73%	0,68%	3,86%	3,08%	10,77%	12,73%	5,79%	5,63%	4,69%	5,14%	5,30%	**9,53%**	**32,07%**
13	0,33%	0,40%	1,55%	1,78%	7,09%	7,95%	3,36%	2,63%	2,83%	2,67%	2,74%	2,43%	**64,24%**
Uncondtional frequency	*1,42%*	*1,65%*	*2,67%*	*2,97%*	*12,49%*	*13,57%*	*5,98%*	*5,26%*	*3,89%*	*3,68%*	*3,92%*	*3,40%*	*39,10%*

Table 3: Contingency table for the medium trading activity group.

High	t												
t-1	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
1	**23,68%**	0,40%	**14,43%**	0,72%	**27,07%**	5,09%	**6,70%**	**4,60%**	1,47%	4,76%	1,89%	1,60%	7,58%
2	0,35%	**25,20%**	0,58%	**14,59%**	4,92%	**27,51%**	**5,01%**	**6,56%**	4,00%	1,36%	1,51%	1,77%	6,64%
3	**10,62%**	0,75%	1,00%	0,75%	11,87%	8,62%	**45,52%**	1,47%	2,61%	1,72%	2,76%	2,52%	9,78%
4	0,68%	**12,53%**	0,69%	1,13%	7,92%	14,32%	1,53%	**41,71%**	1,85%	2,48%	2,48%	2,63%	10,05%
5	**1,91%**	0,43%	1,59%	1,15%	**49,89%**	9,72%	4,07%	2,04%	2,95%	3,18%	3,38%	2,71%	16,97%
6	0,36%	**2,15%**	1,19%	1,90%	9,15%	**45,15%**	2,08%	3,84%	3,85%	3,45%	2,53%	3,87%	20,47%
7	1,03%	1,51%	**3,46%**	**4,38%**	14,46%	14,96%	2,77%	4,06%	**7,40%**	3,35%	**7,95%**	4,12%	30,57%
8	1,53%	1,07%	**4,67%**	**3,29%**	13,98%	15,65%	4,39%	2,83%	3,47%	**7,08%**	4,14%	**7,91%**	29,99%
9	0,54%	0,91%	2,10%	0,60%	15,34%	**22,02%**	4,10%	2,70%	**6,91%**	4,52%	**4,56%**	4,50%	**31,20%**
10	0,89%	0,57%	0,68%	1,94%	18,50%	19,19%	2,80%	3,42%	4,69%	**7,04%**	4,06%	**5,19%**	**31,01%**
11	0,74%	0,91%	2,23%	2,95%	**18,91%**	15,40%	4,17%	3,68%	**5,14%**	4,41%	**8,09%**	4,74%	28,63%
12	0,73%	0,71%	2,70%	2,03%	14,04%	20,81%	3,57%	3,45%	4,58%	**5,02%**	4,36%	**8,83%**	29,17%
13	0,30%	0,36%	1,43%	1,44%	8,70%	10,94%	1,63%	1,42%	3,09%	2,89%	2,46%	2,67%	**62,66%**
Uncondtional frequency	*1,19%*	*1,42%*	*1,78%*	*1,85%*	*17,80%*	*18,83%*	*3,45%*	*3,24%*	*3,65%*	*3,50%*	*3,25%*	*3,53%*	*36,50%*

Table 4: Contingency table for the high trading activity group.

Since our objective is to analyze how the probability of a given event varies as a function of the previous event, we emphasize the three largest numbers per column in bold. The numbers on the diagonal tend to be larger than the other in the same column, so that the probability that a given type of order or trade occurs is large after this event has just occurred than it would be unconditionally. A similar effect was also pointed out in Biais et al. [6] and Abad [1].

Large (small) market orders on one side of the book are particularly frequent after large (small) trades on the same side of the book. Limit orders placed inside the quote are frequent after market orders which clean the depth at the first quote, large market orders and after limit orders of the same type in the case of the low and medium trading activity group. Limit orders placed at the quote are more likely after a limit order[3]. In the case of orders placed outside the quote they are more likely after limit orders of the same type and aggressive limit orders. These results are similar for all the sub-samples. The no activity event normally occurs after a no activity event or after the placement of orders out of the quote in most of the cases[4].

