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‘Determining the Intensity of Buy and Sell Limit Order Submissions: a Look at the Market Preopening Period’
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Determining the Intensity of Buy and Sell Limit Order Submissions: A Look at the Market Preopening Period

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JEL Classification: G12, G14, G15, C32.

Keywords: market microstructure, limit order, duration, intensity, liquidity

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Abstract

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1. Introduction

In a limit order market, traders submit orders to either buy or sell an asset for a specific price and associated volume. In other words, the limit order represents a pre-commitment that the trader is willing to either buy or sell a specified amount of an asset at a predetermined price. This order remains open until it is either executed or cancelled. However, in a limit order market there is no designated market maker, and orders are only executed when the price associated with a limit buy order is matched with the price of a limit sell order.\(^1\) In addition, limit orders that are unexecuted are queued and form what is known as the limit order book. The limit orders that comprise the book have a price and time priority rule associated with them, in that the highest price for a buy order and the lowest price for a sell order is given priority to be executed before any other limit order. In the case of two limit orders having the same price, then the first to be submitted to the book is executed before the most recent limit order. In essence, the limit order book represents a source of information about the characteristics of the market in general, individuals’ valuation for an asset and the level of liquidity demanded and supplied at different prices.\(^2\)

Hence, the obvious question here is what information can be inferred from the limit order book by traders so as to shape their expectations about the fundamental value of the asset? Further, can traders infer information from an open limit order book in the absence of trading considering that it is possible for previous commitments to be revised or cancelled at any time? On some exchanges, after an overnight or weekend halt in the trading process, there is a preopening period that precedes the initiation of trading. During this period traders can submit limit orders similar to a call auction process in which eligible orders are executed only at the opening session of the trading day. In essence, this period represents an information aggregation process about the fundamental value of the asset, since there is no trade execution taking place and traders are indicating their valuation of the asset. Consequently, by observing each other’s actions, traders can detect trends in the order process and form expectations about both the probable opening price of the asset or the general direction of prices. However, orders submitted during this period are non-binding and can be subsequently cancelled or revised, making inference somewhat more challenging.

\(^1\) The execution of trades is also possible using market orders. However, market orders can be considered as limit orders that request a trade immediately at the best available price.
\(^2\) See Parlour and Seppi (2007) for a comprehensive survey of literature on limit order markets.
The main focus of this paper is to determine whether traders utilise information inferred from the characteristics of recent limit order submissions and changes in the limit order book to form strategies to submit either buy or sell orders during the preopening period. In other words, do traders observe the actions of other traders and make inferences that impact the intensity of their order submission during the market preopening period? If so, then order submissions should tend to cluster during the preopening, since all traders act off the same information. We further explore which specific information from the order book is most significant in determining the driving factor behind the submission of limit orders by traders. Additionally, we seek to determine if different sides of the market are more or less impacted by what can be inferred during the preopening period.

We make two key contributions to the literature. First, previous work on market preopening (such as Vives, 1995; Medrano and Vives, 2001; Madhavan and Panchapagesan, 2000; Barclay and Hendershot, 2003; and Biasis, Hillion and Spatt, 1999) mostly focuses on determining the presence of price discovery and how it is impacted by differences in the characteristics of exchanges. To our knowledge we are the first to model and explain the intensity of buy and sell order submissions during the market preopening period. Further, we determine the factors that are most important in driving the intensity of order submissions during a period of no active trade execution. In addition, the theoretical literature on the market preopening proposes that information asymmetry drives order activities during this period. In our analysis, we formulate and test hypotheses that are reflective of information asymmetry to determine if there is sufficient evidence to support the theoretical predictions.

Second, our model focuses solely on explaining limit order submissions and thus provides further insights into the reasons why traders submit orders during the preopening period. Previous studies (Engle and Lunde, 2003; Bauwens and Giot, 2000; and Hall and Hautsch, 2007) analyse the intensity of order submissions during the regular trading period, necessarily incorporating factors such as market orders and trade execution intensities to explain limit order submissions. Since we analyse the preopening period, we focus entirely on the effects of limit order submissions and changes to the limit order book on the intensity of further order submissions.

To analyse the preopening order submission processes, we model the bid and ask duration processes separately using the Log-ACD model proposed by Bauwens and Giot (2000). A key advantage of this approach is that it allows the incorporation of additional factors into the
conditional expectation equation of the ACD model without the necessity of imposing positivity constraints on the coefficients. In addition, the error structure is assumed to follow a Weibull distribution, which allows for some degree of flexibility in the hazard function. To determine the impact of activity in the limit order book and incoming orders, we incorporate explanatory variables into the conditional expected duration equation that reflect the impact limit order arrival, the current spread, mid-quote volatility and revisions or cancellation of orders previously submitted to the limit order book. In order to present a clearer interpretation for the arguments being proposed, we formulate the arguments around order submission intensities as opposed to durations. The intensity is the reciprocal of expected duration and represents the instantaneous rate at which orders arrive to the limit order book.

The empirical results reveal that the intensity of buy order submissions react more to information regarding the information content of an incoming order and any changes to the state of the current order book when compared to the reaction of the sell order intensity. In fact, we find that the greater the price of an incoming bid order relative to the best bid price, then the greater the increase in the intensity of bid order submissions. However, there is no substantial evidence that the intensity of ask order submissions is affected. Whenever the price of an incoming ask order is small relative to the best ask price, this coincides with a period of low sell order submission intensity. This reduction in sell order intensity is attributable to sell side traders trying not to propel additional negative signal into the market. However, there is no evidence that the price associated with an incoming ask order impacts the intensity of bid order submissions. Additionally, we find that the intensity of bid (ask) order submissions increases (decreases) whenever the price associated with an incoming bid order is greater than or equal to the best ask price, thus resulting in the spread being locked or crossed. Similarly, when the price of an incoming ask order is equal to or less than the best bid price, this increases the intensity ask order submissions and reduces the submissions of bid order submissions. Essentially, this finding is consistent with that of Cao, Ghysels and Hatheway (2000), who conclude that a locked or crossed inside spread is indicative of information based trading.

Changes made to the limit order book, such as cancellations and revision of previously submitted limit orders have a mixed impact on the intensity of order submissions. For instance, we find that the cancellation of a bid or ask order has a negative impact on the intensity of both the bid and ask order submissions. In addition, the volume associated with a cancelled ask order increases the intensity of ask submissions as traders take the opportunity
to submit sell orders when volume is removed from the order book. On the bid side, we find that the volume associated with a cancelled bid or ask order reduces the intensity of bid order submissions. In effect, this indicates that traders cancel bid orders in an environment of low bid submissions and as a result traders on the sell side tend to reduce the number of sell orders in the book since the demand for liquidity is low. Revisions of previous order do not seem to have a consistent impact on the intensity of bid order submissions and do not significantly affect the intensity of sell order submissions.

The remainder of the paper is organized as follows: in section 2 we outline the economic intuition and derive testable hypotheses based on the existing literature. Section 3 describes the econometric methodology while section 4 provides details of the data and the explanatory variables. Section 5 reports and discusses the empirical results and section 6 concludes these findings.

2. Economic Intuition and Testable Hypotheses

2.1 Is there evidence of clustering in the bid and ask quote duration processes during the preopening period?

The market preopening period serves as an information aggregation process after a halt in the trading due to an overnight or weekend closing of the exchange. During this period, traders who receive private information about the fundamental value of the asset devise strategies to exploit their informational advantage since there is no execution of trades. However, by placing limit orders, informed traders inadvertently reveal a portion of their private information. In an open limit order book market, private information is revealed as every trader observes the actions of other traders in an effort to determine the direction of prices and form expectations about the fundamental value of the asset. Information revelation is further amplified during preopening since there is no execution and traders have the option to cancel or revise previous quotes without any cost or obligations. As such, uninformed traders observe the order flow and any adjustments to previous orders and form expectations about the potential opening price for the asset. For instance, in Vives (1995), competitive informed traders and noise traders submit limit orders to buy or sell an asset during the preopening period without knowing whether their trades will be executed at the opening of trading. However, towards the end of the preopening period, informed traders reveal a significant
portion of their private information through limit order submissions continuously improving
the information set of other traders. As a result, the relatively rapid erosion of the private
information set dramatically reduces the incentive for informed traders to post further quotes
towards the end of the preopening period.

