How to Open and Close the Market: Lessons from the London Stock Exchange*

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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 success decreases 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.

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1 Introduction

The open and close of markets have enormous significance for traders and regulators. The open assimilates the information gathered overnight, and thus performs an important information aggregation and price discovery functions while the close is important since the closing price serves important benchmark functions for a vast array of interested parties, particularly at important 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 while the New York Stock Exchange has a stabilized auction market at the open.

The latest example of the application of such position is the pressure on NASDAQ from regulators, such as the SEC, and market participants to adopt a call auction for the open and close (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 to close the market. Instead it has introduced the so-called NASDAQ Official Closing Price (NOCP), which incorporates a limited call auction element into the present dealer quotes system. While NASDAQ has not yet implemented any changes to its opening procedures, a similar hybrid system is expected to be introduced in 2004.

The existing literature on opening mechanism has focused exclusively on the price discovery issue of *single mechanisms operating alone*. 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, this time 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. On the other hand, Madhavan and Panchapagesan (2000) use the open on the NYSE (which uses a stabilized auction mechanism) and show that specialists set more efficient prices than would an auction with public orders and in this way they facilitate price discovery. Turning to the evidence on closing calls, Pagano and Schwartz (2003) show that the introduction of a closing call on the Paris Bourse has improved market quality in that it resulted in lower transaction costs for traders and better price discovery.

This paper differs from the existing literature in that it does not solely focus on the price discovery process in the pre-opening period but is rather interested in analyzing the actual performance along different dimensions, including the price informativeness, of *two different trading systems - the call mechanism versus the dealership mechanism - operating at the same time* during market open and close under different market conditions. 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? And, given NASDAQ's caution with respect to call auctions, can we say anything about the best trading mechanism for opening and closing markets?

We document evidence that sheds light on these questions. Our investigation is made possible by the unique natural experiment afforded by the institutional structure of the London Stock Exchange (LSE). Uniquely among major stock exchanges, the LSE operates a parallel trading system in which the main order-driven auction trading mechanism (SETS) operates alongside an "off-exchange" dealer system. The opening and closing trades on the order book system (SETS) are determined by the outcome of a call auction[1], while the dealer system relies on the traditional bid-ask quotes of market makers. In such a set-up traders have a choice at the open and close since they can either submit an order to the call auction or go to the dealer system. The choice offered to traders on where to execute their trades provides a natural experiment on the relative advantages of these two systems. Another reason that makes the LSE a good natural experi-

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

ment is given by the fact that, in contrast to NYSE specialists, London dealers' participation is entirely voluntary since they do not have price continuity obligations, and do not have any obligations to quote prices at all. Most importantly, we can document how these costs and benefits 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 much of the mainstream academic literature on market microstructure that emphasizes the importance of asymmetry of information among traders. 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 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].

Contrast this position with the findings by Angel and Wu (2001) who examine a simulated call auction on NASDAQ using actual NASDAQ orders. They 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. Specialized intermediaries such as market makers may do a better job of buffering those air pockets than investors. 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]

We argue that in the real world, liquidity is often latent: if *all* the liquidity in the market came to the call auction, then the price will be close to the efficient markets price. However the call auction only attracts the tip of the liquidity iceberg, and the rules of a call can make this worse - everybody wants everybody else to show everything early, while they want to show nothing themselves. In other words, the concern is that even though the call auction would perform well if all traders submitted their reservation prices into the call, no-one can guarantee that all interested parties will do this. This argument is closely related to the ideas behind the coordination motives for trade. The idea is that one 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.

In doing so, we shall be drawing on one major literature strand: the thick market externalities concept. For example, 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. Pagano (1989) outlines a model in which the depth and liquidity of a market depends 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 auction market than for the dealership market. In other words, the potential gains from trading in the call market is 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. For example, Shin (1996) shows how price uncertainty may reinforce any reluctance to trade in a call auction, which then has the potential to become self-fulfilling. In contrast, a dealership market is much more robust to detrimental feedback effects. Dealers can short-circuit the vicious circle of price volatility and lack of liquidity, leading to more price volatility.

We 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 important factors at work in the choice of markets 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. Furthermore, we also use a multinomial logit analysis to analyze the determinants of the success and failure of the call and dealership systems at the open and close under different market conditions. We find that call auctions are at their worst for small and medium sized stocks, especially on slow trading days, and even for large stocks call auctions perform less well on days when (a) trading is expected to be slow, (b) price uncertainty is high, (c) the order flow is unbalanced, and (d) adverse selection costs are high. The results indicate that traders are willing to pay the higher trading costs on the dealership system at the open rather than migrating to the call auction where no spread is paid. We go on to identify the market-wide factors that determine the probabilities of the dealership and call auction to (a) function separately, (b) function jointly, and (c) fail to function.