Similarly to Biais et al. [6] we find the diagonal effect for limit orders placed within the quote (with the exception of the high trading activity sample), so we observe the undercutting or outbidding behavior of traders competing to supply liquidity. We also observe that new orders within the quotes on the ask (bid) side of the market are particularly frequent after large sales (purchases). According to Biais et al. [6] this could reflect information effects. As a result of the negative signal conveyed by the large sale, the order book is shifted downward. Such shifts are not observed after small trades. The downward shift in the book has two components, the decrease in the bid, merely reflecting that the large sale consumed the liquidity offered at the quote, and the subsequent decrease in the ask, reflecting the reaction of the market participants to the large sale. The decrease in the bid could be a transient decrease in the liquidity on this side of the book, or a permanent information adjustment. In contrast to the

[3] The only exception is given by the limit orders placed at the quote on the sell side, which are likely also after market orders of small size on the buy side.

[4] For the high trading activity group it can be anticipated by limit orders placed at the quote.

behavior of the bid, the decrease in the ask is likely to reflect the information effect. The behavior generates positive serial correlation for changes in the mid-quote. The asymmetry in the response of the ask and bid at the next point in event time illustrates the distinctive pricing consequences of the liquidity and informational hypotheses. According to Lo and Sapp [21], the ask side reacts more aggressively than the bid side to an increase in the number of marketable limit orders on the same side of the book and the same result is observed in response to opposite side market orders.

5 Regression Analysis

In this section we perform a multinomial logit analysis of the determinants of aggressiveness.

5.1 Description of the Variables

The **relative inside spread** for an order placed at time t is computed looking at the ask and bid prices existing right before the order is placed (i.e. the moment at which the trader makes the decision) and it is given by

$$\text{Relative inside spread}_{t-1} = \frac{\text{askprice}_{t-1} - \text{bidprice}_{t-1}}{\frac{\text{bidprice}_{t-1}+\text{askprice}_{t-1}}{2}}.$$

Volatility is the sum of the absolute value of changes in transaction price in the last ten minutes before the placement of the order divided by the actual price[5].

Depth is defined as the number of shares outstanding at the best quote at the same side of the book at the moment of the placement of the order divided by the median number of shares outstanding at the best quote on the same side of the market. **Opposite Depth** is the number of shares outstanding at the best quote on the opposite side of the book divided by the median number of shares outstanding at the best quote on the opposite side of the book. The median number of shares is computed in both cases by taking into account all the observations of the sample.

Depth out of the best quote is the number of shares outstanding in the levels out of the best quote, i.e. from the second to the fifth level on both sides of the book. In the same way as the depth this measure is divided by the median number of shares outstanding between the second and the fifth level on the same side of the book.

The difference between the best and worst prices for the bid (ask) side of the market is defined as the best bid (highest ask) price minus the lowest bid (best ask) price standing in the market. It is considered a proxy for asymmetric information.

Finally, we introduce some variables representing the dynamics of the market in the last 15 minutes before the introduction of the orders:

[5] The actual price is the price negotiated in the market at the moment of the placement of the order. The definition of volatility without being divided by the actual price is due to Cho and Nelling [9]; we think it is better to divide by the actual price in order to normalize.

- **number of market orders introduced in the market** in the last 15 minutes on the buy and sell side;
- **number of limit orders introduced in the market** 15 minutes before the placement on the buy and sell side. We distinguish between limit orders introduced inside the quote, at the quote and outside the quote.
- **number of cancellations introduced** 15 minutes before the placement on the buy and sell side. We distinguish between cancellations occurred at the best quotes and out of the best quotes.

5.2 Hypotheses and Model

As previously explained, in our econometric analysis we divide market orders in large (volume greater than the median) and small (volume smaller than the median). The trader has therefore to decide among the following alternatives:

1. Introduce a market order with a size larger or equal than the volume of the median market order (buy and sell side).
2. Place a market order with a size smaller than the volume of the median market order (buy and sell side).
3. Place a limit order with a price which improves the best quote (buy and sell side).
4. Place a limit order at the quote (buy and sell side).
5. Place a limit order out of the quote (buy and sell side).
6. Place no order or 'avoid placing an order'.