Vives (1995) predicts that the intensity of both the bid and ask order processes increases
during the early stages of the preopening and through continuous revelation of information
about the fundamental value of the asset by informed traders, the intensity of both order
processes diminishes towards the end of the preopening. However, this prediction rests on the
assumption that uninformed traders learn about the fundamental value of the asset by
observing the order flow from the inception of the preopening period towards the opening of
trade. As a result, this assumption is not supported by the empirical findings of the
preopening period by Biasis, Hillion and Spatt (1999), who find that there is no evidence of
learning during the early stages of the preopening only during the last half an hour of the
preopening period. Consequently, two possible scenarios can be contemplated. On the one
hand, the informed traders may decide not to submit orders during the early stages of the
preopening and only submit their information based orders close to the end of the preopening
period. Utilising such a strategy eliminates both the revelation of information and learning by
other market participants during the early stages of the preopening period. However, towards
the end of the preopening period when informed traders begin to submit their information
based quotes the learning process resumes and the intensity of the quote processes increases.

On the other hand, the informed traders might act strategically and induce additional noise in
the early stages of the preopening period. Acting strategically, informed traders intentionally
induce distortions into the learning process of the uninformed traders diminishing their ability
to form expectations about the fundamental value of the asset from the order flow. Medrano
and Vives (2001) show that when manipulative behavior is incorporated into the information
aggregation process the strategic informed trader posts contrary orders during the early stages
of the preopening intending to offset the information revealed when other competitive
informed traders submit orders. However, towards the end of the preopening period, the
strategic informed trader reverses the contrary orders and places orders consistent with their
information set. As a consequence, contrary to the predictions of Vives (1995), Medrano and
Vives (2001) posit that manipulative behavior by an informed trader causes the intensity of
order submission to increase towards the end of the preopening period.
The predictions presented above are conflicting with regards to which stage of the preopening that is characterised by an increase in the order submission intensity. However, they make one similar conclusion that there is tendency for clustering of order submission during the preopening period due to informed trading. Further, if the private information set of the trader implies a higher fundamental value than the price implied by the market, then the intensity of order submissions will be more focused on the bid side of the market and vice versa. However, if private information arrives randomly to the market then both sides should display similar degrees of clustering. Therefore, in such a situation the intensity of orders on both side of the market will be examined separately. The testable implications are as follows:

(a) The preopening period exhibits clustering in the bid and ask order submission processes.

(b) The intensity of the bid and ask submission processes will display similar levels of clustering.

2.2 The impact of limit order prices on the intensity of the bid/ask order processes

Submitting limit orders reveals the willingness of a trader to purchase or sell a number of units at a specific price. Both the price and the volume that constitutes the limit order contain significant private information about the trader's valuation of the asset. However, in the preopening period, since there is a significant delay between the submission of orders and the execution of trading, the trader’s valuation becomes public information before any potential benefits can be realised. Thus with each limit order submission market participants revise their expectations about the probable fundamental value of the asset and devise strategies to profit from their updated information set. For instance, in the case where the limit order is placed by an informed trader, the uninformed trader without knowing the type of trade (informed or liquidity motivated) that is submitted, assesses the aggressiveness of the order based on its characteristics. As a result, if the uninformed trader infers that the quote is information based then their order strategy will reflect the updated information set. Hence, we predict that the intensity of the order processes will be affected by the information that can be inferred from the posted limit orders.

Though the prices associated with limit orders contain significant information about traders’ valuation of the asset, this information cannot be revealed in isolation. In effect, the information that is inferred from the price of an incoming limit order is in relation to the price
of the best bid/ask order in the limit order book. To determine the relationship between the price associated with an incoming limit order and the bid/ask order intensity, we follow applicable arguments from Hall and Hautsch (2007). In their analysis, the intensity of the buy and sell arrival process in the limit order book of the Australian Stock Market is estimated using an Autoregressive Conditional Intensity (ACI) model. They argue that when a trader submits a limit buy order with a price that is higher than the current best bid, this reveals that the trader is more aggressive to get their order executed and places a higher valuation on the asset. Hall and Hautsch (2007) further argues that a trader who sets the bid limit price above the prevailing best bid price indicates that they are only faced with a low adverse selection risk and displays an upper tail expectation that is higher than the best bid price. Effectively, this will constitute a positive signal to the market and as a result the net buying pressure is expected to increase.\(^3\) Similarly, when the price of an incoming ask limit order is set above the best ask, this conveys a positive signal in that the trader’s upper tail expectation is higher than the prevailing best ask price. Accordingly, the net buying pressure is expected to increase. In addition, the converse of these relationships also holds true, in that, the price of an incoming limit bid (ask) order that is set below the current best bid (ask) represents a negative signalling effect and as a result, the net buy pressure is expected to decrease.

However, within the context of the preopening period we further argue that due to the absence of trade execution, the magnitude of the difference between the price of the incoming bid (ask) and the best bid (ask) price has a more relevant impact on the intensity of the order processes. For instance, if there is manipulation by an informed trader during the preopening period such as in Medrano and Vives (2001), then the manipulative trader will implement negative signalling strategies to offset any positive signal revealed by other informed traders. In essence, if the information is consistent with a higher fundamental asset value, the strategic trader would impose a negative signal by placing ask limit orders. Thus, for the effect to be strong or credible the price of the limit ask orders must be close to or lower than the price of the best ask. The converse of this argument also holds true. However, as Medrano and Vives (2001) show, towards the end of the preopening period the strategic trader is compelled to place orders that are in line with the private information in order for the strategy to yield a positive payoff. Therefore, towards the end of the preopening period the strategic trader will

\(^{3}\) Hall and Hautsch (2007) define the net buy pressure as the ratio of the estimated buy and sell intensities.
submit bid orders and in order to increase the probability that their orders are executed at the opening, the price of the limit order must be close to or greater than the best bid price. The more aggressive the strategic trader is the higher the price of the submitted bid limit order.

Alternative, in terms of the Vives (1995) framework which does not incorporate manipulative behavior by an informed trader, the impact of the price of an incoming limit order and the intensity of the order processes will be the same as expressed above, though the arguments are different. Essentially, Vives shows that the order flow conveys significant information about the traders’ valuation of the asset from which other traders can infer and learn about the fundamental value of the asset throughout the preopening period. Therefore, an informed trader will increase the probability that their order is executed by submitting limit orders with prices that are close to or greater (less) than the best bid (ask) price. We propose that uninformed traders that notice this trend will adjust their order strategies in a similar fashion and as such the intensity of the bid or ask orders will increase. Consequently, this process will continue recursively until prices converge to their fundamental value, at which the intensity of orders by informed agents reduces dramatically due to the erosion of their private information.

The implication is that the more aggressive a trader is in getting their bid order executed at the opening, then the higher difference between the price of the best bid and the price of an incoming bid order. Accordingly, if a trader is aggressively seeking to get their ask order executed at the opening, then the difference between the price of their incoming limit order and the best ask will be higher. The same arguments are applicable if a strategic trader intentionally induces a negative signal to offset the information that is revealed by other informed traders. Thus in both cases, due to the presence of informed trading and learning by uninformed traders, the intensity of the order processes will be positively impacted the greater the difference between the price of the limit order and the price of the best bid/ask. From these arguments we propose three testable hypotheses.

(c) The intensity of bid order submissions increases with the difference between the best bid price and the price of an incoming bid order.

(d) The intensity of ask order submissions decreases with the difference between the best bid price and the price of an incoming bid order.
(e) The intensity of ask order submissions increase with the difference between the price of an incoming ask order and the best ask price.

(f) The intensity of bid order process decreases with the difference between the price of an incoming ask order and the best ask price.