This paper is organized as follows. Section 2 outlines the hypotheses tested. Section 3 describes the institutional details of the market open and close on the LSE. Section 4 explains the data. Section 5 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 6 presents the results on individual trader's choice between call and dealership and estimate the probability of each system's success under different market conditions. Section 7 concludes.

2 Related Literature and Hypotheses

The benefits of temporal consolidation of the order flow in a call auction have been well-documented (Schwartz, 1991). Besides the fact that the call has a zero spread, there are the advantages of minimal market impact, fairness of a single price, "bagging" of limit orders, and insurance against price uncertainty. In addition, because the call auction removes the risk associated with order sequencing, it will actually stabilize prices. Two potential problems of call auctions concern transactions uncertainty, and the possibility that the submission of actual orders may differ from traders' reservation prices. On the other hand, in a dealership system intermediaries quote prices at which they are willing to buy and sell quantities of the security, and investors approach one or more dealers sequentially to execute a trade.

We now relate the call's advantages and disadvantages at the daily open and close of a stock market with the functioning of an alternative dealership system. We first make the comparison within a theoretical framework in order to draw out testable hypotheses about which trading systems will be chosen by traders at the open and close of markets.

The dominant paradigm in the market microstructure literature over the last twenty years has been strategic trading with private information and the adverse selection problems that arise from this setting. In examining alternative trading systems, Madhavan (1992) compares a quote driven mechanism with competing dealers with an order driven mechanism that may be organized as a continuous or as a periodic auction. Madhavan demonstrates that at times of information asymmetry the periodic call auction functions well where a dealer market fails. This occurs because pooling orders for simultaneous execution in a call auction overcomes the problems of information asymmetry. The implication of this result is that a call auction will be a more robust trading mechanism for (a) securities that suffer from high adverse selection problems, or (b) on days when asymmetric information is high.

An alternative theory of trading behavior outside the standard asymmetric information setting is based on the coordination motives for trade. Pagano (1989) outlines a model in which the depth and liquidity of a market depends on the conjectures that traders make about the trading decisions of others; higher participation encourages further participation, thereby amplifying the gains. Pagano shows that if the traders can choose to trade in different markets, they will all prefer to trade on the same market. This is because the liquidity value effect of that market increases, and dominates the speculative value. We can extend the ideas from Pagano (1989) to generate a testable hypothesis for our market set-up. A trader's decision to submit an order will depend on the likelihood that her order will be executed. This in turn depends on how many other traders on the other side of the market have decided to submit orders. This coordination problem is central to the functioning of the call auction but not to the dealership market. This is because traders need to find a counter-party on the call market whereas there is always a counterparty in the dealership system. In the case of the call, buyers (sellers) will be more likely to enter a call auction if they believe that there will be many sellers (buyers). Diamond (1982) calls these spillover effects "thick market externalities" where the gains from trading is a function of the number of traders that are expected to choose to trade at a particular marketplace. The higher trading activity in the market, the easier it will be for traders to transact, resulting in bigger gains from participating in trading activity.

A number of papers have linked together the coordination motives for trade within an asymmetric information environment. For example, Admati and Pfleiderer (1988), Foster and Viswanathan (1990) and Chowdhry and Nanda (1991) examine the effect that discretionary liquidity traders have on market equilibrium. These discretionary traders have coordination motives to minimize trading costs. Admati and Pfleiderer (1988) demonstrate that uninformed investors trade in those periods when they believe the market will be most liquid, which is when other liquidity traders are trading. There will be more informed traders in these high volume periods and they will compete with each other and reduce each others' profits to the benefit of liquidity traders. Similarly with multiple trading venues, Chowdhry and Nanda (1991) show that traders will converge on the market with the highest liquidity, even though it may be the one with the highest concentration of informed traders. Foster and Viswanathan (1990) assume long-lived private information that depreciates over time due to regular public signals. In this case discretionary liquidity traders will defer trading to a time later in the trading day when public information is revealed, and informed traders trade more aggressively early in the period while they still have private information. The implication is that more information will be revealed on comparatively low trading volume. In contrast Admati and Pfleiderer are unable to predict the specific time of day that trades will be coordinated.[2]

The differences between the two contrasting theories of asymmetric information and coordination motives have strong predictions about where traders will choose to locate when dealing in certain types of stocks and under different market conditions. One such prediction is where to trade medium-sized and smaller stocks. According to the adverse selection models of Madhavan (1992), since asymmetric information is likely to be more prevalent in smaller stocks, we would expect the benefits of the call auction to be at their greatest, and trades in these securities 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.

