Opening and Closing the Market:
Evidence from the London Stock Exchange

Andrew Ellul
Indiana University
anellul@indiana.edu

Hyun Song Shin
London School of Economics
h.s.shin@lse.ac.uk

Ian Tonks
University of Bristol
i.tonks@bristol.ac.uk

Abstract

Various markets, particularly NASDAQ, have been under pressure from regulators and market participants to introduce call auctions for their opening and closing periods. We investigate the performance of call markets at the open and close from a unique natural experiment provided by the institutional structure of the London Stock Exchange. As well as a call auction, there is a parallel "off-exchange" dealership system at both the market's open and close. Although the call market dominates the dealership system in terms of price discovery, we find that the call suffers from a high failure rate to open and close trading, especially on days characterized by difficult trading conditions. In particular, the call's trading costs increase significantly when (a) asymmetric information is high, (b) trading is expected to be slow, (c) order flow is unbalanced, and (d) uncertainty is high. Furthermore, traders' resort to call auctions is negatively correlated with firm size, implying that the call auction is not the optimal method for opening and closing trading of medium and small sized stocks. We suggest that these results can be explained by thick market externalities.

1 Introduction

The open and close of markets have enormous significance for traders and regulators. The open assimilates information gathered overnight, and performs important information aggregation and price discovery functions while the closing price serves as a benchmark for an array of interested parties, particularly at critical calendar dates. Much of the received thinking emphasizes the virtues of a call auction in opening and closing markets to produce efficient prices. Most European markets have call auctions both at the open and close (Paris, Frankfurt, London) while the New York Stock Exchange has a stabilized auction market at the open. Recently there has been pressure on NASDAQ, from the SEC and market participants, to adopt a call mechanism (Ewing, 2000). NASDAQ set up a special committee to consider the issues, and has decided that a pure call auction was not the best mechanism. Instead it has introduced the NASDAQ Official Closing Price (NOCP) in 2003 and a similar NASDAQ Official Opening Price (NOOP) in April 2004, both of which incorporate a limited call auction element into the dealer quotes system.

The literature studying opening mechanisms has focused exclusively on the price discovery issue of *single mechanisms operating alone.* Biais, Hillion and Spatt (1999) and Cao, Ghysels and Hatheway (2000) analyze the pre-opening on the Paris Bourse (opens through an automated call) and NASDAQ (which before opened exclusively through market makers' quotes) respectively, and find that price discovery occurs as participants learn from indicative prices. Madhavan and Panchapagesan (2000) show that specialists using a stabilized auction mechanism at the open on the NYSE, set more efficient prices than would an auction with public orders and in this way facilitates price discovery. Bacidore and Lipson (2001) use stocks that moved from NASDAQ to NYSE to investigate the effects of opening and closing procedures used by the NYSE and NASDAQ. They find that the specialist-managed opening auction on the NYSE reduces trading costs, but only limited evidence that the closing call produces benefits. Pagano and Schwartz (2003) show that the introduction of a closing call on the Paris Bourse has improved market quality resulting in lower transaction costs for traders and

1

better price discovery.

This paper differs from the existing literature in that it analyzes the performance along different trading dimensions of two different trading systems - the call mechanism versus the dealership mechanism - competing together for order flow during market open and close. We address the following questions: What factors determine the desirability of call auctions and dealership markets at such important trading periods? How sensitive are call auctions to trading conditions and the presence of informed traders? Under which conditions does such a mechanism promote the most efficient price discovery process? Our investigation is made possible by the unique natural experiment afforded by the institutional structure of the London Stock Exchange (LSE) where the main order-driven trading mechanism (SETS) operates alongside a parallel "off-exchange" dealer system. The opening and closing trades on SETS are determined by a call auction[1], while the dealer system relies on market makers' quotes. In such a set-up traders have a choice where to trade at the open and close.

The competitive structure on the LSE is similar to that on NASDAQ after the introduction of the NOCP and NOOP, since on both exchanges stocks can open and close through different trading systems. The choice offered to LSE traders on where to execute their orders, provides a natural experiment on the relative advantages of these two systems. Furthermore, in contrast to NYSE specialists, London dealers' participation is entirely voluntary since they do not have any price continuity obligations and no obligations to quote prices at all. Most importantly, we can document how the costs and benefits of the two systems depend on the overall trading environment, and thereby determine the desirability of call auctions over dealership markets.

The caution expressed by NASDAQ is at odds with the literature that emphasizes the importance of asymmetry of information among traders. For example, in comparing dealership and auction markets, Madhavan (1992) shows that a periodic call auction and order driven systems in general are more robust to the problems of asymmetric information. Economides and Schwartz (1995) propose

---

[1]The opening call has been in place since October 1997, while the closing call was introduced in May 2000.

2

the call auction at the open as the ideal solution to the problem of assimilating diverse information from traders to achieve informational efficiency of prices, and thereby minimize adverse selection problems where some traders have superior information to others. Domowitz and Madhavan (2001) go so far as to state that *"The benefits of an opening auction are, in theory, most valuable for thinly traded assets where public information is poor and hence adverse selection is a serious problem"* [p. 18].

On the other hand, there is evidence that a call mechanism may suffer because liquidity is often latent, especially at crucial times such as open and close. For example, Angel and Wu (2001) examine a simulated call auction on NASDAQ and conclude that *"A centralized call may perform worse than the existing opening [on NASDAQ] for several reasons. First, real order flow suffers from "air pockets" that leads to order imbalances...Second, the transparency of a mechanical call may deter many investors who do not want their trading interest widely displayed. Third, much liquidity provision is conditional and not easily captured by the current generation of centralized call facilities."* [p.3]

If all the liquidity in the market came to the call auction, then the price will be close to the efficient market price. However the call auction could be attracting only the tip of the liquidity iceberg, and the rules of a call can make this worse - everybody wants everybody else to reveal their orders without revealing anything themselves. This argument is closely related to the ideas behind the coordination motives for trade. The idea is that a trader's decision to submit an order depends on the likelihood that her order will be executed, but this in turn depends on how many other traders on the other side of the market have decided to submit orders. Buyers will be more likely to enter a market if they believe that there are many sellers, and conversely, sellers are more likely to enter a market if they believe that there are many buyers. Diamond (1982) terms these spillover effects "thick market externalities", in which the gains from trade depend on the number of other traders who decide to come to the market. The more traders are expected in the market, the greater is the expected ease of transaction, and hence the bigger is the expected gain from participating in trading activity. In Pagano (1989), depth and liquidity depend on the conjectures that traders make

about the trading decisions of others. Higher participation encourages further participation, thereby amplifying the gains.

Thick market externalities have a self-fulfilling element: the more traders believe that the market will be active, the more they will be willing to participate, which brings about the more active markets that they hypothesized in the first place. Given the decentralized nature of trading decisions on the call, thick market externalities are stronger for the call mechanism than for the dealership market. The potential gains from trading in the call market are more sensitive to the degree of participation from other traders, as compared to the dealership market where an intermediary is always available to execute an order. Price uncertainty may reinforce any reluctance to trade in a call auction, which then has the potential to become self-fulfilling. Dealers can short-circuit the vicious circle of price volatility and lack of liquidity, leading to more price volatility.

We first analyze the issue of price discovery at the open and close and find that for most stocks the open (and close) call has better price discovery properties than the opening (and closing) dealers' quotes. We then develop an endogenous switching regression model to investigate the choice made by individual traders where to trade at the open and close. By modelling the microeconomics of traders' decisions, we are able to identify the factors that influence the choice of market and to quantify the benefits of immediacy offered by the dealership market at the open and close. We find that trading costs on the call market increase with price uncertainty, adverse selection and order flow imbalance while they decrease with high expected volume and for small and medium sized orders. The results indicate that traders are sometimes willing to pay higher costs on the dealership system, especially at the open, rather than migrating to the call where no spread is paid.

This paper is organized as follows. Section 2 describes the institutional details of the market open and close on the LSE and explains the data used in our study. Section 3 provides the first look at the actual usage of the call and dealership system at the open and call and investigates the price discovery issue. Section 4 develops an endogenous switching regression model to investigate the traders' decision on where to trade at the open and close. Section 5 concludes.