2.3 The impact of locked or crossed inside spreads on the intensity of the bid/ask process

During the regular trading period, a trade is executed whenever the price associated with an incoming bid (ask) order is equal to or greater (less) than the prevailing best ask (bid) price in the limit order book. Essentially, this makes it impossible for the price of the best bid to be equal to or greater than the price of the best ask in the limit order book. However, during the preopening period there is no execution of traders taking place. As a consequence, the price of an incoming bid (ask) can be set at or above (below) the best ask (bid) which results in a locked or crossed inside spread. A locked inside spread refers to the situation where the prices of the best bid and ask are equal. Accordingly, a crossed inside spread refers to the situation where the best bid is greater than the best ask in the limit order book. Cao, Ghysels and Hatheway (2000) examines the impact of locked and crossed inside spread on the price discovery process of the Nasdaq market preopening period and finds that when the market is locked or crossed, significant information is being revealed about the fundamental value of the asset.

Therefore, we argue that a trader who locks or crosses the inside spread by submitting a bid limit order that is equal to or greater than the best ask, sends a positive signal by revealing that their valuation for the asset is either equal to or greater than the prevailing best ask price. Additionally, by employing such an aggressive strategy to increase the probability that their order is executed at the opening of trades also increases the probability that the trader possesses private information about the fundamental value of the asset. Consequently, this should positively impact the intensity of the bid order submissions and negatively impact the ask order process, since the information is on the bid side of the market. However, based on the same arguments, if the market is locked or crossed by an incoming ask order, then this sends a negative signal regarding the fundamental value of the asset. Thus, the intensity of the bid submissions is expected to be negative impacted and the intensity of the ask order submissions positively impacted. The testable hypotheses in this situation are as follows:
(g) The intensity of bid order submissions is positively impacted when the inside spread is locked or crossed by an incoming bid order.

(h) The intensity of ask order submissions is negatively impacted when the inside spread is locked or crossed by an incoming bid order.

(i) The intensity of ask order submissions is positively impacted when the inside spread is locked or crossed by an incoming ask order.

(j) The intensity of bid order submissions is negatively impacted when the inside spread is locked or crossed by an incoming ask order.

2.4 The impact of incoming limit order volume on the intensity of the bid/ask process

The volume that is associated with a submitted limit order is said to be related with informed trading as relatively higher volume is an indication of a trader’s aggressiveness to profit from private information [O’Hara (1997)]. Specifically, order flow during the preopening period is vital in the information aggregation process as market participants can infer valuable information about the fundamental value of the asset. In both Vives (1995) and Medrano and Vives (2001), order flow during the preopening represents an important variable in the determination of the prices set during the period. In other words, the price at each point during the preopening is conditional upon the order flow that emanates from the traders. They show that an increase in order flow signifies the arrival of private information and prices are impacted accordingly. In essence, order flow is a major conveyor of information regarding the fundamental value of the asset, from which uninformed traders can make inferences.

There are a few points here to note, first, in Vives (1995) order flow during the preopening period first increases and then diminishes towards the end of the preopening as more and more information about the fundamental value of the asset is revealed by the informed traders. In the limit, prices equal their fundamental value and informed traders have no incentive to place additional orders since their information advantage has been eroded. Second, Medrano and Vives (2001) contend that due to the manipulative behavior of the strategic informed trader, order flow during the preopening period will be ‘U’ shaped due to the submission of manipulative orders during the early stages of the preopening and then the resubmission of “serious” orders towards the end of the preopening period. They further
predict that the intensity of order submission increases towards the end of the preopening period. However, both Vives (1995) and Medrano and Vives (2001) predict that the increased order flow will be positively related to the intensity of the order processes during the preopening period.

Essentially, the impact here is twofold. First, if volume is a purveyor of private information during the market preopening period, then the volume associated with an incoming bid (ask) limit order will be positively related to the intensity of the bid (ask) order process and inversely related to the intensity of the ask (bid) quote process. In essence, a high order volume on the bid side indicative of private information that is reflective of a higher fundamental value compare with the present prices, which leads to a tendency for the intensity of the bid quote process to increase. However, since there is no trading during the preopening period, other traders in the market observe this trend, and learn from the order flow. Hence, under the assumption of learning, high order flow on the bid side of the market should reduce the intensity of orders on the ask side of the market and vice versa. Therefore, the testable hypotheses are as follows:

\[(k) \text{ The intensity of bid order submissions increases with the volume of an incoming bid order.}\]

\[(l) \text{ The intensity of ask order submissions decreases with the volume of an incoming bid order.}\]

\[(m) \text{ The intensity of bid order submissions decreases with the volume of an incoming ask order.}\]

\[(n) \text{ The intensity of ask order submissions increases with the volume of an incoming ask order.}\]

2.5 The impact of order revisions and cancellations on the bid/ask intensity

Limit orders that are submitted during the preopening period are non-binding and traders have the option to cancel or revise their order without cost or obligation anytime before the order is filled at the opening. An order revision corresponds to any modification that a trader makes to a previous order that does not alter the type of order (bid or ask). For instance, if a trader changes the price or volume of a previously submitted order, then this constitutes a
revision. However, if a trader contemplates modifying the type of order from say a buy to a sell, then the order will have to be cancelled and the desired type of order submitted. The exact reason for a cancellation will be unknown since there are a variety of reasons that can be contemplated when an order is cancelled. For instance, if a strategic trader possesses private information about the fundamental value of the asset in the framework of Medrano and Vives (2001), the strategic trader submits limit orders during the early stages of the preopening that are contrary to what is implied by their private information. If the strategic informed trader is to profit from the private information, the contrary orders need to be cancelled and an order reflective of the private information is submitted. In essence, the cancellation of a previous order will be associated with an informed event and as such should have a significant impact on the intensity of the bid/ask process.

Alternatively, if the information aggregation process commences towards the end of the preopening period as in Biasis, Hillion and Spatt (1995), then this provides additional reasons for cancelations and revisions. Essentially, their analysis found that towards the end of the preopening period quotes become informative and reflects learning among traders. Therefore, uninformed at this time will be able to form more informed estimation about the fundamental value of the asset and as such will modify their previous orders to reflect their updated information set. Thus, if the price of their initial order was under or over estimated then they will revise their orders close to their latest estimation of the fundamental value. Additionally, if based on the information that is being revealed by the informed traders, uninformed traders realises that they are on the wrong side of the market, which therefore means that the previous order will have to be cancelled and a new order submitted. Nonetheless, under these assumptions, cancelation and/or revision of a previously submitted order is information driven and will significantly impact the intensity of the order processes.

The main implications are, first, the cancellation of a previous bid order is expected to negatively impact the bid order intensity and positively impact the ask order intensity. Accordingly, the cancellation a previous ask order is expected to negatively impact the ask order intensity and positively impact the bid order process. The argument here is that in light of learning, a cancelled order implies that the trade direction of the trader’s order strategy has changed sign. In essence, the trader may infer that the information flow is concentrated on the opposite side of the market and therefore no longer have an interest in their current order. Further, we expect that the impact should be more significant the higher the volume
associated with the cancelled limit order and if the order that is being cancelled is the best bid
or ask in the order book.

Second, the impact of a revised order will be dependent on the direction of the change in
relation to the best bid/ask order. If the limit bid price is revised upwards closer to the best
bid then this represents a positive signal that the trader has placed an improved valuation on
the asset, which may be a result of learning, and as such should have a positive relation with
the intensity of the bid order process. The converse of this argument should also hold true in
the case of the ask order process. We therefore posit that on the one hand, a revision of a bid
order price in the direction of the best bid will increase the intensity of the bid order
submissions and reduce the intensity of the ask order submissions. On the other hand, if
there is a revision in a previous ask order price in the direction of the best ask then this bears
a negative signal and as such should increase the ask order intensity and reduce the bid order
intensity. In addition, the magnitude of these relationships should also be increasing in the
volume of the order being revised and if the revised order is the best bid or ask. Thus the
testable hypotheses are as follows:

(o) The cancellation of a bid order negatively impacts the intensity of bid order
submissions and positively impacts the intensity of ask order submissions. This impact
increases with the volume of the cancelled bid order and when the cancelled bid order
is the best bid.