According to Focault [13] the percentage of limit orders increases with the spread. Harris and Hasbrouck [18] and Smith [28] show empirically that the relative inside spread is positively related to the likelihood of limit orders and inversely related to the likelihood of market orders. The quoted bid–ask spread represents a potential cost to market orders and a potential benefit to limit orders. So, if the relative inside spread increases, limit orders become more likely than market orders since the transaction costs are higher (see also Al-Suhaibani and Kryzanowsky [3] for a similar analysis). According to Cao et al. [8] a wider spread encourages the submission of aggressive orders and discourages the placement of market orders and less aggressive limit orders.

Hypothesis 1 *Wider spreads increase the probability of more aggressive orders.*

Parlour [22] notes that the arrival of a limit buy (sell) order lengthens the queue at the bid (ask) side of the book and therefore reduces the attractiveness of submitting additional limit orders of the same kind. So, if the depth on one side of the book increases then it becomes more likely to observe a market order than a limit order on the same side since the chances of execution of the latter are low. If the depth on the same side of the book increases then more aggressive orders are more likely, since the execution of less aggressive orders takes more time (Cao et al. [8]). Traders have to jump the queue by submitting

more aggressive orders. The thicker the book on one side, the stronger the order aggressiveness for the placement of the new orders on the same side (Ranaldo [25]). Also, market and limit orders on the other side are more likely to be submitted, except aggressive limit orders.

Hypothesis 2 *An increase in depth on one side of the book increases the likelihood of more aggressive orders on the same side of the book. An increase in the depth on the opposite side of the book increases the probability of submitting any types of orders except aggressive limit orders.*

If we consider the depth out of the best quote (between the second and the fifth level) we observe that an increase in this measure increases the probability of placing aggressive orders (market orders and limit orders placed at or inside the quotes). Limit orders with negative price aggressiveness are less likely since there is more competition in order to be executed. An increase in the depth out of the best quote on the opposite side of the book makes the placement of market orders of large size more likely since its complete execution is guaranteed.

Hypothesis 3 *If the depth out of the best quote increases the probability of placing market orders and aggressive limit orders on the same side of the book increases and the probability of non-aggressive limit orders is reduced. On the opposite side of the book an increase in the depth out of the best quote incentives the placement of market orders of large size.*

Focault [13] proposes a model of a dynamic market where increased volatility makes traders place limit orders at less competitive prices. Handa and Schwartz [17], Smith [28], Ahn, Bae and Chang [2], Hollifield, Miller, Sandas and Slive [20] and Ranaldo [25] find evidence of the direct relation between volatility and the placement of limit orders. On the other hand, Cohen et al. [10] finds that as price volatility increases risk averse traders increase their propensity to use orders that reduce uncertainty. This implies that market orders and more aggressive orders increase when volatility increases. So, if we combine both positions, we can conclude that the placement of any order is more likely than the no activity event when the volatility increases.

Hypothesis 4 *When volatility increases the no activity event is less likely.*

The difference between the best and the worst prices posted on a given side of the market may be considered as a measure of the difference in opinion among traders (Lo and Sapp [21]). If the difference between prices increases it means that there is asymmetry of information among traders and it is possible to supply liquidity in the market by introducing limit orders out of the best quote on the same side of the book. On the other side of the book the potential asymmetry of information may encourage the placement of aggressive orders.

Hypothesis 5 *If the difference between the best and the worst price on one side of the market increases the probability of limit orders out of the best quote on the same side of the book and the probability of more aggressive orders on the other side of the book increases.*

Looking now at the dynamic aspects of the market, we start observing that the volume of transactions occurred in the recent past generates two main effects:

an information effect and erosion of market depth. According to Lo and Sapp [21] the first one results from the fact that trades are believed to be correlated with private information, so investors use changes in market orders to update their information. An interesting example is given by the dynamic equilibrium model of Goetler et al. [16], which suggests that changes in the efficient price of the asset induce an increase in the number of market orders in order to take advantage of this information. We therefore expect an increase in the submission of aggressive orders following the submission of market orders, especially on the same side of the market. Looking the contingency tables in section 4.3, we can observe that the placement of market orders is followed by the placement of market orders in most of the cases (the diagonal effect). According to Biais et al. [6] it can reflect a strategic order splitting, an imitation effect or the reaction, at different times, to the same event.

Another possible consequence of the placement of market orders is the erosion of the market depth: the spread becomes wider so the submission of aggressive limit orders on both sides of the book is more likely in order to supply liquidity.