2   Institutional Design and Data

Following a lengthy period of pressure from market participants and regulators, in October 1997 the LSE introduced SETS, an order-driven trading system, as the official trading system for its most liquid FTSE100 constituent securities. The previous quote-driven dealer system was allowed to continue in parallel with the official SETS system, with dealers voluntarily quoting prices over the telephone and trading off-exchange. The LSE also changed the way in which the market opens: a call auction replaced the dealers' quotes that were submitted at the beginning of each day's Mandatory Quote Period. On May 30th 2000 the LSE introduced a call auction at the close. Next we explain the operational details of the opening and closing call auctions.

2.1   Opening Call Auction

Features of the opening call auction algorithm have evolved since its introduction. Originally only limit orders were allowed during the 10 minute pre-opening period, immediately before the official opening of the market. During the pre-open orders may be cancelled and the LSE disseminates the best bid and ask quotes submitted, if there are any.[2] At the end of this pre-opening period the order book is frozen, and provided that the order book has crossing orders, an algorithm runs which crosses the orders present on the two sides of the market. Before May 2000 this algorithm calculated the price at which the maximum volume of shares in each security can be traded, and in cases where there were two or more prices which satisfied this criterion, the average price was used. The call's price determination algorithm runs through each security in turn, with a random process in terms of the securities' sorting. The matching algorithm was originally thought to take two to three minutes to run through all SETS stocks. In practice, however, matching never hits the ceiling of this time configuration. In fact, the data at our disposal shows that the call algorithm rarely takes more

---

[2]Up until May 2000 the LSE did not calculate or disseminate the "indicative price" (the price at which the call crosses, conditional on all the orders submitted to the system), though some data vendors' information systems were able to disseminate the call's indicative price because the algorithm used by LSE allowed such vendors to use the orders in the system to calculate such a price.

than 30 seconds to execute.[3] No trading in any SETS security can take place while the algorithm runs. When the matching exercise is finished, trading moves into the continuous trading mode. Any remaining unexecuted orders are left on the book for execution during the normal trading period. Once the uncrossing process for each security is complete, continuous automated execution in that security begins and orders can be entered and deleted as before.

The opening mechanism has undergone a number of structural changes since it was introduced in 1997 to "make the process more efficient and aim to encourage more widespread use of auctions in SETS" (Market Enhancements: Guide to Release 3.1, November 2000). There have been three alterations to the official opening time. From SETS's introduction until 20 July 1998, the opening time was 08:30 a.m. Between 20 July 1998 to 20 September 1999 it was changed to 09:00 a.m., and since then the market's opening has been 08:00 a.m. In addition on 30 May 2000, the LSE introduced a series of measures to make the opening call more attractive. These were (a) the ability to submit market orders, besides limit orders, (b) the calculation and dissemination of the indicative call price; (c) a more efficient and faster matching in the call algorithm; and (d) the introduction of a random end to the call.

The price at which execution takes place in the trading environment since May 2000 is based on the following rules: (a) maximum volume transacted; (b) if more than one price with equal value for (a) is obtained, the minimum order surplus is used; (c) if more than one price with equal values for (a) and (b) is obtained, the market pressure rule is used; and (d) if more than one price with equal values for (a)-(c) is obtained, a reference price (usually the last automatic trade price) is used.

Market orders submitted in the pre-opening take price and time priority over limit orders. The pre-opening phase takes place over the ten minutes before the official open.

---

[3]It is possible that the random end will be after the 30 seconds due to either (i) price monitoring, that occurs when the potential call price hits the configurable price limits set by the LSE, or (ii) market order extensions, that have been introduced to maximize the probability of execution taking place during the call.

2.2 Closing Call Auction

The closing call auction was introduced on 30 May 2000, as part of a broader reform package. Continuous trading on SETS comes to an end at 4:30 p.m. Then, in the five minute interval up to 4:35 p.m., both limit orders and market orders are accepted for the closing call. When a market clearing price exists after this period, the closing call algorithm runs to clear the market. The algorithm and price-setting rules for the closing call are identical to the opening call. If the closing call does not generate a price, then the settlement price for a stock at the end of the day is calculated from the last ten minutes of continuous trading.

2.3 Dealership Market

In addition to SETS, trading may also take place "off-exchange", through a dealership system. Dealers provide liquidity off-exchange and act as voluntary market makers in contrast to their obligations as market makers prior to October 1997. These dealers, as LSE members, must report non-order book trades within three minutes of execution.

2.4 Submission of Orders

Orders can be submitted to the call auction by (a) individual investors (retail or institutional) directly to the call auction or the dealership system; or (b) by LSE member-firms either (i) on behalf of retail/institutional investors, or (ii) for their own account. Up until 1 April 2001, there were no charges for order entry or deletion on the call market. Charges were only levied for trades executed. For the opening and closing call auctions trades the charge is split between both participants. From 1 April 2001 the LSE has introduced a charge (1 pence) for order entry and deletion. On the other hand, traders contact the dealer by phone to arrange execution of orders on the dealership system.

2.5 Data

Our dataset consists of securities with access to both the SETS system and the off-exchange dealer facility. In May 2000 when the closing call auction was intro-

duced, there were 175 securities registered on SETS and all were constituents of either the FTSE 100 or FTSE 250 indices. The transactions, quotes and order book data was provided by the LSE's "Transaction Data Service". The data set covers the period from June 1998 to December 2000 and contains (a) trades data (for all trades taking place on the order book and the dealership system) to the nearest second, (b) quotes data containing the best ask and best bid prices *on the order book*, and (c) order history data of all orders submitted to the order book. The order history data contains the date and time when the order is submitted, the order type, quantity of shares and also prices. We merge the trade dataset and the order history dataset to build the entire order book for each trading day using an algorithm that takes into consideration the date and time of the order's submission, execution or cancellation. Trades data from SETS (with a symbol "AT") contains the transaction date, transaction time (to the nearest second), the trade price, trade size and trade direction. In addition, there is also a code for the trade counterparties. The LSE gives each counterparty a code for each particular security for each month with codes changing every month. However, there is no information as to the final identity of the counterparty. From May 2000, orders executed in the call phase are signed as "UT" to differentiate them from those taking place in the continuous trading mode. Before 30 May 2000, call-executed trades were time-stamped at exactly 09:00 a.m. or 08:00 a.m. depending on the time when the call took place. From 30 May 2000, call-executed trades are time stamped at the exact time when they are executed. All trades in this period are found to have been transacted within 30 seconds from the open. Trades data from the dealership system contains similar information and trades are time-stamped to the nearest second.

[Table 1 here]

Table 1 reports some descriptive statistics on the securities used in our analysis. Panel A reports statistics on the FTSE 100 securities used for the open analysis over the period 1 June 1998 to 31 December 2000. The securities are split into five quintiles based on market capitalization with the top quintile including the largest companies with an average market capitalization of 28,860

million GBP as at December 31 1999. The bottom quintile includes the smallest companies in the FTSE 100 index with an average market capitalization of 2,112 million GBP. Note that the capitalizations of the stocks in the bottom quintile are still rather large in absolute terms. The Volume column reports the total daily value of trading transacted on the order book or the dealer market (averaged over days and securities in that quintile). The average daily trading value by stock on SETS for the top quintile is 55.9 million GBP, and on the dealer system is 69.5 million GBP. The First Trade column reports the average value of the first trade of the day on the call market and the dealer system. Panel A of Table 1 suggests that the dealership market is used more than the order book during the day and at the open and close. Furthermore, the first trade of the day is typically larger on the dealer system.

Panel B of Table 1 reports the same information for the securities used for the market close analysis. The dataset includes a wider set of securities (FTSE 100 and some of the FTSE 250 securities), with a larger presence of smaller stocks and over a shorter period, i.e. from 30 May 2000 to 31 December 2000. Examining Volume, Last Trade and Trades columns in Panel B we can see the same patterns observed in Panel A.