(p) The cancellation of an ask order negatively impacts the intensity of ask order
submissions and positively impacts the intensity of bid order submissions. This
impact increases with the volume of the cancelled ask order and when the cancelled
bid order is the best bid.

(q) The revision of a bid order price closer to the best bid price increases the intensity of
bid order submissions and reduces the intensity of ask order submissions. This
impact increases with the volume of the revised bid order and when the revised order
is the best bid.

(r) The revision of an ask order price closer to the best ask price increases the intensity
ask order submissions and reduce the intensity of bid order submission. This impact
increases with the volume of the revised ask order and when the revised order is the
best ask.
2.6 The impact of the bid-ask spread and mid-quote volatility on the bid/ask process

In a limit order market the inside spread is computed by finding the difference between the prices of the best bid and best ask order in the order book. This measure is closely associated with the level of liquidity in the limit order book. Essentially, a wide spread is indicative of low market liquidity and a narrow spread indicates a relatively high level of liquidity in the market. In the context of the preopening period in which there is no active execution of trades, the best bid represents the highest valuation that a trader has placed on the asset under consideration. Similarly, the best ask is the lowest price that a trader is willing to sell the same asset. Therefore, we can argue that if the highest value to buy is close to the lowest value that a trader is willing to sell, then this should signify a greater level of liquidity in the market. As a consequence, we expect the intensity of both the bid and the ask order processes to also be positively impacted by a narrow spread. In essence, with greater level of liquidity suppliers in the market, it should hold true that the intensity of the order process also increases.

Another source for inference used by traders during the preopening is the past behavior of order prices during the period. Under the assumption of learning, traders observe the evolution of prices as a basis to form their own expectation of the fundamental value of the asset. In fact, the preopening period is preceded by a halt in the trading process which may have resulted in variation in traders’ expectations about the fundamental value of the asset when trade resumes. As a consequence, the differences in expectations that manifest itself during the order submission process should provide significant information about the direction of the asset’s fundamental value when observed by uninformed traders. Further, as market participants learn from these differences in valuation that are realised over time and the direction of the fundamental value can be inferred, they will begin submitting orders. Consequently, we expect the intensity of both the bid and the ask order submissions to increase. To measure the impact of variation in expectation about the fundamental value on the intensity of the bid and ask order processes, we use the mid quote volatility as a proxy. In essence, if there is a high level of variation in valuation (or uncertainty) about the fundamental value of the asset after the overnight or weekend halt in the trading process, then

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4 A similar argument is articulated by Hall and Hautsch (2007). They argue that the inside spread directly affects the intensity of the trade process on both sides of the market. However, they do not present a case for the response to the quote processes.
this should be reflected in the volatility of the mid-quote. We therefore expect that in light of learning, a high mid-quote volatility should have a negative impact on both the bid and ask order submission intensity. Therefore, the testable hypotheses in this case are as follows:

\((s)\) The intensity of both the bid and ask order submissions should decrease when there is an increase in the inside spread.

\((t)\) The intensity of both the bid and ask order submissions should be positively impacted when there is a decrease in the volatility of the mid-quote.

3. Econometric Methodology

3.1 The ACD Model

To model the bid and the ask order duration processes we utilise the Log ACD model of Bauwens and Giot (2001), which is an extension of the ACD model first introduced by Engle and Russell (1998). To present a clear case for the use of the Log ACD model we first discuss the theoretical underpinnings of the basic ACD framework. In the model proposed by Engle and Russell (1998), the series \(\{t_i, t_{i-1}, \ldots, t_1\}\) represents the clock time that quotes are posted and the duration of each quote relative to the occurrence of the previous quote is defined as \(x_i = t_i - t_{i-1}\). Engle and Russell (1998) further define \(\psi_i\) as the conditional expectation of the \(i\)th duration, such that

\[
\psi_i = \psi_i(x_{i-1}, \ldots, x_i; \theta) = E(x_i | x_{i-1}, \ldots, x_i),
\]

where \(\theta\) is a vector of parameters. In addition, they propose that the \(i\)th duration is the product of the conditional duration at period \(i\) and an independently and identically distributed (\(iid\)) variable \(\varepsilon_i\), such that \(x_i = \psi_i \varepsilon_i\), where \(\varepsilon \sim iid\) with density function \(f(\varepsilon, \phi)\) where \(\phi\) is a parameter vector. By construction, the error structure for the ACD model is defined as

\[
\varepsilon_i = x_i / \psi_i,
\]

where \(E(\varepsilon_i) = 1\).

In order to derive the framework for modelling the conditional duration \(\psi_i\), Engle and Russell (1998) assume that the durations are conditionally exponentially distributed and as such the hazard function is constant and equal to one. Specifically, the hazard function \(\lambda_0(t)\) is the ratio of the probability density function \(P_0(t)\) to the survival function \(S_0(t)\), such that
\[ \lambda_0(t) = P_0(t)/S_0(t). \] They further propose that the conditional intensity of the ACD model can be expressed as

\[ \lambda(t | N(t), t_1, ..., t_{N(t)}) = \lambda_0(t - t_{N(t)})/S_0(t_{N(t)+1}) \cdot 1, \]

where \( N(t) \) is a counting function, \( t_{N(t)} \) and \( \psi_{N(t)} \) are the time and conditional duration when the counting function is evaluated respectively. Therefore, if the survival function \( \lambda_0(t) \) is assumed to be equal to one by imposing the assumption of exponentially distributed durations, then the conditional intensity becomes

\[ \lambda(t | x_{N(t)}, ..., x_t) = \psi_{N(t)+1}^{-1}. \]

As a result, Engle and Russell (1998) propose the following parameterization for the conditional duration process which is referred to as the Exponential ACD (EACD) model:

\[
\text{EACD}(m,q): \quad \psi_i = \omega + \sum_{j=1}^{m} \alpha_j x_{i-j} + \sum_{j=1}^{q} \beta_j \psi_{i-j} \quad (1)
\]

where \( \omega, \alpha, \beta \geq 0 \) since \( \psi_i \geq 0 \) and for stationarity \( |\alpha + \beta| < 1 \).

However, Engle and Dufour (2000) argue that the standard ACD specification in equation (1) has several disadvantages. For instance, the imposition of a linear parameterization structure for the conditional duration \( \psi_i \) combined with the non-negative attribute of durations in general, necessitates positivity constraints when estimating the model coefficients \((\omega, \alpha, \beta)\). Without this constraint it would be possible for the model to predict negative durations. This problem is further amplified if additional explanatory variables which are negatively related to the duration process are included in the ACD structure.

An attempt to circumvent this problem is proposed by Bauwens and Giot (2000) in their Log-ACD model. Estimating the log of the conditional duration \((\log \psi_i)\) instead of the conditional duration \((\psi_i)\), eliminates the need to place positivity restrictions on the coefficients. In addition, by estimating the log of the conditional duration the autocorrelation will exhibit a more appropriate hyperbolic decay and as such will be able to capture a greater degree of persistence in the duration series. Bauwens and Giot (2000) propose the following structure for the parameterization of the Log-ACD model, which they referred to as the Log2ACD model.

\[ \text{Log2ACD}(m,q): \quad \phi_i = \omega + \sum_{j=1}^{m} \alpha_j x_{i-j} + \sum_{j=1}^{q} \beta_j \psi_{i-j} \quad (1)
\]

where \( \phi_i = \psi_i \).

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5 If \( F_0(T) \) is the cumulative probability distribution corresponding to the probability density \( P_0(t) \), then the survival function \( S_0(t) = 1 - F_0(t) \).