In order to summarize, we expect that after an increase of the number of market orders the placement of market orders and aggressive limit orders is more likely.

Hypothesis 6 *An increase in the number of market orders increase the probability of placement of market orders and aggressive limit orders on both sides of the book.*

When the number of limit orders placed inside the quote increases, the spread narrows and the cost of submitting a market order is reduced, so the placement of more aggressive orders is more likely. We can observe this effect in the contingency tables for the low and medium trading activity groups. In the case of the number of limit orders placed at or out of the quotes we can observe that an increase of this measure leads to the placement of limit orders of the same type. This effect is found, for example, in Biais et al. [6].

Hypothesis 7 *The higher is the aggressiveness of the previous limit orders, the higher is the aggressiveness of the new orders placed.*

When the number of orders cancelled at the quote increases this means that more traders are willing to give up their priority in trading on that side of the market; if traders have private information, this can be considered a signal that bad news about the asset are likely to appear. In fact, if the cancellations on the ask (bid) side are correlated with an expected increase (decrease) in price, this would lead traders to post more orders out of the best quote on the same side of the market to accommodate adverse price change and to post more market orders on the opposite side to execute the trade before the price change is realized to take benefit of the information.

If traders are uninformed and they observe that the spread is wider, they may be encouraged to submit aggressive limit orders on both sides of the book. According to Parlour [22], the cancellations of order at the best quote lowers the competition for the best limit orders on the same side of the market so we expect an increase in the submission of limit orders on the same side of the market. This effect, however, should be included in the coefficient of the spread variable.

Hypothesis 8 *When there is private information, an increase in the number of cancellations occurred at the best quote increases the probability of the placement of less aggressive orders.*

According to Lo and Sapp [20], if we observe an increase in the number of the cancellations out of the best quote the placement of more aggressive orders in order to jump the queue and to obtain priority on execution is more likely.

Hypothesis 9 *An increase in the number of cancellations out of the quote increases the probability of more aggressive orders on the same side of the book.*

5.3 The Model to be Estimated

In order to test the hypotheses we use a multinomial logit specification. As explained in the introduction, for the estimation we divide market orders in large and small. Denote the no-activity event as Category 0, this means that we have 10 additional categories: market orders of large size to buy and to sell (categories 1 and 2); market orders of small size to buy and to sell (categories 3 and 4); limit orders with positive price aggressiveness to buy and to sell (categories 5 and 6); limit orders with price aggressiveness equal to zero to buy and to sell (categories 7 and 8); limit orders with negative price aggressiveness to buy and to sell (Categories 9 and 10).

Let $i \in \{0, 1, 2, 3, ..., 10\}$ denote an index corresponding to the events and let j index the stock. We postulate the relationship

$$\ln\left(\frac{\Pr_{i,j}}{\Pr_{0,j}}\right) = \beta_i X_j \qquad \text{for } i \in \{1, 2, 3, ..., 10\}\,.$$

where X_j is the vector of explanatory variables and β_i represents the vector of coefficients. We assign the value of zero for the dependent variable to the no activity event, so the probability for the other events is modeled relative to this event. We consider the following explanatory variables: relative inside spread ($spread$), volatility ($volat$), the depth of the best quote on the bid and ask side ($depth\_bid, depth\_ask$), the depth out of the best quote on the bid and ask side ($depth\_out\_bid, depth\_out\_ask$), the difference between the best price and the worst price on both sides of the book ($\Delta price\_bid, \Delta price\_ask$), the number of market orders on both sides of the book in the last 15 minutes (MKB, MKS),the number of limit orders with positive price aggressiveness on both sides of the book in the last 15 minutes ($LPOSB, LPOSS$), the number of limit orders with price aggressiveness equal to zero on both sides of the book in the last 15 minutes ($LNULB, LNULS$), the number of limit orders with negative price aggressiveness on both sides of the book in the last 15 minutes ($LNEGB, LNEGS$), the number of cancellations at the quotes on both sides of the book in the last 15 minutes ($CANB, CANS$) and the number of cancellations out of the best quotes on both sides of the book in the last 15 minutes (CAN_out_B, CAN_out_S). All these variables are computed at the moment of the placement.