3   Usage of the Call and Dealership

We initially examine differences between the call and dealer system at the open and close by comparing usage of the two systems in terms of the number of trades taking place across the two systems. We define success or failure of the call and dealership systems based on whether a trade is executed in each system. If the first (last) trade of the day occurs in the call phase we say that the call functions at the open (close) for that stock on that day. The call is defined as not functioning when the book is empty or it contains orders but the algorithm fails to match buyers and sellers. We define success on the dealership system similarly, and we say that the dealership system functions at the open (close) if there is a least one trade on the dealership mechanism in the time interval from 10 minutes before the official opening and the subsequent 30 seconds after the

9

official opening (a trade between 4:30 p.m. and 4:37 p.m.). We recognize that a voluntary dealer may be willing to accept an order at any time and that her quotes show a willingness to trade. However, we use a much stricter definition of success and failure where dealers' quotes have to be competitive enough to generate a trade for the system to be successful. Likewise, we define a call's outcome as successful only if orders cross, rather than the mere fact that orders are placed on the call.

We can then identify four different states at the open and at the close for each stock on each day: (a) State 1 where neither system functions {no trade on call and no trade on dealership}, (b) State 2 where only the call functions {trade on call and no trade on dealership}, (c) State 3 where only the dealership system functions {no trade on call and trade on dealership} and (d) State 4 where both systems function {trade on call and trade on dealership}. Table 2 reports the distribution of the different States at the open and close for by size quintile. The units are stock-days - the number of times that any stock in the relevant size category traded at the open and close. Note that there are far fewer observations for the close, since the closing call auction has operated only since May 30th 2000.

[Table 2 here]

An initial conjecture is that the decision to trade on one system rather than the other, is an independently distributed random variable. However the chi-squared statistic on the independence of elements in these tables is easily rejected implying that there is a strong pattern in the joint mode of opening and closing the market. This behavior needs to be explained. In addition, the independence of the elements in each row of the tables is also rejected. One important finding in panel A of Table 2 is that the probability of both types of trading mechanism functioning *at the open* is relatively rare: if the market opens at all, it tends to be either the dealer market or the call auction that executes, not both. In contrast, panel B of Table 2 shows that the probability of both types of trading mechanisms functioning *at the close* is high. Summary statistics on the modes of opening and closure are presented in Exhibits 1 and 2 below. First, consider the probability of each mode of opening (call only, dealer only, and both) conditional

10

on there being an opening on at least one system (shown in Exhibit 1 derived from panel A of Table 2).

Exhibit 1:Probabilities Conditional on an Opening Trade

Market Cap	Call Only	Dealer Only	Both
Top 20%	0.36	0.49	0.15
Next 20%	0.24	0.64	0.12
Next 20%	0.17	0.72	0.10
Next 20%	0.15	0.76	0.09
Bottom 20%	0.11	0.82	0.07

The most striking feature evident from Exhibit 1 is that the use of the dealer market decreases as firm size increases while the call functions more as firm size increases. As we move down the category of stocks classified by market capitalization, the probability that the opening happens only on the dealer market increases from 49% for the largest stocks to 82% for the smallest stocks. The probability that an opening occurs in the call auction only falls from 36% for the largest quintile to 11% for the smallest quintile of stocks. At the same time, the probability that there is an open on both markets declines from 15% for the largest stocks to just 7% for the smallest stocks.

A similar pattern is evident for the probabilities conditional on a closing trade, as reproduced in Exhibit 2 (derived from panel B of Table 2).

Exhibit 2: Probabilities Conditional on a Closing Trade

Market Cap	Call Only	Dealer Only	Both
Top 20%	0.08	0.07	0.85
Next 20%	0.13	0.10	0.77
Next 20%	0.15	0.21	0.63
Next 20%	0.07	0.48	0.45
Bottom 20%	0.06	0.64	0.31

Exhibit 2 shows that the conditional probability of having exclusively the dealer system closing the market increases from 7% for the largest stocks to 64% for the smallest stocks. On the other hand, the conditional probabilities for closing exclusively on the call, and having a closing trading on both systems decreases as the firm size decreases.

In summary our initial look at the data in Table 2 is that there is a higher incidence of traders using the dealer market for smaller stocks at the open and close. This is in spite of the fact that the standard asymmetric information market microstructure theories would suggest that the call is appropriate mechanism for opening a market, particularly for smaller stocks where asymmetric information is likely to be more prevalent.

3.1   Price Discovery

Which system contributes most to price discovery process? Although the call does not function very frequently at the open, does it produce better price discovery than the dealership system? Biais, Hillion and Spatt (1999) analyze the price discovery process during the pre-opening on the Paris Bourse (that opens through an automated call) and find that the first part is characterized by noisy indicative prices giving way to a second part where indicative prices signal information showing that learning takes place. Cao, Ghysels and Hatheway (2000) find similar results for the pre-opening on NASDAQ (which occurs through market makers' quotes). They find that the nonbinding quotes on NASDAQ contain trade information and that price discovery does take place in the pre-open phase. Here we want to address the price discovery performance of the call and the dealership markets. We shall first investigate the absolute differences between call and dealership prices at the open and at the close and benchmark prices. Following this, we shall turn our attention to the weighted price contribution of each market mechanism.

We measure the absolute deviations of call and dealership prices at the open and close from a benchmark price that is assumed to fully reflect all available trade information. Using the appropriate benchmark price is difficult given the fragmented nature of trading on the LSE. We choose to work with the volume-

weighted price obtained from all trades on both SETS and the dealership system during a specific interval. For the open, we determine the benchmark price from all trades executed on the two systems between 8:45 a.m. and 9:15 a.m. Finding the benchmark price for the close is a difficult task since there is no continuous trading *after* the close as there is after the open. This means that results could be dependent on the benchmark price chosen. In order to minimize this problem, we use two different benchmark prices, each obtained from different time periods and with different inputs. First, we calculate the volume-weighted price of all trades executed on the dealership system between 4:37 p.m. and 4:45 p.m. Secondly, we calculate the volume-weighted price obtained from all the firm orders submitted to the subsequent opening call and all trades on the dealership system on the following day between 7:50 a.m. and 7:59:59 a.m.

We use actual call and dealership prices from the open and call periods. For each stock, we compare the open (close) call and dealership prices with the corresponding benchmark price.

[Table 3 here]

Table 3 shows that the call, both at the open and at the close, produces the lowest absolute price deviation (in percentage) compared to the dealership system. Since we want to analyze the performance of both the open and close calls we use the period 30 May 2000 - 31 December 2000 when both these two algorithms were functioning for the same set of securities. For example, for the top market capitalization decile, the open call produces an absolute deviation of 0.759% whereas the dealership system produces a deviation of 1.281%. This holds true for the stocks in the top seven deciles. However, for the bottom three deciles the mean absolute differences are either lower for the dealership system or not statistically significant. This shows that, although the call auction does not function very frequently at the open, when it does it produces better price discovery than the dealership system but the quality of the price discovery deteriorates as market capitalization decreases.

The evidence on the closing call is more mixed. For the top two deciles we also find that the absolute deviation is lower for the closing call rather than the

dealership system. However, two of the top five deciles (the third and fourth deciles when we use the first definition of the benchmark price) produce call deviations that are not statistically significantly different than the dealership deviations. On the other hand, we also find that two of the bottom five deciles produce call deviations that are smaller than the deviations on the dealership.

The evidence presented here shows a different outcome to the one found by Angel and Wu (2001) from a simulated call auction using actual NASDAQ data. While they found that for all firm sizes, the absolute differences between prices at the open and benchmark prices were larger on the call we find the opposite. This means that in our set-up prices on the call are more indicative than dealers' quotes of future trading activity.

We next turn our attention on how new information gets impounded in prices during the pre-open, open, pre-close and close periods. To measure the extent of price discovery in each period we use the weighted price contribution (WPC) measure in line with Barclay and Warner (1993), Cao, Ghysels and Hatheway (2000) and Barclay and Hendershott (2001). We divide the open in two periods: (a) 7:50 a.m. - 7:55 a.m., and (b) 7:56 a.m. - 8:00:30 a.m. The close period is defined as 4:30:01 p.m. - 4:37 p.m.