6 See Engle and Russell (1998) for a complete outline and explanation of these arguments and their proofs.

7 Bauwens and Giot (2000) also propose an alternative parameterization Log1-ACD which is not considered here.
$\log_2 ACD(m,q): \quad \psi_i = \exp\left(\omega + \sum_{j=1}^{m} \alpha_j e_{i-j} + \sum_{j=1}^{q} \beta_j \ln \psi_{i-j}\right) \quad (2)
$

where $|\beta|<1$

3.2 Error Distribution

Another important point in the estimation process is that $\epsilon_i \sim iid$ with probability density function $f(\epsilon, \phi)$, where $\phi$ is a coefficient vector which determines the shape of the distribution. However, due to the non-negative nature of duration data series in general, $f(\epsilon, \phi)$ should have a non-negative support which restricts the distributions that can be considered. In the basic model, Engle and Russell (1998) propose the use of the exponential distribution for the density function. Essentially, assuming exponentially distributed error terms imposes a flat hazard curve on the conditional duration structure which is tested and rejected in the empirical analysis of Engle and Russell (1998). They argue that greater flexibility is needed in the hazard function and estimate the standard ACD model assuming a Weibull distribution resulting in the Weibull ACD (WACD) model.

To incorporate a more flexible hazard function in the ACD structure, different distributions have been proposed. For instance, Dufour and Engle (2000) implement the Generalised Gamma distribution, Grammig and Maurer (2000) proposes the use of the Burr distributed error structure and Hautsch (2002) employs the Generalised F distribution for the ACD specifications. The Exponential and Weibull distributions are special cases of the Burr, Generalised Gamma and Generalised F distributions. However, due to the complexity of these distributions, not all moments may exist without placing restrictions on the distribution parameters during the estimation process, complicating the estimation process of the models under consideration.

Consequently, due to the number of parameters to be estimated in this analysis, we will assume a Weibull distributed error structure (equation (3)) so as to minimise the number of estimated parameters and the complexity of the estimation process. Additionally, by incorporating additional explanatory variables into the conditional expectation equation, we expect that a greater amount of the persistence will be captured by the model, which makes utilising a more flexible distribution unnecessary.
f(x_i | x_{i-1},...,x_i;\theta) \equiv \frac{\gamma}{x_i} \left[ x_i \Gamma(1+1/\gamma) \right]^{\gamma} \exp \left( - \left[ \frac{x_i \Gamma(1+1/\gamma)}{\psi_i} \right]^{\gamma} \right) \tag{3}

where \( \gamma \) is a non-negative parameters related to the slope of the distribution and \( \Gamma(\cdot) \) is the gamma function.

3.3 \textit{Estimation and Inference}

Since \( x_i \) represents the pooled process of the bid and ask order durations, let \( t_i^a \) and \( t_i^b \) be the clock time associated with the submission time of an ask order and a bid order respectively. Therefore, the duration of a specific order to the next order of the same type is \( x_i^k = t_i^k - t_{i-1}^k \), where \( k = a, b \). Thus, the conditional expectation of the duration of type \( k \) is defined as \( \psi_i^k \), such that \( \epsilon_i^k = x_i^k / \psi_i^k \) and \( E(\epsilon_i^k) = 1 \). For simplicity, we incorporate only one lag of the error and conditional expectation in the model, which is refer to as the LogACD(1,1). Additionally, given we wish to explain the fundamental drivers of the order submission processes, additional factors enter into the conditional expectation equation. Let \( Z_{i-1}^k \) be a vector of explanatory variables that are now at time \( t_{i-1} \) with corresponding parameter vector \( \eta^k \):

\[
\psi_i^k = \exp(\omega^k + \alpha^k \epsilon_{i-1}^k + \beta^k \ln \psi_{i-1}^k + Z_{i-1}^k \eta^k) \tag{4}
\]

The augmented LogACD(1,1) model is estimated using maximum likelihood implementing the BHHH algorithm. The log-likelihood function is:

\[
L = \sum_i \ln(\gamma) - \ln(x_i^k) + \gamma \ln[x_i^k \Gamma(1+1/\gamma)] - \gamma \psi_i - \left( \frac{x_i^k \Gamma(1+1/\gamma)}{\psi_i} \right) \tag{5}
\]

4. Data and Explanatory Variables

The data used in this analysis is extracted from the Maltese Stock Exchange historical data base over the period January 2000 to June 2006. The Maltese Stock Exchange is an electronic continuous limit order market with active execution of trades beginning at 10:00 am and ends at 12:30 pm. Prior to the initiation of trading, the preopening period begins at 8:30 am and
ends at 10:00 am when the clearing algorithm that determines the equilibrium prices is executed. The sample studied in this analysis comprises the three most active stocks during the market preopening period. These are HSBC Bank Malta plc (HSB), Bank of Valletta plc (BOV) and the Malta International Airport plc (MIA). Table 1 provides summary statistics.

The total number of events occurring in the samples is 24,189 for BOV, 24175 for MIA and 19,770 for HSB. The events comprise the submission, revision and cancelation of limit orders, which accounts for approximately 57%, 12% and 31% of the total in the case of BOV. For MIA, approximately 50%, 13% and 35% of the total events represents limit order submissions, cancellation and revision of orders respectively. The proportions for HSB are 61% for limit order submissions, 9% for cancelled orders and 30% of the events represents order revisions. Other events that occur in the data are omitted since they constitute a very small percentage of the total events and lack any economic interpretation.

From the summary statistics in Table 1, it is evident that there is a high degree of persistence in both the bid and ask duration series for all three stocks since the Ljung-Box statistic is highly significant even at 30 lags. The HSB bid duration series seems to be the most persistent and the ask durations of HSB appear to be the least persistent based on the Ljung-Box statistic. In fact, the bid duration series tend to be significantly more persistent than the ask duration series for all stocks, which is indicative of a buyer’s market or the effect of short sale constraints.

To test the hypotheses discussed in section 2, we construct explanatory variables by recreating the limit order book at each point in time for the entire sample. Table 2 provides an outline of the variables, their definitions and corresponding coefficients. We argue in section 2.2 that the difference between the price associated with an incoming bid order and the best bid positively (negatively) impacts the intensity of the bid (ask) processes. Similarly, we argue that the difference between the price of the best ask order and the price associated with an incoming ask will impact the intensity of bid and ask order submissions negatively and positively respectively. To capture these impacts, the variables $lbb_i$ and $lba_i$, are incorporated, to measure the difference between the log price of best bid and the log

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8 As of 23 October 2006, the preopening period changed to 9:30 am to 10:45 am with the continuous open from 10:45am to 12:30pm. This has been accounted for in our estimation.

9 For hypothesis $a$ and $b$, which speaks to the presence of clustering during the market preopening period, are tested by examining the coefficient $(\beta^a)$ associated with the lagged conditional expected duration.
price of the incoming bid order and the difference between the log price of an incoming ask order and the log price of the best ask in period \( i \) respectively.\(^{10}\)

In section 2.3, the discussions highlight the impact of a locked or crossed inside spread on the intensity of the bid (ask) order process. To test this hypothesis, we construct two variables. First, to determine the impact of an incoming bid order that lock or crosses inside spread, we define the dummy variable \( bgba_i \), which takes the value of one when the price of an incoming bid is greater than or equal to the best ask price. Second, to measure the impact of an incoming ask order that locks or crosses the inside spread, we define the variable \( albb_i \), which assigned a value of one when the price of an incoming ask order is less than or equal to the best bid price.

Hypothesis \( k \) in section 2.4 proposes that the intensity of the bid order submissions increases with the volume associated with an incoming bid order. However, hypothesis \( l \) proposes the opposite impact on the ask submission, as the volume associated with an incoming bid order negatively impacts the intensity ask order submissions. In addition, hypothesis \( m \) and \( l \) proposes that the volume associated with an incoming ask order positively impacts the intensity of the ask order submissions and negative impacts the intensity of the bid order submissions. To test these hypotheses, the log volume of the incoming bid order \( (lbv_i) \) and the log volume of the incoming ask order \( (lav_i) \) are incorporated into the model.

To measure the impact of cancelations of orders and their associated volume on the order submission processes as proposed in hypotheses \( o \) and \( p \) in section 2.5, we define several variables. First, the dummy variables \( dcby_i \) and \( dca_i \) are constructed, which assign a value of one if a bid or an ask order is cancelled respectively. Further, to examine the impact of the best bid/ask being cancelled, we define \( dcbb_i \) and \( dcba_i \) as dummy variables that indicate when the cancelled order is the best bid or the best ask respectively. In addition, the impact of volume associated with the cancelled order is measure using the variables \( lcby_i \) and \( lcay_i \), which are the log volumes associated with the cancelled bid and ask order respectively.