Another variable that will allow 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 theory predicts that traders prefer to trade on the call auction. In contrast, the coordination theory suggests that increased uncertainty will deter traders from submitting orders to the call

[2] O'Hara (1995) points out that the conclusions of these models are very sensitive to the assumptions made and the strategy spaces allowed for by the discretionary liquidity traders.

since it is less likely traders expect to find a match. With increased uncertainty, traders who wish to execute a trade are more likely to go to the dealer market.

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 auction market than for the dealership market. In other words, the potential gains from trade in the call auction market is more sensitive to the degree of participation from other traders, as compared to the dealership market. Therefore an additional variable that will allow us to discriminate between the two theories is the degree of market activity expected on a particular day. If the extent of market activity is expected to be high, then the coordination motive for trade will encourage traders to place orders in the call auction. One measure of market activity is the volume of daily trade. On days when traders expect the market to be active, characterized by high trading volumes, then the coordination theories would predict that it is more likely that traders will submit orders to the call auction, confident that their trades will be executed. Another measure of market activity is the number of firm orders submitted in the bidding process just prior to the execution of the call auction.

However, trading volume can have wider implications for the trading process since high volume could be driven by the presence of informed traders or liquidity traders or both. In this sense, increased trading volumes may be indicative of informed trading. According to Madhavan (1992) these circumstances will then lead to traders preferring the call auction. One testable hypothesis from the Admati and Pfleiderer (1988) model is that high volume periods, due to informed and discretionary and non-discretionary liquidity traders concentrating their trades, also produce more informative and highly volatile prices. On the other hand, a prediction from the Foster and Viswanathan (1990) model is that low volumes are associated with higher volatility (since trading is driven by informed traders). These two models imply that volume should be interacted with price volatility - the latter acting as a proxy for the presence of informed traders

- to investigate traders' preference of trading location.

We have identified a set of competing hypotheses between two alternative microstructure approaches to investigate which trading system will be chosen by traders to trade at the open or close of the market.

Adverse Selection Hypothesis: In choosing the trading location - call versus dealership - traders will trade on the market that is robust to adverse selection and uncertainty. Hence:

i. For smaller stocks (prone to asymmetric information concerns) traders prefer to trade in the call auction where information asymmetries are resolved efficiently;

ii. On days with high uncertainty traders will prefer to trade in the call auction;

iii. Trading volumes:

a. When *both trading volume and price volatility are high* discretionary traders prefer the call auction where adverse selection issues are resolved efficiently (following from Admati and Pfleiderer);

b. When *trading is low and price volatility is high* traders prefer the call auction (following from Foster and Viswanathan).

Coordination Hypothesis: In choosing the trading location traders will choose the market that minimizes the coordination problems.

i. For smaller stocks traders shun the call auction where coordination problems are acute, and instead prefer to trade through an intermediary;

ii. On days with high levels of uncertainty traders will shun the call auction because of increased coordination problems and will trade in the dealership system;

iii. Trading volume:

a. For any given stock, the call auction is more likely to function on days when market activity (as measured by trading volume) is expected to be high;

b. There is *no relationship* between the call's functioning and a measure that *interacts trading volumes with price volatility.*

3 Institutional Details

With the introduction of SETS in October 1997 the LSE also changed the way 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 then introduced a call auction at the close. We first give some institutional details of the opening call and then proceed to describe the closing call.

3.1 Opening Call Auction

The opening call auction algorithm has evolved since its introduction. Originally only limit orders were allowed during the pre-opening period - the 10 minutes immediately before the official opening of the market. During the pre-open, orders may be cancelled and the Exchange disseminates the best bid and ask prices submitted, if there are any. 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.

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 one by one, but there is 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 the SETS securities. In practice, however, given (a) the absence of sufficient limit orders in the pre-opening period for the entire list of SETS securities, and (b) following the enhancements aimed at making the algorithm run faster, matching never hits the ceiling of this time configuration (three minutes). In fact, the data at our disposal shows that the call algorithm rarely takes more than 30 seconds to execute. No trading in any SETS security can take place while the algorithm is running. 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.

This opening mechanism has undergone a number of structural changes over the period 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 major changes in the opening time through the call. From SETS's introduction until 20 July 1998, the opening time was set at 08:30 a.m. (pre-open period 08:20 a.m. to 08:30 a.m.). Between 20 July 1998 to 20 September 1999 the opening time was set at 09:00 a.m. (pre-open period 08:50 a.m. to 09:00 a.m.), and after such date the market's opening was set at 08:00 a.m. (pre-open period 07:50 a.m. to 08:00 a.m.).