Following Barclay and Hendershott (2001) we measure the WPC for each day and for the cross-section of the FTSE 100 stocks for both the open and close analysis over the period 30 May - 31 December 2000. For each of the trading days and for each of the trading periods j defined above, the WPC is calculated as:

$$WPC_j = \sum_{s=1}^{S} \left[\frac{|return_s|}{\sum_{s=1}^{S} |return_s|} \right] \times \left[\frac{return_{j,s}}{return_s} \right]$$

where $return_{j,s}$ is the return during period j for stock s and $return_s$ is the close-to-close return for stock s. The first term is the weight factor for each stock whereas the second term provides the contribution of each period to the total close-to-close returns. The returns for each day are calculated using the same volume-weighted average price from trades on both the order book and the dealership system. One should also note that while no trading occurs on the

order book after the closing call until the next day, the same does not apply for the dealership system. In fact, some trades on the dealership are reported to have taken place between 4:37 p.m. and the 7:50 a.m. on the next day.

[Table 4 here]

Table 4 reports the WPC for the different trading periods for both the call market (Panel A) and dealership system (Panel B). Given that the duration of the trading period has changed three times over the period 1998 - 2000, and given that we need one common period to investigate the WPC, we decided to conduct our analysis for the FTSE 100 securities over the period 21 September 1999 - 31 December 2000 when the trading day opened at 8:00 a.m. and closed at 4:30 p.m. It appears that the first part of the pre-open period (7:50 a.m. - 7:55 a.m.) does not produce any significant price discovery neither on the call nor on the dealership market. On the call this happens largely because the order book is generally empty at this stage. Significant price discovery takes place in the second part of the pre-open period that starts from 7:55 a.m. and concludes when the open call algorithm has run its course. In general, we find that for most stocks the call's contribution to the WPC on the order book is larger than that of the closing (and opening) dealers' quotes to the dealership's WPC. The interesting result is that the open call's WPC is larger than the dealership for three of the top five decile groups while the dealership's WPC shows that more information is impounded at the open for the bottom three decile groups. The amount of information impounded in the prices at the close is, an average, double that found for the open.

4 Choosing Between Call and Dealership Markets

Up to now we have found that the call functions only infrequently at the open, and that the dealership system is a more popular trading venue at the open. This is puzzling since we have seen that the cost of trading in the dealership is higher than the zero cost of using the call. We have also found evidence indicating that

15

the call mechanism, when it opens, has better price discovery properties. To complete the analysis we need to understand how traders choose where to trade. Understanding this issue is complicated by the fact that unobserved heterogeneity can be driving the results we have obtained so far. For example, the previous analysis indicates that the call is not very liquid at the open, especially for smaller stocks. However, this result has to be put under scrutiny since we know that traders self-select in terms of trading location and this depends in part (a) on their unobserved heterogeneity, (b) on expected trading costs. This requires a careful consideration of selection biases before presenting convincing evidence on the performance of call and dealership markets.

4.1   An Endogenous Switching Model

Traders will migrate to the trading system at the open and close that provides best execution. We assume that traders want to minimize trading costs by solving a discrete choice problem. Conditional on deciding to submit an order, a trader has a two-way trading choice: (a) send the order to the call market, or (b) send the order to the dealer market. The observed trading cost to trader i in market s is:

$$y_{s,i} = \beta_s X_s + \theta_{s,i} + u_{s,i} \tag{1}$$

where s is the market mechanism, and s can take on two values: either the call market C, or the dealership system D. X_s is a vector of relevant explanatory variables, and $\theta_{s,i}$ captures the unobserved heterogeneity of the individual trader. One possible example is the level of trader's impatience, measuring trader i's urgency to trade. A trader who has an urgent desire to trade will prefer to trade in the dealer market, since there is some uncertainty that an order submitted to the call market will not be executed. We assume that this uncertainty generates a cost for the impatient trader so that for the call market $\theta_{C,i} > 0$, but for the dealer market $\theta_{D,i} = 0$. Another example would be the case of a trader who wishes to trade in medium or large orders, instead of small sized orders. The main issue faced by this type of trader is the cost associated with the relatively low depth on the call system. In this set-up, trader i chooses to trade in that

16

market with the lowest effective trading cost, where the effective trading cost to trader i in market s is $y^*_{s,i}$.

After specifying the trading costs in both systems we proceed to investigate the trader's behavior. We assume that a trader has some information set, Ψ_i, that will be used by the trader decide where to submit her order. This calls for an investigation of the differential costs of trading in one system rather than the other. In our case, the differential trading cost, $\bar{\nu}_i$, is represented as:

$$\bar{\nu}_i = \lambda' \Lambda_i + E\left[y_{C,i} - y_{D,i} \mid \Psi_i\right] \tag{2}$$

where λ' is a vector of constants and Λ_i represents variables influencing the trading decision. Substituting each of the trading cost equation for the call market and dealership market in (1) into (2) above, we get the decision criterion function for trader i:

$$\bar{\nu}_i = \lambda' \Lambda_i + (\beta_C - \beta_D) X_i + \Psi_i \tag{3}$$

which in turn can be represented as:

$$\bar{\nu}_i = \omega' \Omega_i + \Psi_i \tag{4}$$

where $\Omega_i = (\Lambda_i, X_i)$ and ω is a vector of coefficients. Assuming that ν_i is then the market chosen by trader i, then ν_i takes the value of 1 in the case that the trader chooses the dealership system and 0 in the case where the trader chooses the call market. From a data point of view, we will observe a trade on the dealership system if $\bar{\nu}_i > 0$ and if $\bar{\nu}_i < 0$ then the trader decides in favor of the call market.

It might be argued that we can directly estimate the effect of $X_{s,i}$ on trading costs from (1). However an OLS regression on each market would yield inconsistent estimates because of selection biases. A trader's unobserved heterogeneity will influence the trading venue's choice and the trading costs in that venue. This will produce an estimation framework where the error term of the trading cost equation in (1) will be correlated with the trader's criterion function in (3). From

the standard properties of the normal distribution, we know that the expected trading costs conditional on observing a trade on the dealership market is

$$E\left[y_{D,i}|\bar{\nu}_i = 1\right] = \beta_D' X_i + \sigma_D \left[\frac{\phi\left(\omega'\Omega_i\right)}{\Phi\left(\omega'\Omega_i\right)}\right] \tag{5}$$

and, similarly for observing a trade on the call market:

$$E\left[y_{C,i}|\bar{\nu}_i = 0\right] = \beta_C' X_i + \sigma_C \left[\frac{-\phi\left(\omega'\Omega_i\right)}{\left(1 - \Phi\left(\omega'\Omega_i\right)\right)}\right] \tag{6}$$

where σ_D (σ_C) is the covariance between the disturbance terms θ and u_D (u_C), $\phi\left(\omega'\Omega_i\right)$ is the standard normal density function and $\Phi\left(\omega'\Omega_i\right)$ is the cumulative standard normal distribution.

Due to this bias we shall use the two-stage econometric procedure proposed by Lee, Maddala, and Trost (1979). We will first estimate ω from actual realizations of ν using a probit model which will generate the maximum likelihood estimates of ω. These estimates will then be used in our second-stage estimation of the trading cost equation for each market. The model for the expected trading costs estimated in the second stage is as follows:

$$E\left[y_i\right] = \beta_C' X_i + \left(\beta_D' - \beta_C'\right) X_i \Phi + \phi_i \left(\sigma_D - \sigma_C\right) \tag{7}$$

Estimated probabilities $\bar{\Phi} = \Phi\left(\bar{\omega}'\Omega_i\right)$ and $\bar{\phi} = \phi\left(\bar{\omega}'\Omega_i\right)$ for each order at the open and close, obtained from the first-stage probit model, will be used to estimate equation (7).