We estimate the following model for each stock i and time t over which an event occur:

$$\text{Event type}_{i,t} = \alpha + \beta_1 (spread)_{i,t} + \beta_2 (volat)_{i,t} + \beta_3 (depth\_bid)_{i,t} +$$

$$+\beta_4 (depth\_ask)_{i,t} + \beta_5 (depth\_out\_bid)_{i,t} + \beta_6 (depth\_out\_ask)_{i,t} +$$
$$+\beta_7 (\Delta price\_bid)_{i,t} + \beta_8 (\Delta price\_ask)_{i,t} + \beta_9 (MKB)_{i,t} + \beta_{10} (MKS)_{i,t} +$$
$$+\beta_{11} (LPOSB)_{i,t} + \beta_{12} (LPOSS)_{i,t} + \beta_{13} (LNULB)_{i,t} + \beta_{14} (LNULS)_{i,t} +$$
$$+\beta_{15} (LNEGB)_{i,t} + \beta_{16} (LNEGS)_{i,t} + \beta_{17} (CANB)_{i,t} + \beta_{18} (CANS)_{i,t} +$$
$$+\beta_{19} (CAN\_out\_B)_{i,t} + \beta_{20} (CAN\_out\_S)_{i,t} + e_{i,t}$$

The model is estimated for each stock and for the three subsamples classified according to the trading activity. When we run regressions for a single stock we keep i fixed and run the regression. When we estimate, say, the low trading activity sample then we include in the regression all observations (i, t) such that stock i is a low trading stock.

5.4 Results

The results obtained by the estimation are presented in tables 5, 6 and 7.

The signs of the coefficient estimates indicate the direction of change in the likelihood of observing the given event relative to the likelihood of observing a no-activity event (our base case). The relative magnitudes of the coefficients indicate the relative magnitudes of the effects of the different explanatory variables on the various order types. In the analysis of the three subsamples almost all the coefficients of the independent variables are significant at 1%, the coefficients in bold are not significant.

HIGH										
	1	2	3	4	5	6	7	8	9	10
spread	-287,54	-121,08	-120,92	-32,23	448,54	449,03	196,16	114,11	62,46	49,74
depth_bid	0,0307	0,0518	0,0134	0,0567	0,0443	-0,1050	-0,1096	0,0218	-0,0669	0,0169
depth_ask	0,0429	0,0109	0,0490	-0,0063	-0,1132	0,0287	0,0056	-0,0773	***-0,0002***	-0,0673
volat	17,2667	18,7869	18,6183	20,2656	14,3078	13,3186	17,4830	17,8362	15,2303	16,4003
Δprice_ask	-0,4844	-1,1607	-1,0917	-2,1378	0,4713	-1,1913	-1,9149	-1,2591	0,2612	2,5338
Δprice_bid	1,6577	1,0562	1,2054	0,2142	-1,1300	1,5876	***-0,1006***	***-0,0391***	3,0330	-1,2964
depth_out_bid	0,0110	0,0726	0,0170	0,0895	0,0216	-0,0129	0,0486	0,0449	0,0278	0,0246
depth_out_ask	0,0621	0,0256	0,0765	0,0175	0,0140	0,0238	0,0570	0,0493	0,0221	0,0734
MKB	0,0026	0,0002	0,0036	0,0010	0,0016	0,0011	0,0005	0,0012	0,0016	0,0014
MKS	0,0013	0,0024	0,0017	0,0027	0,0011	0,0018	0,0017	0,0012	0,0018	0,0017
LPOSB	0,0209	-0,0199	0,0097	-0,0331	0,0184	0,0083	-0,0075	-0,0092	0,0101	-0,0123
LPOSS	-0,0290	***-0,0001***	-0,0339	-0,0019	***-0,0013***	0,0107	-0,0229	-0,0239	-0,0171	-0,0111
LNULB	0,0011	0,0099	-0,0063	0,0030	***-0,0001***	-0,0043	0,0232	0,0024	0,0043	-0,0012
LNULS	0,0021	***-0,0005***	0,0016	-0,0025	-0,0090	-0,0015	0,0030	*0,0236*	***-0,0006***	0,0020
LNEGB	***-0,0003***	-0,0073	0,0092	-0,0018	-0,0029	-0,0027	***-0,0003***	*-0,0042*	0,0121	-0,0092
LNEGS	-0,0021	0,0098	-0,0050	0,0124	-0,0046	-0,0043	***0,0008***	*0,0050*	-0,0064	0,0256
CANB	-0,0260	-0,0088	-0,0185	-0,0246	0,0147	0,0079	***-0,0026***	***0,0027***	***-0,0002***	-0,0086
CANS	0,0162	***0,00004***	-0,0257	-0,0121	0,0213	0,0272	0,0239	0,0145	0,0201	0,0180
CAN_out_B	-0,0073	0,0155	-0,0153	0,0069	-0,0038	0,0051	-0,0059	0,0102	-0,0027	0,0260
CAN_out_S	0,0161	-0,0150	0,0162	-0,0210	0,0046	-0,0028	0,0035	-0,0030	0,0171	-0,0083
const	-2,0047	-1,8398	-2,0765	-1,7333	-3,3464	-3,4960	-2,9354	-3,0117	-3,4405	-3,1730