In addition to these opening hours changes, on 30 May 2000, the LSE introduced an additional series of measures to make the opening call more attractive. by giving a more robust structure to the way the call runs. The main changes implemented in the opening call 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 new 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, the 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 with the normal time priority being applied to the market orders. The pre-opening phase takes place between 07:50 a.m. to 08:00 a.m. after which the call matching algorithm runs and during which the continuous trading mode is disabled. The random end of the call is configured to be between 0-999 seconds, but in practice it takes 30 seconds to run. 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.

3.2 Closing Call Auction

The closing call auction was introduced on 30 May 2000, as part of a broader package of reforms to the SETS system. 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 for the closing call is identical to the opening call. The price at which the execution takes place is based on the rules outlined above for the open 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 the continuous auction period (from 4:20 p.m. to 4:30 p.m.).

3.3 Dealership Market

In addition to the SETS system, trading may also take place "off-exchange", through a dealership system. Dealers providing liquidity off-exchange act as voluntary market makers and not as obligatory market makers, as was the case prior to October 1997. These dealers, as members of the LSE, must follow trade reporting rules. Exchange rules require that non-order book trades should be reported within three minutes of the trade's execution.

3.4 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 Exchange 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.

4 Data

Our dataset consists of a sample of constituents of the FTSE 100 and FTSE 250 indices because these (mostly liquid) securities are the ones with access to both the SETS system and the off-exchange dealer facility. In May 2000 when the closing call auction was introduced, 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 limit prices. We merge the trade dataset and the order history dataset to build the entire order book for the entire trading day using an algorithm that takes into consideration the date and time when an order is submitted and when it is either executed or cancelled. Trades data from the SETS system (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. As 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, all trades in the call auction were time-stamped at exactly 09:00 a.m. or 08:00 a.m. depending on the time when the call took place (refer to the Institutional Design Section for more explanation). As from 30 May 2000, the call trades are time stamped at the exact time (to the nearest second) 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. The rules require that "non order book trades" are reported within three minutes of the trade being executed. The quotes data provide the best ask and best bid quotes on the order book time-stamped to the nearest second. There is no quotes data from the dealership system.

[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 31st 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 bottom quintile of stocks are still rather large in absolute terms, but are dominated by the stocks in the largest quintile. 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 systems. The descriptive statistics in 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. It can be seen that as market capitalization falls there is less trading in the smaller securities, and for each market capitalization quintile, there is more daily volume going through the dealer system than the order book, both by value and number of trades. In addition the first trade of the day is typically larger on the dealer system than on the call.

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) but over a shorter period, i.e. from 30 May 2000 to 31 December 2000.[3] Examining Volume, Last Trade and Trades columns in Panel B we can see the same patterns observed in Panel A.

We now examine the volatility of returns on the order book over various time intervals and again we partition the sample into five categories by market capitalization. The summary statistics for these five size categories, and information on the volatility of returns are presented in Table 2.

[Table 2 here]

The volatility of returns is calculated as the standard deviation of daily returns and averaged across the stocks. Trades executed at various intraday time intervals on the order book over the period 30 May 2000 to 31 December 2000 are considered. The open-to-open volatility is always higher that the close-to-close volatility across all size categories. Our results for the larger stocks confirm the earlier findings for the NYSE by Amihud and Mendelson (1987) and Stoll and Whaley (1990). Given the institutional differences between London and New York, these findings are particularly noteworthy. Another interesting feature in Table 2 is that the open-to-close volatility is always higher than the overnight (close-to-open) volatility again across all size categories. This implies that stock returns are more sensitive to information that is released throughout the day,

[3] In Panel B there are more securities in each quintile, because the dataset includes the smaller stocks in the FTSE250 index, so the average market capitalization of each quintile is smaller than in Panel A.

than when the market is closed.

Having examined patterns in return volatilities, we now turn to examining spread patterns on the two systems. The quoted spread on the order book are the best quotes obtained directly from the order book's continuous trading phase, since there is no spread on the call auction at the open or close. The order book spreads are reproduced in Panel A of Table 3, averaged across all stocks in each size category at various daily time intervals. Since the bid-ask spread in the dealer market is not publicly available we use the Roll (1984) estimator in order to get a measure of the dealers' effective bid-ask spreads in the following way:

$$S = 2\sqrt{-Cov(\Delta P_t, \Delta P_{t-1})}$$

where ΔP_t is the price change over a two-minute interval. The estimated bid-ask spreads are presented in Panel B of Table 3 for a variety of times during the day.