Measuring trading costs correctly is rendered difficult by the different natures of the call auction and the dealership system. The bid-ask spread is not a good measure for our purpose. Although we can measure spreads on the dealership system we cannot do so for the call auction because the call produces a single price. Furthermore, we also want to capture dynamic trading costs in the sense that traders, besides deciding where to trade at the open (and close), also have to decide whether to trade at the open (or close) or wait for some time and trade during the continuous trading phase. For example, if a trader wants to trade early on during the trading session, she can either submit an order at the open

(on the call or dealership system) or submit it soon after the continuous mode starts. Likewise, a trader who wants to trade at the close has a similar decision to take: either place an order at the closing phase (close call or dealership system after 4:30 p.m.) or else place her order towards the end of the continuous trading mode.

Our measure of trading costs is the absolute difference between (a) the price of each *firm* order submitted to the call auction, or (b) the price of a trade on the dealership system and a benchmark price. The benchmark price is assumed to be the price that reflects all the relevant trading information. For the open we define the benchmark price as the volume-weighted price of all trades executed half an hour up to an hour after the start of continuous trading. So, for example, for the period 21 September 1999 - 31 December 2000 we consider trades executed between 8:30 a.m. and 9:30 a.m. For other periods, with different trading day duration we change the definition of the benchmark period accordingly. For the close we define the benchmark price as the volume-weighted price of the last 30 minutes of continuous trading. The evidence provided by Biais *et al.* (1999) shows that one problem with this definition of trading costs is that some of the orders submitted to the call auction have noisy prices, particularly those that are submitted towards the beginning of the period, and are subsequently cancelled before the call auction crosses. In order to avoid this problem we only consider those *orders that are submitted in the pre-open (pre-close) and not cancelled.* Although these are firm orders, it does not mean that such orders will necessarily get executed on the call market.

The variables used for the first-stage probit model for the open (close) periods are the following: (a) the logarithm of the firm's market capitalization, (b) the average effective spread on the order book in the first (last) 15 minutes of continuous trading, (c) the logarithm of the mean order size submitted to the call or dealership market relative to the mean stock order size computed across both markets, (d) close-to-open (open-to-close) market returns, and (e) close-to-open (open-to-close) own returns.

We divide the explanatory variables X_s in (1) into three broad categories: (a) measures of the *state of the order book* before the call algorithm executes during

the pre-open or pre-close periods and when bids are submitted, (b) measures that capture the state of the *entire market*, in particular with respect to trading activity, and the degree of uncertainty; and (c) other control variables that provide information on investors' intentions.

The following are the independent variables making up the first category:

(a) **Time-weighted order flow imbalance during auction (OFI_{jd}):** This variable is calculated for stock j for every minute on the pre-open (pre-close) period on every day d in the following way

$$OFI_{jd} = \frac{\sum_{i=1}^{N_B} V_i^B - \sum_{i=1}^{N_S} V_i^S}{\sum_{i=1}^{N_B} V_i^B + \sum_{i=1}^{N_S} V_i^S}$$

and weighted by the time (in seconds) elapsed from the beginning of the auction divided by the total number of seconds employed by the auction. V_i^B is the buy-initiated volume submitted to the auction by trader i and V_i^S is the sell-initiated volume submitted to the call auction. This variable measures the degree of order asymmetry in the order book. The reason for the time weighting is that, since traders can withdraw orders before the auction enters the execution phase, we want to give more weight to the orders that are found on the book just before the auction executes. These orders are more indicative of the true order flow asymmetries because early orders can be withdrawn. Large imbalances imply coordination problems, and the coordination hypothesis predicts that traders will steer clear of the call auction whenever significant imbalances occur.

(b) **Price revisions during auction (ΔP_{jd}):** This variable measures the absolute price revision that takes place from the start until the end of the call process. The idea behind this variable is that when there are lots of bidders, the price gets "trapped" between very narrow ranges. If there are few bidders, the price could range more widely, capturing the law of large numbers as argued by Satterthwaite (1994). We expect that higher price dispersion imply higher coordination problems, leading to a lower likelihood of the call functioning.

(c) **Bid dispersions during auction (BD_{jd}):** A decision faced by the bid-

ders in the opening and closing auctions is whether to split up their bids and by how much to disperse their bids. Any buyer wants to get her order filled as much as possible and this is especially true when the bidding behavior of the other participants tend to suggest that the price is high. Conversely, if the participants' bidding behavior indicates a low price then the buyer would like to end up with the smallest numbers of shares. Consistent with the findings in Nyborg, Rydqvist and Sundaresan (2002), when uncertainty in the market is high we expect bidders to increase their bid dispersions. This variable is measured as the standard deviation of the volume-weighted bids in each auction. We measure both the "Trader's Bid Dispersion" which is the bid dispersion of the broker submitting an order to the call, and the "Market's Bid Dispersion" which is the overall bid dispersion in the call market. According to the adverse selection hypothesis the call is more robust to uncertainty in the presence of asymmetric information, and would predict that traders choose the call when there is increased uncertainty in the market. In contrast, the coordination theory would predict that with more uncertainty in the market the less likely that the call will function.

(d) **Herfindahl index (H_{jd}):** This variable measures the concentration of the orders submitted to the auctions. The concentration in question is from the brokers submitting orders rather than from the final client. For each order the LSE dataset provides the broker's identification code. We do not know the name of the broker, just the identification code. For each auction we compute the Herfindahl Index to obtain the concentration levels in each auction. This variable is a measure of information asymmetry and the lower is the Herfindahl index the more traders are in the market and the more likely it is that the call auction functions.

The variables making up the second category are the following:

(a) **Trading volume (TV_{jd}):** If thick market externalities exist, then we expect that the conditions generating such externalities will also induce investors to go to the market. This means that the volume of transactions is expected to be high when markets experience thick externalities. Hence, actual volume transacted will be a proxy for these conditions generating thick externalities. We use the normalized dollar-volume in the (a) first hour of continuous trading for

the open call, and (b) in the last hour of continuous trading for the closing call. However in the presence of asymmetric information informed traders will also trade when the market is most liquid, so that both adverse selection and coordination theories would predict that the larger the trading volume, the greater the chance that traders will go to the call auction. In order to distinguish between these theories in the presence of an increase in trading volume we will need to examine the adverse selection variable described below.

(b) **Variability** (σ_{jd})**:** Ausubel (1997) shows how the "champion's plague" could occur in multi-unit auctions. One of the decisions facing traders at the open and close auctions is how much to bid for. The "champion's plague" in the presence of reservation prices suggests that, when uncertainty is high, bidders will reduce the number of shares they will bid for. Extending this argument to the call auction we conjecture that when uncertainty is high bidders will prefer not to participate at all in calls, preferring instead either the dealership market or not to trade. On the other hand the adverse selection hypothesis (Madhavan, 1992) predicts that an increase in uncertainty will cause traders to prefer the call since it is more robust in such market conditions. We measure uncertainty by the normalized standard deviation of returns in the first (last) half hour of continuous trading for the open (close).

(c) **Dealers' inventory** (DI_{jd})**:** The (voluntary) dealer's inventory could have an impact on the open and close of trading. Domowitz and Madhavan (2001) point out that a potential disadvantage of the dealership system is that opening prices in such a system might be biased because of a dealers' inventory positions at the start of trading. We expect that a dealer who has an unbalanced inventory position at the end of the trading day will want to balance inventory at the first possible opportunity, i.e. the open call. Likewise, a dealer that has experienced shocks to his inventory during a given trading day will want to re-balance her position towards the end of the trading day. Given that the closing call is the last possible opportunity for inventory re-balancing in any given day, we expect that the higher the inventory's disequilibrium the more likely that a dealer will use the closing call. We measure this variable in the following way: for each dealer we compute the amount of buys and sells she does for each single

day and compute the imbalance at the end of continuous trade (for the close call) and after the closing call (for the open call). For the open call we use the dealers' inventory position during the previous day (hence in the opening call auction on day T we use the dealers' inventory position on day $T-1$). For the close call we use the dealers' inventory position during that day (hence closing call auction on day T we use the dealers' inventory position on day T).