In hypotheses \( q \) and \( r \), we propose that revision of a bid (ask) order closer to the best bid (ask) positively impacts the intensity of the bid (ask) order submission and negatively impacts the

\(^{10}\)The order of the variables are reversed in this case since we want to examine the effect of the price associated with an order getting close to the best bid/ask. In other words the value of these variables should be closer to zero the closer the order is to the best bid/ask in the limit order book.
intensity ask (bid) order submissions. This impact is measured by incorporating into the model, the log ratio of the revised price to the previous price for a revised bid order and the log ratio of the previous price to the revised price for a revised ask order, which are denoted as \( lrb_i \) and \( lra_i \) respectively. In essence, if the revised bid order is closer to the best bid then the log ratio is large since the revised price will be larger. This argument also holds true in the case of a revised ask quote, however, the order of the variables are reversed. \(^{11}\) To measure the impact of revised best bid/ask, the variables \( lrb_i \) and \( lra_i \) are interacted with dummies indicating when the best bid is revised and when the best ask is revised respectively. In addition, we measure the impact of the volume associated with a revised bid or ask order by incorporating the variables \( rbv_i \) and \( rav_i \), which are the log volume associated with the revised bid and ask orders respectively.

The final set of variables being considered in this analysis is intended to measure the impact of the bid-ask spread and the mid quote volatility on the intensity of the order processes, which are discussed in hypotheses \( s \) and \( t \). If we denote \( \log \text{bb}_i \) and \( \log \text{ba}_i \) as the log best bid and log best ask price in period \( i \), then the spread is \( \text{spr}_i = \log \text{bb}_i - \log \text{ba}_i \), which is the difference between the log best ask and the log best bid prices. Additionally, the mid-quote volatility \( (mqv_i) \) is measure by the change in the mid quote from period \( i-1 \) to period \( i \), such that \( mqv_i = mq_i - mq_{i-1} \), where \( mq_i = ba_i + bb_i / 2 \), \( mq_i \) is the mid quote during period \( i \) and \( ba_i \) and \( bb_i \) are the best bid and ask prices respectively.

5. Empirical Results

The results were generated by estimating two separate models for each of the three stocks, one for the duration series of the bid submission process and the other for the durations of the ask submission process. All the regressors are assumed to be weakly exogenous to the conditional expected duration and enter the model in lagged one period. Table 3 reports the estimates of the parameters and the model diagnostics. Since our arguments are in terms of intensity as opposed to durations, we will also discuss the results of the model in terms of intensities, which is the reciprocal of the conditional expected duration.

\(^{11}\) The best ask will be the minimum price at which an agent is willing to sell the asset. As a result, any revision of an ask towards the best ask will be a decrease in the price. Thus, the log ratio of the previous ask price to the revised price will be positive.
5.1 *The presence of clustering in the bid and ask order submissions.*

In hypotheses \( a \) and \( b \) we argued that by breaking the pooled order submission process into its bid and ask components and modelling each duration series separately, the resulting processes will remain highly persistent due to the presence of informed trading. In addition, we posit that both processes would display similar levels of persistence. Based on our findings, we can confirm hypothesis \( a \) as the persistence which infers clustering, measured by the coefficient of the autoregressive conditional duration variable, ranges between 0.875 to 0.986 for the bid submission series and 0.891 to 0.977 for the ask submission series. Thus, there is a tendency for periods of high intensity to be followed by periods of high intensity and periods of low intensity to be followed by periods of low intensity during the preopening period. With regards to hypothesis \( b \), we find that by comparing the level of the autoregressive coefficient for each stock, the bid series tends to displays a higher degree of persistence in duration series for two of three stocks examined. Therefore, we cannot confirm hypothesis \( b \) based on the findings in our results.

5.2 *The impact of limit order prices.*

We contend in section 2.2 that the price associated with an incoming limit order contains significant information that impacts the intensity of the order submission processes. The results confirms hypothesis \( c \), which states that the intensity of bid order submissions is impacted positively when the price of an incoming bid order is closer to the prevailing best bid price. However, we only find weak evidence that the price of an incoming bid relative to the best bid price impacts the intensity of ask order submissions negatively as proposed in hypothesis \( d \). Specifically, the coefficient associated with the variable \( lbb_i \) is negative and significant on the bid side for two stocks and positive and significant for one stock on the ask side. Additionally, the results reveal weak evidence that the difference between the price of an incoming ask order and the best ask price, measured by the variable \( lba_i \), impacts the intensity of ask submissions negatively, which is contrary to our predictions in hypothesis \( e \). Conversely, the estimated coefficient for the variable \( lba_i \) displays a negatively impacts on the intensity of bid order submissions and supports hypothesis \( f \).
Overall, the results reveals that traders that place the price of an incoming bid order high relative to the best bid sends a positive signal to the market by revealing that they are aggressively trying to increase the probability that their orders are executed at the opening of the market. In effect, this positive signal increases the intensity of bid order submission. However, traders on the sell side are not induced by this increase bid order submissions as no additional liquidity is provided by posting additional sell orders. Accordingly, when a trader submits a sell order with a price that is larger relative to the best ask, this is viewed by the market as a negative signal about the fundamental value of the asset. As a consequence, traders on the buy side refrain from submitting additional buy orders. However, when traders on the sell side view this information, they tend not perpetuate additional negative signal into the market (which would further reduce the intensity of buy orders) as they do not act on this realisation. Essentially, this finding provides some evidence that activity during the preopening period is not characteristic of information based trading as in the cases of Vives (1995) and Medrano and Vives (2001).

5.3 The impact of locked or crossed inside spread.

We find strong evidence supporting hypotheses $g$ and $h$, which predicts that when the price of an incoming bid order is set at or below the best ask price that locks or crosses the inside spread, there is a positive impact on the intensity bid order submissions and a negative impacts on the intensity of ask order submissions. The results show that the coefficient associated with the variable $bgba_i$ has a positive and significant coefficient for all three stocks on the bid side and a positive and significant coefficient for two of three stock on the ask side of the market. In addition, the results also confirms hypotheses $i$ and $j$, that proposed that an incoming ask order that results in a locking or crossing of the inside spread, measured by $albb_i$, impacts the intensity of the bid order submissions negatively and positively impacts the intensity of ask order submissions.

In essence, whenever a trader sets the price of an incoming bid order below the price of the prevailing best ask, this sends a strong positive signal to the market that the trader is aggressively trying to increase the probability that their order is executed at the opening and increases the probability that the trader is informed. As a result, the positive signal induces buy side traders to submit additional bid order. However, traders on the sell side of the market observe this positive signal and reduce the intensity of their sell order submissions. If
the inside spread is locked or crossed by an incoming ask order, then this sends a strong negative signal about the fundamental value of the asset. Consequently, the intensity of bid order submissions by traders reduces and the intensity of sell order increases. Overall, a locking or crossing of the inside spread indicative of information based trading and is strongly acted upon by the traders in the market. These results are consistent with the finding of Cao, Ghysels and Hatheway (2000), that contends a locked or crossed inside spread is consistent with information being revealed about the fundamental value of the asset and under the assumption of learning other traders will act on this information.

5.4 The impact of limit order volume.

The results reveal that high volume associated with incoming bid orders has a negative impact on both the intensity of bid and ask order submissions. Essentially, this finding confirms hypothesis \( l \) and is contrary to the prediction of hypothesis \( k \). Specifically, the coefficient associated with the variable \( lbv_i \) is positive and significant on the bid side for all three stocks and positive and significant for two stocks on the ask side. We find similar conflicting results with regards to hypothesis \( m \), where the coefficient associated with the variable \( lav_i \) is negative and significant for all three stocks being investigated. However, we find no evidence to support hypothesis \( n \), which states that the volume of an incoming ask order will positive impact the intensity of ask order submissions. This implies that high volumes that are associated with an incoming ask order increases the intensity of bid order submissions but does not generally affect the intensity of ask order submissions.