[Table 3 here]

Comparing spreads across the two panels it is generally the case that spreads on the order book during its continuous phase are slightly higher than those on the dealership, though these differences are not statistically significant. However there are two caveats. First as we explained above, we have quoted spreads for the order book but effective spreads for the dealership system. Secondly, since the dealership spreads are estimated from transactions prices there may be some selection bias in the trades that are routed to this system. It is clear that within each size category spreads narrow substantially throughout the day: for the smallest quintile of stocks spreads in the last five minutes of trading are half their size in the first five minutes; for stocks in the largest quintile spreads by the end of the day have been reduced to a fifth of their value at the start.

5 Differences in the Usage of the Call and Dealership

We initially examine differences between the call auction and dealer system at the open and close by comparing various properties of the trades taking place across the two systems. We shall proceed in the following manner: If the first (last) trade of the day occurs in the call phase we will say that the call auction functions at the open (close) for that stock on that day. The call auction will not function when the book is empty or it contains orders but the algorithm cannot match buyers and sellers. Any orders that are unexecuted at the end of the call auction, remain on the order book, unless they are cancelled. At the open, such unexecuted orders will be automatically eligible for execution during the continuous phase. We are also able to identify the first trade of the day in a stock on the dealership system. In order to make a similar comparison between trades on the dealership system and the call auction, we will say that the dealership system functions at the open 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 official opening of the day. We can define the call auction and dealership systems operating at the close in a similar manner. The closing auction takes orders after the markets close at 4.30 p.m. until 4.35 p.m., at which time the closing algorithm runs, and is typically completed by 4:37:00 p.m. A trade in the dealership at the close is defined as a trade that takes place in the interval 4.30 p.m. to 4.37 p.m.

We now proceed to make a direct comparison of the success of the call auction in opening and closing the market. As explained above we may categorize the call auction and dealership systems as operating at the open if a trade occurs on either system in the open time interval, i.e. ten minutes before to 30 seconds after the official open. We can define the call auction and dealership systems to function at the close in a similar manner. 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}. Tables 4 and 5 report the distribution of the different States at the open and close for each of the size quintiles. 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.

[Tables 4 and 5 here]

It might be conjectured 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 Table 4 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 from Table 5 the probability of both types of trading mechanism 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 on there being an opening on at least one system (shown in Exhibit 1 derived from Table 4).

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 Table 5).

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

In Exhibit 2, 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 has produced some interesting patterns. From Tables 4 and 5 we can see 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 trading costs for smaller stocks are higher than for larger stocks and this would suggest that traders of these stocks can benefit more by migrating to the call where no spread is paid. On the surface, these findings suggest support for the coordination hypothesis, rather than the adverse selection hypothesis. At the very least, we have sufficient grounds to develop a more systematic empirical investigation of the main effects.

The summary statistics so far give us a good idea of the *cross section* variation, but a better understanding of the problem can only be gained by looking at the variation of the open and close *over time*, and determining the factors that influence individual traders' decisions on where to trade and the market-wide impacts on the mode of opening and closure.

5.1 Price Discovery

Up to now we have found that the call functions only infrequently at the open, but that the dealership system is a more popular trading venue at the open. But what can we say about the price discovery process? Which system has the most efficient 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 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. They find that the non-binding 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 auction and the dealership market. 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. We use actual call and dealership prices from the open and call periods. For each stock, we compare the open call price with the average mid-quote on the order book between 8:45 a.m. and 9:15 a.m.. Likewise, for each stock we compare the dealership prices at the open with the average trade prices on the dealership system between 8:45 a.m. and 9:15 a.m.. For the closing period, we compare the closing call price (closing dealership price) with the average mid-quote (average trade price) on the order book (on the dealership system) between 3:45 p.m. and 4:15 a.m.

[Table 6 here]

Table 6 shows that the call auction, 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 decile we also find that the absolute deviation is lower for the closing call rather than the dealership system (0.245% against 0.337%). However, three of the top five deciles produce call deviations that are not statistically significantly different than the dealership deviations. On the other hand, we also find that, with the exception of stocks in the bottom decile, the bottom five deciles produce call deviations that are smaller than the dealership deviations. We also use different benchmark periods (around noon for the open and around 3:00 p.m. for the closing call) but the results do not change.

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. - 8:01 a.m. The close period is defined as 4:30 p.m. - 4:37 p.m.

In line with 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 for both the order book and the dealership system. As explained above, trades on the London Stock Exchange fragment between the two systems but arbitrage considerations dictate that prices on the two systems cannot diverge from each other. Since we do not have one price for the entire market (although the official price is the one produced by the order book) we calculate the WPC for the call market (dealership market) using prices from the order book (dealership system). Furthermore 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 7 here]

Table 7 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. The interesting result is that the open call's WPC is larger than the dealership for the two top quintiles by market capitalization while the dealership's WPC shows that more information is impounded at the open for the bottom two quintiles by market capitalization. The amount of information impounded in the prices at the close is, an average, double that during the open (for the call, the WPC at the close is 15.8% and 7.4% at the open).