(d) **Adverse selection costs (AS_{jd}):** The market microstructure literature shows that investors react to the perceived presence of private information in the market. We measure the level of asymmetric information by extracting the adverse selection component of the actual bid-ask spread on the order book in the first hour of continuous trading for the open call and in the last hour of continuous trading for the closing call. Standard market microstructure models predict that the call mechanism is robust to the presence of asymmetric information and hence predict that traders will use the call mechanism more frequently when adverse selection costs are high. Under the coordination theory traders facing this type of uncertainty react by becoming very cautious in their bidding and it is likely that traders withdraw from the trading process. We use the Booth *et al.* (1995) methodology to measure the adverse selection component of the effective spreads in the first (last) half hour of continuous trading for the open (close).

In addition to the variables listed above, we also use **order size** (OS_{ijd}) of every order submitted to the call market and the trade size on the dealership system to capture the trader's characteristics. Furthermore, since the call market suffers from low depth, traders are aware that large orders can produce a significant price impact on the call market whereas such concerns are less severe for orders submitted to the dealership system.

The control variables are the following:

(a) **News dummy ($News_{jd}$):** We control for any significant news issued by firms. Days following the issue of significant news (earnings announcement, dividend announcement and mergers) take a value of 1 and 0 otherwise.

(b) **Day-of-the week dummy variables ($DDum$):** We also used a dummy variable for each day of the week as a control for calendar effects.

(c) **Cross-listed firms ($CSDum$):** We also control for components of the

23

FTSE 100 Index that are cross-listed on the New York Stock Exchange. The overnight period is shorter for these stocks and this could influence trading behavior.

4.2 Results

Table 5 shows the results of the endogenous switching regression model for both the open (Panel A) and the close (Panel B).

[Table 5 here]

The coefficient estimates for $\beta_1 - \beta_9$ represent the slope of the trading costs on the call market; β_{10} represents the difference between the trading costs on the dealership market and the call market; and $\beta_{11} - \beta_{19}$ represent the difference in the slopes of the trading costs between the two markets. The results show that (a) order imbalance ($\beta_1 > 0$), (b) adverse selection costs ($\beta_6 > 0$), (c) price uncertainty ($\beta_7 > 0$), and (d) order size ($\beta_8 > 0$) increase the trading costs of the call market, both at the open and at the close. On the other hand, the call's trading costs are lower when trading volume is high ($\beta_5 < 0$). The results also show that the dealership system suffers from higher fixed costs compared to the call market ($\beta_{10} > 0$). Furthermore, the marginal trading costs in the dealership market are lower than those on the call market when (a) order imbalance is high ($\beta_{11} < 0$), (b) adverse selection costs are high ($\beta_{16} < 0$), (c) price uncertainty is high ($\beta_{17} < 0$), and (d) order size is large ($\beta_{18} < 0$), whereas marginal costs on the dealership are higher when trading volume is high ($\beta_{15} > 0$). Finally, the statistical significance of β_{20} shows the presence of traders' selection biases between the two market systems. The R^2 is low - 5.28% - but the F value is 280.26 and we can strongly reject the hypothesis that the independent variables used in this model have no explanatory power of trading costs on the two markets.

Analyzed together, the results show that the dealership system generates lower trading costs than the call market at low levels of trading volume but the result flips when volume is high. For example, considering the open call (close call) we find that decreasing trading volume with one standard deviation from its average generates trading costs that are about 0.65% (0.25%) lower on the dealership

24

system; whereas increasing trading volume with one standard deviation makes the call market cheaper by about 0.89% (0.14%) compared to the dealership market.

On the other hand, small orders receive better execution (lower trading costs) on the call market compared to the dealership system, whereas larger orders get better execution on the dealership system. For example, considering the open call (close call) we find that decreasing the average trade size by one standard deviation from its average value makes the call market cheaper by about 0.62% (0.13%) while increasing it by one standard deviation from its average volume makes the dealership system less expensive by about 0.57% (0.14%) compared to the call market.

When the presence of informed traders increases, trading costs on the call market are higher than the dealership market. Furthermore, when price uncertainty is high we also find higher trading costs on the call. In both cases, this will make traders less likely to choose the call market. Such evidence goes against the prediction of the asymmetric information models that conjecture that call markets are better suited to deal with adverse selection and uncertainty issues than the dealership system.

Our findings are supportive of the coordination motives rather than the theories of asymmetric information For example according to the adverse selection models, in so far as asymmetric information is likely to be more prevalent in smaller stocks, we would expect the benefits of the call to be at their greatest, and trades in these stocks are more likely to take place on the call auction. On the other hand the rival coordination theory would suggest that since smaller stocks have a relatively small shareholder base, it will be more difficult to find a counterparty to a potential trade. Thus, the coordination theory would predict that it is stocks with the larger market capitalization that will transact on the call auction .In fact we find that medium-sized and smaller stocks are more likely to trade on the dealership, which is consistent with the coordination theory.

Another variable that allows us to distinguish between the two alternative theories is the degree of uncertainty associated with the underlying security. Madhavan (1992) shows that as the variance of returns of the security increases it

is more likely that the dealership will fail to function, but that the call auction remains robust to the increased uncertainty. So for days characterized by high variability of returns, the asymmetric information theories predict that traders will prefer to trade on the call system. In contrast, the coordination theory suggests that increased uncertainty will deter traders from submitting orders to the call since it is less likely traders expect to find a match, preferring instead the dealer market. Again we find that on days when the degree of uncertainty is high traders migrate to the dealer market, consistent with the predictions of the coordination theories.

Thick market externalities have a self-fulfilling element: the more traders believe that the market will be active, the more they will be willing to participate, which brings about the more active markets that they hypothesized in the first place. The potential gains from trade in the call market is more sensitive to the degree of traders' participation, compared to the dealership market. If market activity is expected to be high, then the coordination motive encourages traders to place orders in the call market. Consistent with the coordination theoeries, we find evidence showing that on days when the market is expected to be very active, it is more likely that traders submit orders to the call market rather than trade on the dealership market.

4.3   Robustness

We check the robustness of the endogenous switching model in several ways. The first robustness check deals with the definition of trades at the open and close on the dealership system. It should be recalled that we define a trade at the open (close) as one that takes place between 7:50 a.m. and 8:00:30 a.m. (4:30 p.m. and 4:37 p.m.). Due to possible slow reporting on behalf of the dealers we could be biasing our results against the dealership system. Hence, we run both the endogenous switching model taking into consideration - one at a time - dealership trades up to (a) 8:01 a.m., (b) 8:02 a.m., and (c) 8:03 a.m. for the open analysis, and dealership trades from 4:30 p.m. up to (a) 4:38 p.m., (b) 4:39 p.m., and (c) 4:40 p.m. for the close analysis. The results (not shown here) for both the endogenous switching model and the multinomial logit are very similar

to the ones shown in Table 5.

Next, we test for possible asymmetries between buyer- and seller-initiated orders and we reestimated the endogenous switching model for buy orders (buy trades on the dealership) and sell orders (sell trades on the dealership) separately. While the estimated coefficients were different than the ones reported in Table 5, the overall outcome is not different than the one presented above.

We also checked for the endogeneity of normalized volume and returns volatility by using predicted volume and pridicted volatility. The results obtained are similar to those in Table 5. Finally, we run the endogenous switching model with the square-root transform of the order size and we found no significant differences from the results shown above.

5 Conclusions

This paper has investigated the trading patterns at the opening and closing of the London Stock Exchange where traders can choose between a call market and a dealership system to place orders. Our initial results identified a puzzle in the use of these two markets at the open and close of daily trading: although no direct trading costs are incurred on the call and spreads are usually high on the dealership market, we are more likely to see smaller stocks opening and closing using dealers. Adding to this puzzle is the fact that when the call does execute, price discovery is more efficient on the call than the dealership. So although the call auction is both cheaper and informationally more efficient that the dealership, traders still prefer to use the dealer market under certain market conditions and for medium and small companies.

We examined traders' decisions on the choice of trading venue. In the presence of uncertainty, traders shy away from the call and prefer to trade on the dealership market. The call is popular on days with higher expected trading volumes, and when adverse selection costs are low. Our findings are at odds with the mainstream asymmetric information models, they are consistent with coordination motives for trade.