Table 5: Multinomial Logit for the **High** trading activity group.

MEDIUM										
	1	2	3	4	5	6	7	8	9	10
spread	-189,82	149,48	-133,96	-83,43	140,06	141,09	23,86	**0,82**	**2,72**	**-3,24**
depth_bid	0,0209	0,0437	0,0121	0,0314	0,0319	-0,0559	-0,0861	0,0089	-0,0613	0,0034
depth_ask	0,0612	0,0280	0,0439	0,0113	-0,0443	0,0483	0,0140	-0,1027	0,0155	-0,0493
volat	31,3189	26,6393	31,2300	28,8608	20,6785	21,8027	23,9249	27,9433	28,3553	27,4561
Δprice_ask	0,2092	0,5561	0,0956	0,5979	1,5756	0,4580	-0,3644	0,3903	0,7039	2,2381
Δprice_bid	0,4498	0,8520	0,4642	0,4689	**0,0515**	1,2948	**0,0991**	-1,1854	1,6766	**0,0295**
depth_out_bid	**0,0005**	0,0668	0,0126	0,0489	**0,0057**	-0,0193	0,0338	0,0400	0,0652	-0,0213
depth_out_ask	0,1038	0,0071	0,1013	-0,0092	0,0301	0,0468	0,0474	0,0561	0,0240	0,0795
MKB	0,0141	0,0069	0,0157	0,0083	0,0119	0,0110	0,0086	0,0110	0,0091	0,0118
MKS	0,0036	0,0161	0,0062	0,0175	0,0084	0,0126	0,0120	0,0059	0,0109	0,0087
LPOSB	0,1004	0,0404	0,0809	0,0071	0,1082	0,0583	0,0558	0,0471	0,0851	0,0325
LPOSS	0,0108	0,0802	**0,0029**	0,0666	0,0295	0,0739	0,0132	0,0300	**0,0040**	0,0656
LNULB	0,0335	0,0563	0,0180	0,0452	0,0350	0,0230	0,1116	0,0295	0,0293	0,0357
LNULS	0,0569	0,0241	0,0515	0,0148	0,0217	0,0292	0,0296	0,0950	0,0326	0,0197
LNEGB	0,0047	0,0035	0,0138	**0,0013**	**-0,0001**	-0,0086	**0,0014**	**0,0025**	0,0513	**-0,0027**
LNEGS	-0,0036	0,0068	**0,0001**	0,0195	-0,0103	**-0,0022**	**0,0013**	**0,0031**	-0,0095	0,0637
CANB	0,0406	-0,0598	-0,0493	-0,0469	0,0531	**-0,0036**	-0,0238	**-0,0006**	-0,0339	**0,0066**
CANS	-0,0196	-0,0401	-0,0418	-0,0483	0,0104	0,0538	**0,0050**	-0,0224	0,0387	**-0,0066**
CAN_out_B	-0,0337	-0,0181	-0,0431	-0,0183	-0,0288	-0,0092	-0,0205	-0,0141	-0,0230	**0,0019**
CAN_out_S	**0,0030**	-0,0233	0,0059	-0,0305	0,0097	**0,0002**	**0,0039**	-0,0109	0,0172	-0,0133
const	-2,3471	-2,2959	-2,3561	-2,2298	-3,3379	-3,4733	-3,1864	-3,1102	-3,4711	-3,5728

Table 6: Multinomial Logit for the **Medium** trading activity group.