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 opening (and closing) dealers' quotes to the dealership's WPC. In fact, for three of the five market capitalization quintiles we find that the difference between the call's WPC contribution and the dealership's WPC contribution is statistically significant.

6 Choosing Between Call and Dealership Markets

We now model the decision of traders in choosing which system to use at the open and close of the market. 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 on their unobserved heterogeneity and in part on expected trading costs. This calls for a careful consideration of selection biases before presenting convincing evidence on the performance of call and dealership markets.

6.1 An Endogenous Switching Model

Traders migrate to one trading system rather than another at the open and close depending on which one will provide the best execution for their orders. We assume that traders want to minimize trading costs and this objective will decide where to submit their order/s. In other words, we can perceive investors as solving a discrete choice problem. Conditional on deciding to submit an order, a trader will have a two-way trading avenue choice: (a) send the order to the call market, or (b) send the order to the dealer market. The fundamental issue to deal with here is to acknowledge that with unobserved heterogeneity it is possible that selection biases will have an impact on the choice of market mechanism.

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 - denoted by "C" - or the dealership system - denoted by "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 $\theta_{A,i} > 0$, 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 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 $\lambda^{'}$ 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:

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

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 based in their unobserved heterogeneity. So, for example, an impatient trader who wants to minimize execution costs will choose to trade in the dealer market rather than a call market. Hence the system chosen by the trader is endogenously determined.

This means that the trader's unobserved heterogeneity will influence the trading venue's choice and the trading costs in the venue. This will translate in a situation 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 selectivity 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).

The objective of measuring correctly the trading costs is rendered difficult by the different natures of the call auction and the dealership system. The bid-ask spread does not constitute a good measure for our purpose because although we can measure the spreads on the dealership system we cannot do so for the call auction given that 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 to measure equation (1) 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 variables that provide information on investors' intentions.

The following are the dependent 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 auction 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 amounts of 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 bidders 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) provides a model of multi-unit auctions where the "champion's plague" is obtained. The idea is that multi-unit auctions have the feature that the assets are shared amongst different buyers. After the auction the bidders generate their own conditional expectations of the asset's value based on the amount of shares they have won. In cases where the bidders' valuations are interdependent the "champion's plague" is obtained, i.e. the news is worse the more shares the bidder wins. One of the decisions facing traders in 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 the "champion's plague" argument to the call auction we conjecture that when uncertainty is high bidders will prefer not to participate at all in call auctions, 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}):** We want to capture the (voluntary) dealer's inventory behavior because their portfolio rebalancing activities 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 the dealership might be biased because of a dealers' inventory positions that they inherit 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 and this is provided by the open call (Hansch, Naik and Viswanathan, 1998). Likewise, a dealer that has experienced shocks to his inventory during the trading day would want to attempt to re-balance his position towards the end of the trading day. Given that the closing auction is the last possible opportunity for inventory re-balancing 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 he does for each single day and compute the imbalance at the end of continuous trade (for the close auction) and after the closing call (for the open call). For the open auction 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 auction we use the dealers' inventory position during the present day (hence closing call auction on day T we use the dealers' inventory position on day T).

(d) **Adverse Selection component (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 (Madhavan 1992) predict that the call mechanism is robust to the presence of asymmetric information and hence would predict that traders will use the call auction 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 if these uncertainties are large enough they could induce traders to just withdraw from the trading process.

In addition to the variables listed above, we also use the **Order Size** (OS_{ijd}) of every order submitted to the call market and the trade's size of orders executed on the dealership system to capture the trader's characteristics. Existing literature has already shown that different traders, with different trading objectives, make use of different order sizes. 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 during the overnight period. Days following the issue of significant news (earnings announcement, dividend announcement and mergers) take a value of 1 and 0 otherwise. The news dummy can also be taken as a proxy for uncertainty.

(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 want to control for the presence of some components of the FTSE 100 Index that are listed on the New York Stock Exchange. The overnight period is shorter for these stocks and this should influence trading behavior in the opening and closing periods.

6.1.1 Results

Table 8 shows the results of the endogenous switching regression model for both the open (Panel A) and the close (Panel B).

[Table 8 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 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.