The regulatory implications in terms of market design are notable. Stock

markets around the world have tended to converge on order driven systems as the optimal trading mechanism. Our results suggest that this dominance is premature: although it is the case that the call market functions well for liquid stocks, our results suggest that in smaller stocks with less liquidity, a dealership market with an intermediary continues to provide valuable service. The same applies for the provision of liquidity in difficult market conditions when dealers - even though they have no mandatory requirements - are more likely to provide liquidity than what can be found in call markets.

References

[1] Angel, J.J., and S.Z. Wu, 2001, "Calling the Open: Price Discovery Evidence from NASDAQ", *The NASDAQ Stock Market, Inc. Economic Research.*

[2] Ausubel, L. M., 1997, "An Efficient Ascending-Bid Auction for Multiple Objects" Working Paper, University of Maryland.

[3] Bacidore, J., and M.L. Lipson, 2001, "The Effects of Opening and Closing Procedures on the NYSE and NASDAQ", Working Paper.

[4] Biais, B., P. Hillion, and C. Spatt, 1999, "Price Discovery and Learning During the Pre-Opening Period in the Paris Bourse", *Journal of Political Economy 107, 1218-1248.*

[5] Barclay, M., and T. Hendershott, 2003, "Price Discovery and Trading After Hours", *Review of Financial Studies*, 16, 1041-1073.

[6] Booth, Geoffrey, J.C. Lin, and G.C. Sanger, 1995, "Trade size and components of the bid-ask spread", *The Review of Financial Studies* 8, 1153-1183.

[7] Cao, C., E. Ghysels, and F. Hatheway, 2000, "Price Discovery Without Trading: Evidence from the NASDAQ Pre-Opening." *Journal of Finance*, 55, 1339-1365.

[8] Diamond, P., 1982, "Aggregate Demand Management in Search Equilibrium", *Journal of Political Economy*, 90, 881-94.

[9] Domowitz, I., and A. Madhavan, 2001, "Open Sesame: Alternative Opening Algorithms in Securities Markets", in R.A. Schwartz *The Electronic Call Auction: Market Mechanism and Trading* (Kluwer Academic Publishers, 2001).

[10] Economides, N., and R.A. Schwartz, 1995, "Electronic Call Market Trading" *Journal of Portfolio Management,* 21, 10-18. Reprinted in R.A. Schwartz *The Electronic Call Auction: Market Mechanism and Trading* (Kluwer Academic Publishers, 2001).

[11] Ewing, T., 2000, "SEC Has Urged NASDAQ to Alter the Way the Market Establishes Opening Prices", *The Wall Street Journal*, September 5.

[12] Lee, L.F., Maddala, G.S., and Trost, R.P., 1979, "Testing for Structural Change by D-Methods in Switching Simultaneous Equation Models", *Proceedings of the American Statistical Association*, 461-466.

[13] London Stock Exchange, 2000, "Market Enhancements: Guide to Release 3.1", November 2000.

[14] Madhavan, A., 1992, "Trading Mechanisms in Securities Markets", *Journal of Finance*, 47, 607-641.

[15] Madhavan, A., and V. Panchapagesan, 2000, "Price Discovery in Auction Markets: A Look Inside the Black Box", *Review of Financial Studies* 10, 99-134.

[16] Nyborg, K., K. Rydqvist, and S.M. Sundaresan, 2002, "Bidder Behavior in Multi-Unit Auctions Evidence from Swedish Treasury Auctions", *Journal of Political Economy*, 110, 394-424.

[17] Pagano, M., 1989, "Trading Volume and Asset Liquidity", *Quarterly Journal of Economics*, 104, 255-274.

[18] Pagano, M., and R.A. Schwartz, 2003, "A closing call's impact on market quality at Euronext Paris", *Journal of Financial Economics*, 68, 439-484.

[19] Satterthwaite M., and S.R. Williams, "The Rate of Convergence to Efficiency in the Buyer's Bid Double Auction as the Market Becomes Large", *Review of Economic Studies*, 56, 477-498.

Table 1: **Descriptive Statistics**

PANEL A: SECURITIES USED FOR THE OPENING ANALYSIS

Quintile	Market Cap Mean	Market Cap Median	Price	Volume x1,000 OB	Volume x1,000 Dealer	First Trade x10 OB	First Trade x10 Dealer
Top	28,860	24,081	797	55,950	69,560	4,492	9,455
Next	7,596	6,895	593	15,680	24,280	3,386	3,111
Next	4,746	4,125	601	11,090	19,050	3,374	4,163
Next	3,136	2,985	568	5,381	9,740	2,653	3,794
Bottom	2,112	1,988	372	4,794	8,949	2,766	3,304

PANEL B: SECURITIES USED FOR THE CLOSING ANALYSIS

Quintile	Market Cap Mean	Market Cap Median	Price	Volume x1,000 OB	Volume x1,000 Dealer	Last Trade x10 OB	Last Trade x10 Dealer
Top	21,951	15,022	887	35,810	47,030	9,541	66,066
Next	5,292	5,286	716	8,859	15,180	4,273	38,981
Next	2,839	2,739	603	5,109	9,614	3,808	28,940
Next	1,396	1,298	473	2,830	6,296	3,522	20,122
Bottom	468	447	305	1,010	2,827	1,918	8,744

The table reports descriptive statistics for FTSE 100 and FTSE 250 companies used for Opening and Closing analysis and trading on the Order Book (OB) and the Dealer market simultaneously. Panel A shows descriptive statistics for the FTSE 100 stocks employed for the Opening Call during the period 1 June 1998 - 31 December 2000. Panel B shows descriptive statistics for FTSE 100 and FTSE 250 used for the Closing analysis for the period 30 May 2000 - 31 December 2000. Market capitalization is in Sterling million. Panel A reports market capitalization on 1 June 1998 while in Panel B capitalization is reported on 31 December 1999. For each quintile, we report the mean and median capitalization. Price is the mean cross-sectional average price, in pence, for each quintile. In Panel A, Volume is the mean daily Sterling-Volume for each security; First Trade is the mean Sterling-Volume of the first trade for each day. Panel B reports the mean daily Sterling-Volume (Volume) for each security in the FTSE 250 index and the mean Sterling-Volume of the last trade (Last Trade).

Table 2**: Opening and Closing Procedures on the London Stock Exchange**

Market Cap	Panel A: Opening of Market				Panel B: Closing of Market			
	No Open	Call Only	Dealer Only	Both Systems	No Close	Call Only	Dealer Only	Both Systems
Highest	7142	2938	3832	375	179	230	167	4036
	[10.15%]	[4.17%]	[5.45%]	[0.53%]	[0.78%]	[1.00%]	[0.73%]	[17.60%]
2	7232	2034	4573	228	223	423	325	3613
	[10.28%]	[2.89%]	[6.50%]	[0.32%]	[0.97%]	[1.80%]	[1.42%]	[15.75%]
3	7210	1518	4892	178	368	504	765	2854
	[10.25%]	[2.16%]	[6.95%]	[0.25%]	[1.60%]	[2.20%]	[3.34%]	[12.44%]
4	7392	1410	5211	76	517	92	1885	2168
	[10.50%]	[2.00%]	[7.41%]	[0.11%]	[2.25%]	[0.40%]	[8.22%]	[9.45%]
Lowest	7611	1059	5400	72	667	46	2433	1444
	[10.81%]	[1.50%]	[7.67%]	[0.10%]	[2.91%]	[0.20%]	[10.61]	[6.30%]

The table reports the number of firm-days for each type of opening and closing procedure for the FTSE 100 stocks officially assigned to the order book system (SETS) on 1 June 1998. In Panel A we report statistics for the opening procedures. In Panel B we report statistics for the closing procedures. In parentheses we report the % of firm-days for (i) each type of open for the period 1 June 1998 to 31 December 2000 in Panel A, and (ii) for each type of close for the period 30 May 2000 – 31 December 2000 in Panel B. The column "No Open" ("No Close") reports the number of firm-days where there were no trades at the open (close) neither through the Call nor through the Dealership Market; the column "Call Only" reports the number of firm-days when there was trading exclusively on the Open (Close) Call; the column "Dealer Only" reports the number of firm-days when there was trading exclusively on the Dealership Market; and the "Both" column reports the number of firm-days when there was trading on both the Open (Close) Call and Dealership Market.