LOW										
	1	2	3	4	5	6	7	8	9	10
spread	-127,35	-122,13	-97,39	-48,40	84,03	87,71	10,56	-6,09	10,97	10,52
depth_bid	0,0254	0,0465	0,0082	-0,0286	0,0391	-0,0446	-0,0665	0,0078	-0,0572	**-0,0007**
depth_ask	0,0484	0,0170	**-0,0011**	-0,0096	-0,0249	0,0319	0,0093	-0,1147	**0,0010**	-0,0484
volat	54,9825	53,7326	62,9439	60,3399	49,3459	50,8299	51,9989	50,5389	50,2325	49,8684
Δprice_ask	-0,3371	-0,0931	0,2261	**0,0012**	0,9999	**0,0895**	-0,3814	-0,2098	0,7611	2,0187
Δprice_bid	**0,0496**	0,3412	**0,0301**	0,3565	-0,3576	0,5037	-0,1546	-0,4684	1,2798	**-0,1470**
depth_out_bid	-0,0210	0,0365	-0,0268	0,0211	**-0,0007**	**-0,0053**	**-0,0023**	0,0160	0,0208	-0,0167
depth_out_ask	0,0960	**-0,0034**	0,0581	-0,0146	0,0339	0,0309	0,0400	0,0456	**-0,0081**	0,0796
MKB	0,0472	0,0085	0,0521	0,0191	0,0369	0,0278	0,0256	0,0396	0,0363	0,0417
MKS	0,0117	0,0596	0,0189	0,0664	0,0318	0,0485	0,0448	0,0361	0,0444	0,0396
LPOSB	0,1737	0,1149	0,1533	0,0335	0,1946	0,1042	0,1397	0,1008	0,1776	0,0915
LPOSS	0,1137	0,1340	0,0513	0,1168	0,0817	0,1595	0,0501	0,1067	0,0579	0,1344
LNULB	0,0996	0,1472	0,0689	0,1234	0,0847	0,0588	0,2441	0,0787	0,0960	0,0804
LNULS	0,1443	0,0853	0,1387	0,0666	0,0678	0,0772	0,0762	0,2250	0,0671	0,0863
LNEGB	0,0497	0,0509	0,0563	0,0343	0,0337	0,0158	0,0394	0,0324	0,1513	0,0224
LNEGS	0,0523	0,0579	0,0477	0,0614	0,0339	0,0480	0,0374	0,0579	0,0450	0,1777
CANB	-0,0742	-0,0876	-0,0666	-0,0834	0,0839	**0,0006**	-0,0379	**-0,0129**	-0,0451	-0,0304
CANS	-0,0871	-0,0698	-0,0600	-0,0631	-0,0166	0,0629	**-0,0134**	-0,0217	**0,0057**	-0,0242
CAN_out_B	-0,0755	-0,0618	-0,0814	-0,0262	-0,0742	-0,0300	-0,0769	-0,0379	-0,0886	-0,0408
CAN_out_S	0,0655	-0,0577	-0,0300	-0,0586	-0,0263	-0,0429	-0,0274	-0,0404	-0,0215	-0,0397
const	-2,5410	2,3016	-2,4685	-2,2563	-3,1221	-3,2333	-3,1641	-3,2641	-3,7032	-3,8250

Table 7: Multinomial Logit for the **Low** trading activity group.

Spread

If the spread becomes wider the probability of market orders and less aggressive limit orders is reduced, while the probability of more aggressive limit orders increases since it is possible to improve the best price in the market. This confirms Hypothesis 1.

Depth

If the depth at the best quote on the same side of the book increases then the probability of submitting market orders and aggressive limit orders increases, while the placement of less aggressive orders becomes less likely. With respect to the depth on the opposite side of the book we observe that its increase makes aggressive limit orders less likely and all the other types of orders more likely. This confirms the predictions stated in Hypothesis 2.

In order to analyze the effect of depth out of the best quote on the order

submission strategy we have to distinguish between buy and sell side. On the sell side an increase in the depth out of the best quote makes the placement of market orders on the same side less likely and the rest of orders more likely[6]. An increase in the depth out of the best quote on the buy side makes the submission of aggressive limit orders on the opposite side of the market less likely, while the rest of the orders are more likely. This means that Hypothesis 3 is not completely confirmed.

Volatility

In period of high volatility the probability of no activity is reduced, confirming Hypothesis 4.