In summary, the findings indicates that bid volume does not convey significant information about the fundamental value of the asset since high buy volume is normally submitted in a period of low order submission intensity on both sides of the market. Conversely, whenever large sell volume is submitted to the market, this does not induce sell side traders to submit additional ask orders. However, it increases the intensity of bid order submissions which suggest that traders that are interested in buy the stock take advantage of the sell side liquidity whenever it becomes available. Essentially, this implies that volume during the preopening period is not motivated by information based trading and does not provide any form of signalling about the fundamental value of the asset, as argue in Vives (1995), Medrano and Vives (2001) and Brusco, Manzano and Tapia (2003).
5.5 The impact of order cancellations.

In hypothesis $o$ we argued that the cancellation of previous orders are information driven and indicates that learning is taking place. The evidence suggests that a cancelled order whether bid or ask, have a negative impact on the intensity of both the bid and ask order submissions. This is evident as the coefficients associated with the variables $dcb_i$ and $dca_i$, which indicates a cancelled bid or ask respectively, is positive and significant for the three stocks studied. In essence, when a bid or ask order is cancelled this sends a negative signal to the market and as such reduces the intensity on both (bid or ask) side. Therefore, this confirms a part of hypothesis $o$, which predicts that the intensity of the bid order process will be impacted negatively by the cancellation of a bid order and is contrary to the prediction of a negative impact on the intensity of ask order submissions. In addition, the negative relationship between the cancellation of an ask order and the intensity of both the bid and ask submissions, confirms a part of hypothesis $p$ and is contrary to the latter claim that is made.

Interestingly, we find that the cancellation of the best bid order negatively and significantly impacts the intensity of ask order submissions for two of the three stocks estimated. Therefore, the impact of a cancelled bid order on the intensity of ask order submissions is further enhanced when the cancelled order is the best bid. However, the impact on the intensity of bid order submissions when the best bid is cancelled does not have a consistent impact, as the sign of the coefficient is negative for one stock and positive or insignificant for the others. The result displays a similar image for the coefficients associated with the impact of a cancelled best ask order; the difference is that there is no impact on the intensity of ask order submissions. In essence, the evidence provides no support for hypotheses $o$ and $p$.

The results indicate that the volume associated with a cancelled bid order has no consistent impact on either the intensity of the bid or ask order submission, which is inconsistent with the prediction in hypothesis $o$. In addition, the intensity of bid order submissions decreases in the volume associated with a cancelled ask order, which mean that buy side traders reduce their buy orders is sell side traders are reducing the supply of liquidity. However, the evidence reveals that cancelled ask volume does not significantly impact the intensity of sell order submissions, contrary to our predications in hypothesis $p$. 
In summary we find mixed support for the predictions in hypotheses $o$ and $p$. Essentially, we find that when traders cancel orders, there is a general reduction in the intensity of order submissions on both sides of the market. One explanation is, when traders realise that the prospect of their orders being executed at the opening is low they tend to cancel these orders. Consequently, when there is a reduction in the supply of liquidity, traders on the buy side reduces the intensity of buy order submissions. Similarly, when there is a reduction in the demand for liquidity by the cancellation of bid orders, traders on the sell side will reduce the intensity of sell order submissions. Therefore, cancellation of orders are liquidity motivated as opposed to information driven, since cancellations of orders on one side of the market is not induced by information being observed on the other side of the market as proposed in our hypotheses.

5.6 The impact of limit order revisions

Hypotheses $q$ and $r$ proposes that the revisions of bid (ask) prices closer to the best bid (ask) price will have a positive impact on the intensity on the intensity of the bid (ask) order submissions and negatively impact the intensity of the ask (bid) order submissions. We find no substantial evidence that revision of bid or ask orders have any consistent and/or significant impact on the intensity of buy or sell order submissions. The estimated coefficients of the variables $\text{lr}_{b}, \text{lr}_{a}, \text{dlrb}$ and $\text{dlra}$, which measures the impact of revised bid prices, revised ask prices, revised best bid prices and revised best ask prices respectively, are insignificant on the ask side in most cases. In addition, we do not find consistent evidence of the impact of order revision on the bid side of the market.

The volume associated with a revised bid order, which is measure by $\text{rbv}_{b}$, is hypothesised to have a positively impacts on the intensity of bid order submissions and negatively impacts the intensity of sell order submissions. Additionally, the volume of a revised ask order ($\text{rav}_{a}$) is predicted to negatively impact the intensity of bid order submissions and positively impact ask order submissions. We find no evidence in support of either claim. From our estimation, the size of the volume associated with a bid that is revised closer to the best bid has no impact on either the intensity of the bid or ask order submissions. The same result is observed for the impact of revised ask volume on the intensity of ask order submissions. However, we find that the volume associated with a sell order that is revised closer to the best ask,
positively impacts the intensity of bid order submissions for two of the three stocks in our study.

Overall, we can confirm that revision of previous order prices closer to the best bid or ask does not significantly impact the decision by traders to submit sell orders. However, if the volume associated with a revised ask limit order is high, then this will induce traders to place additional buy orders as the sell side traders are providing liquidity at a better price. This finding is also consistent with the effects of incoming ask volume on the intensity of bid submissions. Therefore, as with the case of order cancellations, the revision of orders closer to the best bid/ask does not seem to be driven by information.

5.7 The impact of mid-quote volatility and inside spread

The arguments made in hypotheses $s$ and $t$ predicts that intensity of both bid and ask order submissions will be negatively impacted by a large inside spread and high mid-quote volatility. The results show an inconsistent impact of the spread and mid-quote volatility on the impact of both types of order submissions relative to the hypotheses proposed. We find that parameter associated with the variable $mqv_i$, which measure the mid-quote volatility, is positive and significant for one of three stocks and negative and significant for another on the bid side. However, we find that there is an increase in the intensity of ask order submissions when the mid-quote volatility is high. In addition, we find that a high spread reduces the intensity of bid order submissions in general, as predicted in hypothesis $t$. However, there is not significant evidence to suggest that the intensity of ask order submissions is impacted.

Essentially, we find that the mid-quote volatility does not significantly impact the decision of traders to submit buy orders. However, sell side traders are induced to provide additional liquidity when the mid-quote volatility is high and does not pay particular attention to the level of the spread. The decision by buy side traders to submit orders is impacted by the spread as a higher spread mean worst terms of trade that they are faced with.

5.8 Model Diagnostics

The shape parameter associated with the Weibull distribution is significant across all the models estimated and is not significantly different from one, which suggests that the durations are distributed exponentially. The mean of the of the estimated errors $\hat{e}_i$, is not
statistically different from one on the bid side. Additionally, the mean of the estimated errors on the ask side tend to be slightly less than one but not statistically significantly less for the three stocks estimated. The standard deviation of the estimated errors on both side of the market is greater than one in all cases which suggest that there might be excess dispersion remaining in the error structure. However, the Ljung-Box statistic at four and sixteen lags for the estimated error and error squared, does not show any significant autocorrelation in the error structure except for one equation. Thus, we can conclude that the models have captured all most of the dispersion in the duration series in general.

5.9 Remarks

It is evident from the results that the bid side of the market reacts more to the information inferred from incoming limit orders and changes to the limit order book during the market preopening period. Ask submissions are less reactive to changes in the limit order book and are less persistent than the bid order submission processes. Additionally, it is evident that the activity of traders during preopening period within the Maltese stock exchange, is not driven by information in general. Our findings suggest that traders act mostly off the provision and demand for liquidity when making their decision to submit and order to buy or sell a stock during the preopening period.

6. Conclusion

This paper examines the duration of bid and ask order submissions during the market preopening period to determine whether traders utilise information inferred from the limit order book to submit orders to buy or sell a stock. We estimate the Log-ACD model of Bauwens and Giot (2001) with data from the Maltese stock exchange covering the period January 2000 to June 2006. In addition, several variables are incorporated into the model to capture information regarding changes to the limit order book and the effects of incoming orders. Specifically, we test for evidence of clustering in the bid and ask duration series, the impact of limit order prices and volume, the impact of mid-quote volatility and inside spread and the impact of cancellation or revisions of previously submitted limit orders on the intensity of order submissions.
The empirical results reveal that the bid and ask duration series are highly persistent indicating the presence of clustering. We find that the bid order process tends to be more persistent than the sell order process for each specific stock. Additionally, the intensity of buy order submissions tends to respond more to the state of the market and the effects of incoming orders in comparison to sell order submissions. Essentially, the intensity of buy order submissions is positively impacted the higher the price of an incoming bid order relative to the best bid, the higher the volume associated with an incoming or revised sell order and whenever the inside spread is crossed or locked by an incoming bid order. Some of the factors that reduce the intensity of buy order submissions include large inside spreads, cancellation of bid or ask orders and if the inside spread is crossed or locked by an incoming sell order.