Table 3: **Mean Absolute Differences in Call and Dealership Markets**

| Market Cap | Panel A: Opening of Market | | | Panel B: Closing of Market | | | | | |
| | | | | Benchmark Price I | | | Benchmark Price II | | |
	Call	Dealers	t-stat	Call	Dealers	t-stat	Call	Dealers	t-stat
Highest	0.759	1.281	**8.55***	0.233	0.303	**4.28***	0.657	1.130	**6.42***
2	1.014	1.315	**7.81***	0.251	0.296	**2.29***	0.863	1.148	**5.04***
3	1.301	1.489	**7.29***	0.376	0.398	1.76	1.070	1.325	**4.53***
4	1.436	1.615	**7.02***	0.371	0.328	1.21	1.397	1.418	1.82
5	2.025	2.304	**6.84***	0.382	0.459	**3.14***	1.723	2.044	**3.84***
6	2.257	2.618	**6.47***	0.456	0.554	**4.49***	1.987	2.306	**3.48***
7	2.881	3.042	**5.17***	0.504	0.635	**6.14***	2.287	2.613	**2.65***
8	3.141	3.181	1.55	0.558	0.709	**5.80***	2.595	2.946	**2.68***
9	3.755	3.416	2.11	0.669	0.689	1.61	2.913	3.219	**2.19***
Lowest	3.921	3.854	1.48	0.856	0.833	1.04	3.195	3.302	1.25

The table reports the Mean Absolute Difference (in %) of prices generated by the Call Market and the Dealership Market from benchmark prices. Panel A reports the Mean Absolute Differences of open prices of the Call and Dealership markets from the volume-weighted average price of all trades executed on the London Stock Exchange between 8:45 a.m. and 9:15 a.m. Panel B reports the Mean Absolute Difference between the close prices of the Call and Dealership Market from two different benchmark prices. Benchmark Price I is the volume-weighted price of all trades executed on the dealership system between 4:37 p.m. and 4:45 p.m. Benchmark Price II is the volume-weighted price obtained from all the firm orders submitted to the subsequent opening call and all trades on the dealership system on the *following day* between 7:50 a.m. and 7:59:59 a.m. The period under consideration is 30 May 2000 – 31 December 2000. The t-statistics of the differences between the Call's and Dealership's Mean Absolute Differences are also reproduced. An * indicates that the mean difference is smaller on the Call and is significant at the 5% confidence level.

Table 4: **Weighted Price Contribution on the Call and Dealership Markets**

Market Cap	Panel A: Call Market					Panel A: Dealership Market				
	7:50 am – 7:55 am	7:56 am – call end	8:00:30 am – 4:30 pm	4:30:01 pm – 4:37 pm	4:38 pm – 7:50 am	7:50 am – 7:55 am	7:56 am – call end	8:00:30 am – 4:30 pm	4:30:01 pm – 4:37 pm	4:38 pm – 7:50 am
Highest	0.009	**0.116*[A]**	0.675*	**0.200*[A]**	0	0.006	0.097*	0.713*	0.181*	0.003
2	0.009	**0.101*[A]**	0.718*	**0.172*[A]**	0	0.006	0.065*	0.804*	0.121*	0.004
3	0.008	0.084*	0.734*	0.174*	0	0.007	0.086*	0.724*	0.179*	0.004
4	0.010	**0.097*[A]**	0.708*	**0.185*[A]**	0	0.008	0.075*	0.751*	0.162*	0.004
5	0.006	0.071*	0.777*	0.146*	0	0.006	0.076*	0.764*	0.149*	0.005
6	0.007	0.070*	0.773*	**0.150*[A]**	0	0.004	0.077*	0.789*	0.128*	0.002
7	0.005	**0.078*[A]**	0.793*	0.124*	0	0.005	0.062*	0.774*	**0.157*[B]**	0.003
8	0.008	0.046*	0.810*	**0.136*[A]**	0	0.005	**0.064*[B]**	0.824*	0.105*	0.002
9	0.005	0.049*	0.801*	0.145*	0	0.005	**0.061*[B]**	0.782*	0.150*	0.003
Lowest	0.007	0.039*	0.857*	0.097*	0	0.004	**0.044*[B]**	0.841*	**0.109*[B]**	0.002

The table reports the weighted price contribution of various trading periods to the close-to-close return price change. Panel A shows the weighted price contribution on the order book while Panel A shows that for the dealership market. Both panels are for the FTSE 100 stocks. The weighted price contribution is calculated across stocks for each day and then averaged across days. Days that have zero returns are removed from the sample. The period under consideration is 21 September 1999 - 31 December 2000. An * indicates that the value is significantly different than zero at the 5% level. An [A] ([B]) indicates that the Weighted Price Contribution of the Call (Dealership) is larger than that on the Dealership (Call) at the 5% level.

Table 5: **Stage II endogenous switching regression**

	PANEL A: OPEN CALL	PANEL B: CLOSE CALL
β_0	**0.3118****	**0.195****
β_1 (Order Imbalance)	**1.7848****	**0.5343***
β_2 (Price Revision)	-0.9111	-0.4751
β_3 (Trader's Bid Dispersion) (x10,000)	0.4237	0.0290
β_4 (Market's Bid Dispersion) (x10,000)	0.0918	0.0187
β_5 (Volume) (x100,000)	**-0.1061****	**-0.0055****
β_6 (Adverse Selection Costs)	**0.0095****	**0.0037***
β_7 (Volatility)	**0.7309***	**0.5418***
β_8 (Order Size) (x10,000)	**0.6474****	**0.1848****
β_9 (Number of Orders)	-0.0264	-0.0027
β_{10} ($\hat{\Phi}$)	**0.6288****	**0.4281****
β_{11} (Order Imbalance*$\hat{\Phi}$)	**-1.2465***	-0.8061
β_{12} (Price Revision*$\hat{\Phi}$)	**1.1290***	0.7552
β_{13} (Trader's Bid Dispersion*$\hat{\Phi}$)	-1.2280	-0.0751
β_{14} (Market's Bid Dispersion*$\hat{\Phi}$)	-0.1784	-0.0337
β_{15} (Volume*$\hat{\Phi}$)	**0.1175***	**0.0065***
β_{16} (Adverse Selection Costs*$\hat{\Phi}$)	**-0.0169****	**-0.0065***
β_{17} (Volatility*$\hat{\Phi}$)	**-0.5426***	**-0.6521***
β_{18} (Order Size*$\hat{\Phi}$)	**-1.3083****	**-0.3397****
β_{19} (Number of Orders*$\hat{\Phi}$)	0.0368	0.0035
β_{20}	**-0.2081****	**-0.1951****

The table reports the coefficient estimates of the second stage endogenous switching regression model of trading costs on the Call Market and Dealership System as follows:

$$y_{s,i} = \beta_0 + \beta_1 OFI + \beta_2 \Delta P + \beta_3 TBD + \beta_4 MBD + \beta_5 TV + \beta_6 AS + \beta_7 \sigma +$$

$$\beta_8 \, Size + \beta_9 OD + \beta_{10} \hat{\Phi}_i + \beta_{11} OFI \hat{\Phi} + \beta_{12} \Delta P \hat{\Phi} + \beta_{13} TBD \hat{\Phi} +$$

$$\beta_{14} MBD \hat{\Phi} + \beta_{15} TV \hat{\Phi} + \beta_{16} AS \hat{\Phi} + \beta_{17} \sigma \hat{\Phi} + \beta_{18} \, Size \hat{\Phi} +$$

$$\beta_{19} OD \hat{\Phi} + \beta_{20} \phi$$

Panel A shows the coefficients for the Open Call while Panel B shows those for the Close Call
* and * * denote significance at the 0.1 and 0.05 levels respectively.