Difference between the best and the worst price.

An increase in the difference between the best price and the one outstanding at the fifth level on the same side of the book makes the placement of limit orders out of the quotes more likely. For the medium trading activity sample an increase in the asymmetry of opinions of the traders leads to the placement of less aggressive limit orders and the introduction of market orders. To analyze the effect of an increase in the difference between the best and the worst price on the opposite side of the book we have to distinguish between the buy and the sell side. An increase of this measure makes the placement of more aggressive limit orders and market orders more likely on the sell side, while aggressive limit orders and market orders become less likely on the buy side. In this way we confirm Hypothesis 5 and we can observe a different behavior depending on the side of the book we are taking into account: orders or trades originating from the ask side are more aggressive than the ones on the buy side. The exception is the high trading activity group, for which this is not true.

Recently placed market orders

When the number of market orders placed in the last 15 minutes increases, we can observe that the placement of all types of orders is more likely. The increase in the placement of market orders and aggressive limit orders is explained, respectively, by the diagonal effect and the increase of the width of the spread in accordance to Hypothesis 6

Recently placed limit orders

If the number of aggressive limit orders placed in the last 15 minutes increases, the probability of introducing all orders on the same side of the book increases for the medium and low trading activity samples. For the high trading activity group, the probability of introducing an order of the same type and market orders and limit orders out of the best quote increases respectively on the sell and buy side.

If the number of orders placed at the quote increases, the probability of placing all orders increases for the medium and low samples; for the high trading activity group the probability of market orders on the opposite side of the book and the placement of limit orders on the same side increases.

If the number of limit orders placed out of the quote increases, the probability of all types of orders increases for the low trading activity sample; for the high and medium trading activity groups the placement of market orders and limit orders out of the quote on the same side is more likely. Aggressive orders and market orders on the opposite side of the book are less likely. So we can conclude

[6] In the case of the low trading activity group, large market orders and limit orders out of the best quotes on the buy side are not significant.

that Hypothesis 7 is only partially satisfied.

Cancellations

When the number of cancellations at the quotes increases the probability of introducing market orders and less aggressive orders is reduced, while the placement of aggressive orders becomes more likely[7]. Thus, Hypothesis 8 is satisfied only partially.

If the number of cancellations out of the best quote increases the probability of all orders decreases for the low and medium[8] trading activity groups. For the high trading activity group we can observe that an increase in this measure decrease the probability of any order on the same side of the book and increases the probability of introducing orders on the opposite side, traders try to take benefit of this situation.

6 Conclusions

In this work we have analyzed the determinants of orders' aggressiveness. We started with an exhaustive classification of order aggressiveness, based on the work of Bias et al. (1995) but including the new category of no-activity as the least aggressive. A descriptive analysis of order aggressiveness for the Spanish market shows that it shares many of the features observed in other studies, such as Biais et al. [6]. Finally, we have used a multinomial logit model to analyze the effect of some explanatory variable on the aggressiveness of the order submission strategy. We have found that wider spreads make the placement of aggressive orders more likely and an increase in the depth on the same side of the book encourages the placement of more aggressive orders in order to obtain priority on execution. These orders are less likely if the depth on the opposite side of the book increases. About the volatility, we can observe that any type of activity is more likely if the market is more volatile. When the opinions of traders about the price of the stock are more dispersed, the placement of less aggressive orders and sometimes the placement of market orders on the same side of the book is more likely. If we consider this measure for the opposite side of the book we observe that more aggressive orders are more likely, in particular on the sell side.

We also consider the dynamics of the market by taking into account the number of orders placed or trades in the last 15 minutes before the placement. When the number of market orders increases, the placement of all types of orders and trades is more likely. We can observe the diagonal effect also for the other types of limit orders except for the high trading activity group, as described in the contingency tables.

If the number of cancellations at the quotes increases the placement of aggressive orders is more likely. For the cancellations out of the quotes on the same side of the book we observe that the placement of any type of orders and trades is less likely but for the high trading activity group an increase in the number of cancellation out of the quotes incentives the placement of orders on the other side of the book.

[7] An exception is given by the sell side of the high trading activity group: if the number of cancellation at the quote increases then the probability of all types of limit orders increases.

[8] An increase in the cancellation on the opposite side of the book increase the placement of some orders on the buy side.

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