Furthermore, we find evidence for a positive impact on the intensity of sell order submissions when the mid-quote volatility is high and when the inside spread is locked or crossed by an incoming ask order. Additionally, the intensity of sell order submissions is reduced when the inside spread is locked or crossed by an incoming bid order, the cancellation of bid or ask orders and the volume associated with an incoming bid order.
References


Table 1. *Summary statistics for limit order submission, revisions and cancellations.*

<table>
<thead>
<tr>
<th></th>
<th>BOV</th>
<th>MIA</th>
<th>HSB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Number of Events</strong></td>
<td>24189</td>
<td>24175</td>
<td>19770</td>
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<tr>
<td><strong>Limit Order Arrivals</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><em>Total orders submitted</em></td>
<td>13835</td>
<td>12191</td>
<td>12043</td>
</tr>
<tr>
<td><em>Number of bid</em></td>
<td>7005</td>
<td>7120</td>
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</tr>
<tr>
<td><em>Number of ask</em></td>
<td>6830</td>
<td>5071</td>
<td>4590</td>
</tr>
<tr>
<td><strong>Cancelled Limit Orders</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Total orders cancelled</em></td>
<td>2833</td>
<td>3335</td>
<td>1790</td>
</tr>
<tr>
<td><em>Number of cancelled bid</em></td>
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<td>1782</td>
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</tr>
<tr>
<td><em>Number of cancelled ask</em></td>
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<td>879</td>
</tr>
<tr>
<td><strong>Revised Limit Orders</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Number of revised orders</em></td>
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<td>5937</td>
</tr>
<tr>
<td><em>Number of revised bid</em></td>
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<tr>
<td><em>Number of revised ask</em></td>
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<td>2740</td>
</tr>
<tr>
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<tr>
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<td>2500</td>
<td>2994</td>
</tr>
<tr>
<td>LB(30) Statistic</td>
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<td>11095.4</td>
<td>12769.6</td>
</tr>
<tr>
<td><strong>Time between bid limit order arrival</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>258.84</td>
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<td>190.80</td>
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<td>Standard Deviation</td>
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<td>2500</td>
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<td>LB(30) Statistic</td>
<td>1128.4</td>
<td>2089.2</td>
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</table>
Table 2. Summary of explanatory variables used in the empirical analysis.

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Variable</th>
<th>Description of Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\zeta_1$</td>
<td>$mqv_i$</td>
<td>The mid-quote volatility captured by the change in the mid-quote.</td>
</tr>
<tr>
<td>$\zeta_2$</td>
<td>$spr_i$</td>
<td>The difference between the log prices of the best ask and the best bid.</td>
</tr>
<tr>
<td>$\tau_1$</td>
<td>$lbb_i$</td>
<td>The log price of the best bid minus the log price of an incoming bid order.</td>
</tr>
<tr>
<td>$\tau_2$</td>
<td>$lba_i$</td>
<td>The log price of an incoming ask order minus the log price of the best ask.</td>
</tr>
<tr>
<td>$\tau_3$</td>
<td>$lbv_i$</td>
<td>Log volume associated with an incoming bid order.</td>
</tr>
<tr>
<td>$\tau_4$</td>
<td>$lav_i$</td>
<td>Log volume associated with an incoming ask order.</td>
</tr>
<tr>
<td>$\varphi_1$</td>
<td>$bgba_i$</td>
<td>Dummy variable that indicates when the incoming bid price is greater than or equal to the best ask price.</td>
</tr>
<tr>
<td>$\varphi_2$</td>
<td>$albb_i$</td>
<td>Dummy variable that indicates when the incoming ask price is less than or equal to the best ask price.</td>
</tr>
<tr>
<td>$\delta_1$</td>
<td>$dcb_i$</td>
<td>Dummy variable indicating a cancelled bid order.</td>
</tr>
<tr>
<td>$\delta_2$</td>
<td>$dca_i$</td>
<td>Dummy variable indicating a cancelled ask order.</td>
</tr>
<tr>
<td>$\delta_3$</td>
<td>$dcbb_i$</td>
<td>Dummy variable indicating when the best bid order is cancelled.</td>
</tr>
<tr>
<td>$\delta_4$</td>
<td>$dcba_i$</td>
<td>Dummy variable indicating when the best ask order is cancelled.</td>
</tr>
<tr>
<td>$\delta_5$</td>
<td>$lcbb_i$</td>
<td>Log volume associated with a cancelled bid order.</td>
</tr>
<tr>
<td>$\delta_6$</td>
<td>$lca_i$</td>
<td>Log volume associated with a cancelled ask order.</td>
</tr>
<tr>
<td>$\phi_1$</td>
<td>$lrb_i$</td>
<td>Log ratio of the revised bid price to the previous bid price.</td>
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<tr>
<td>$\phi_2$</td>
<td>$lra_i$</td>
<td>Log ratio of the previous ask price to the revised ask price.</td>
</tr>
<tr>
<td>$\phi_3$</td>
<td>$dlrb_i$</td>
<td>Dummy variable indicating a revised best bid order interacted with the log ratio of the revised bid price to the previous bid price.</td>
</tr>
<tr>
<td>$\phi_4$</td>
<td>$drla_i$</td>
<td>Dummy variable indicating a revised best ask order interacted with the log ratio of the previous ask price to the revised ask price.</td>
</tr>
<tr>
<td>$\phi_5$</td>
<td>$rbv_i$</td>
<td>Log volume associated with a revised bid order.</td>
</tr>
<tr>
<td>$\phi_6$</td>
<td>$rav_i$</td>
<td>Log volume associated with a revised ask order.</td>
</tr>
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</table>

The variables were calculated by reconstructing the preopening limit order book at every event for the entire sample under study.
<table>
<thead>
<tr>
<th></th>
<th>Bid Side Parameters</th>
<th></th>
<th>Ask Side Parameters</th>
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<td>t-Stat</td>
<td>Coeff</td>
<td>t-Stat</td>
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<td>$\omega$</td>
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<td>2.457</td>
<td>0.004</td>
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<td>27.401</td>
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<tr>
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<tr>
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<tr>
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<td>0.000</td>
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</tr>
<tr>
<td>$\phi_1$</td>
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<td>$\phi_2$</td>
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<td>0.662</td>
<td>-0.001</td>
<td>-2.852</td>
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<tr>
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<td>-0.001</td>
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<tr>
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<td>-6.376</td>
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</table>

Coefficients in bold are significant at the 5% level of significance.
Table 4. *Weibull Parameter and Diagnostic Statistics*

<table>
<thead>
<tr>
<th></th>
<th>Bid Side</th>
<th></th>
<th></th>
<th>Ask Side</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BOV</td>
<td>MIA</td>
<td>HSB</td>
<td>BOV</td>
<td>MIA</td>
<td>HSB</td>
</tr>
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<td>1.01</td>
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<td>0.94</td>
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<tr>
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<td>1.80</td>
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<td>1.25</td>
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<tr>
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<td>6.75</td>
<td><strong>31.85</strong></td>
<td>3.80</td>
<td>8.03</td>
<td>2.68</td>
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<td>LB(16) of $\tilde{\epsilon}_i$</td>
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<td>13.29</td>
<td><strong>57.63</strong></td>
<td>13.77</td>
<td>17.37</td>
<td>8.83</td>
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<td>9.93</td>
<td>3.21</td>
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<td>19.84</td>
<td>18.54</td>
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</table>

Coefficients in bold are significant at the 5% level of significance.