Overall, these results provide preliminary support for the coordination hypothesis. When the presence of informed traders (captured by the adverse selection component of the spread) increases, trading costs on the call market are higher than the dealership market. Furthermore, when price uncertainty is high we also find that trading costs are higher on the call market. If trading costs are higher on the call when adverse selection and price uncertainty are high, we would expect that traders will not choose to trade on 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 and would lend support to the trading coordination hypothesis.

6.2 Multinomial Logit Analysis

Having identified an individual's trading location decision we now want to go on and examine the factors that determine whether the market functions at the open and close and, if it does, which system attracts the order flow. As stated above, the market could be in four different states at the open or close: Inactive Market (State 1), the call mechanism functions *exclusively* (State 2), the dealership market functions *exclusively* (State 3), or Both Systems function together (State 4).

It is straightforward to define orders executed at the open and close call, but less so for the dealership system. As in Section 3 above, we shall define dealership trades at the open as those executed between 7:50:00 a.m. and 8:00:30 a.m. (or the equivalent period when the open started at different times) while trades at the close as those executed between 4:30:00 p.m. and 4:37:00 p.m. (or the equivalent period when the close was defined differently).

Two notes of caution must be made at this stage. In this set-up, the dealer market's success or failure depends on an order actually getting executed at this trading location. Obviously, voluntary dealers should always be ready to trade and they provide their quotes at which they stand ready to trade. In that sense, the dealership system cannot fail. Hence, our measure of success is not based on the mere provision of a quote but rather that the quote is competitive enough to attract a trader to the dealership system. Secondly, given that dealers have up to three minutes to report their trades and if we allow for slow or inexact trade reporting (even if by few seconds) could result in bias against the dealership system in that if an order actually took place at the open (or the close) on the dealership but got reported slightly after 8:00:30 a.m. (after 4:37:00 p.m.) it would not be counted for this analysis. We come back on this point below when we discuss the robustness of our results.

A natural way to model these outcomes is to estimate a multinomial logit model which is appropriate for non-ordered outcomes. In a multinomial logit model, the probability that state y occurs depends on a set of explanatory variables (covariates) X. We estimate a set of coefficients $\beta(y)$ corresponding to each outcome y.

The estimated model for the close has the following form:

$$\begin{aligned} Close_{dj} &= \alpha + \beta_1 OFI_{dj} + \beta_2 \Delta P_{jd} + \beta_3 BD_{jd} + \beta_4 H_{jd} + \beta_5 TV_{jd} + \beta_6 \sigma_{jd} \\ &\quad + \beta_7 MCap_j + \beta_8 RM_d + \beta_9 R_{jd} + \beta_{10} News_{jd} + \beta_{11} DI_{jd} \\ &\quad + \beta_{12} AS_{jd} + \beta_{13} \Upsilon_{jd} + \beta_{14} \sum_{k=1}^{5} DDum_k + \beta_{15} CSDum_j + \varepsilon_{dj} \end{aligned}$$

where $Close_{dj}$ is the dependent variable, the market closing's mode for security j on day d.

The estimated model for the open has the following form:

$$\begin{aligned} Open_{dj} &= \alpha + \beta_1 OFI_{dj} + \beta_2 \Delta P_{jd} + \beta_3 BD_{jd} + \beta_4 BD_{jd-1} + \beta_5 H_{jd} + \beta_6 TV_{jd} \\ &\quad + \beta_7 \sigma_{jd} + \beta_8 MCap_j + \beta_9 RM_d + \beta_{10} R_{jd} + \beta_{11} News_{jd} + \beta_{12} DI_{jd} \\ &\quad + \beta_{13} AS_{jd} + \beta_{14} \Upsilon_{jd} + \beta_{15} \sum_{k=1}^{5} Dum_k + \beta_{16} CSDum_j + \varepsilon_{dj} \end{aligned}$$

State 1 (no trade at open or close) is the base case and all the coefficients obtained will be in respect to State 1. Most of the explanatory variables have been described previously. In addition to the variables explained above, we include the following variables in the multinomial logit:

(a) **Firm's size ($MCap_j$):** The idea behind thick market externalities is that they allow better coordination among traders when there are a large number of potential traders. A trader is more likely to find counter-parties if she wanted to trade in a large firm rather than a medium-sized or smaller-sized firm where it is more likely that shares are closely-held. For the open call analysis we measure the firm's size by its market capitalization on 1 June 1998 while for the close call analysis we use market capitalization on 31 December 1999. According to the adverse selection theory, smaller stocks are more likely to be traded in a call auction. According to the coordination theory the call auction is less likely to execute for smaller stocks.

(b) **Volume - Volatility** (Υ_{jd}): One of the hypotheses to be tested deals with the interaction between volume and volatility at the open and close. In the asymmetric information models explained in Section 2, price volatility proxies for the presence of informed traders. Both the Admati and Pfleiderer (1988) and the Chowdhry and Nanda (1991) models claim that volumes will be high at times when discretionary liquidity traders and informed traders decide to trade. Informed traders will trade at such times because they can more easily find counterparties for their trades. The implication from these models is that whenever volumes are high they are accompanied by high adverse selection problems. On the other hand, the model proposed by Foster and Viswanathan (1990) shows that discretionary traders can separate out from informed traders. In their model the informed always trade early on during the day because this is where their information is most valuable. The discretionary traders know this and stay away from the market, so that at the open there will be low volumes but high adverse selection costs (which manifests itself by high price volatility). We capture the interaction of volume and the presence of informed traders by interacting volume with price volatility.

(c) **Daily Market return** (RM_d) and **daily own return (R_{jd}):** High absolute values for both of these variables are likely to attract traders to the market for portfolio balancing reasons, or because momentum/contrarian traders take a position in the stock. This will generate thick market externalities and make it more likely that the call auction function.

6.2.1 Results

We run the multinomial logit for each stock in our sample and we then take the cross-sectional average to report the results in Table 9. Following Ellul et al (2003) we do not report coefficient estimates from the multinomial logit but rather the impulse sensitivity. In this way we can better show the economic and statistical significance of every explanatory variable's impact on the market open and close. Following this we find the statistical significance of the impulse sensitivity itself.

[Table 9 here]

To compute the impulse sensitivities reported in Table 9, we define the benchmark probability of each event as the estimated logistic function evaluated at the mean of each of the explanatory variables. To compute the change in the probabilities (impulse sensitivities), we successively re-evaluate the estimated logistic function after adding a standard deviation to the mean of the explanatory variable of interest without shocking the means of the other explanatory variables. The reason for focusing on impulse sensitivities is that they are easier to interpret than the magnitude of the coefficients in a multinomial logit. In most cases, the sign of the multinomial coefficient estimate is the same as that of the impulse sensitivity, but not always.

Consistent with the coordination theory, the (a) order flow imbalance, (b) bid dispersion, (c) adverse selection costs, (d) price uncertainty, variables have a negative effect on the probability of the Call Only executing. On the other hand, (a) volume, (b) firm size, and (c) own return have a positive impact on the call's ability to close the market. This shows that traders - once they have decided to trade - will prefer dealership liquidity in uncertain market conditions. The state of the market variables also strongly influence whether the markets function or not and which one will emerge as the preferred system. For example, higher trading volumes and positive market and own returns have a positive impact on the likelihood of the Call Only executing, and these two effects make crossing at the close more probable (a negative effect on Neither Market), consistent with the thick market externalities hypothesis. Days of high volatility makes it less likely that the Call Only will execute, and more likely that no trade will occur at all. The coefficient on the adverse selection and the firm size variables are consistent with the coordination hypothesis: In the presence of adverse selection, the call is less likely to function. This shows that in the presence of uncertainty and at times characterized by slow trading activity and high adverse selection problems, traders shy away from the call market. Furthermore, the interactive variable between volume and volatility is found to have no impact of any significance on the closing mode adding more support to the coordination hypothesis. The evidence in Table 9 (and Table 10 discussed below) goes contrary to the prediction of the information asymmetries models - that suggest the call auction is an efficient mechanism for aggregating information asymmetries and resolving price uncertainty problems- and provides clear support to the coordination hypothesis.

The multinomial logit model on the determinants of the open are presented in Table 10.

[Table 10 here]

We have broadly similar conclusions from our investigation of the open, as we did for the close. Order imbalances and bid revisions representing uncertainty in the market makes it less likely that the call will function, and more likely that traders will migrate to the dealership. The impulse sensitivity for the dealership market for these two variables are higher at the open compared to the close. For example, while shocking the order flow imbalance with one standard deviation increases the Dealership Only state at the close by 1.5% (not statistically significant) the same shock increases the Dealership Only state by a significant 7.6% at the open. We also find that the level of market activity, as measured by volume, has a direct impact on the call and dealership modes and more so than at the close. For example, as volume increases by one standard deviation the Call Only state increases by 8.3% (against 9.1% at the close) and the Dealership Only decreases by 9.5% (as opposed to a decrease of 4.7% at the close). Smaller stocks are less likely to open via a call, and are more likely to open exclusively via the Dealership Only mode. In this regard, we can also see that the opening period is more sensitive to firm size than the close. For example, increasing the firm size by one standard deviation decreases the Dealership Only mode at the open by 7.8% (against 2.8% at the close). Furthermore, as adverse selection increases in the market traders migrate to the dealership system. Considering the different transparency regimes across the two systems makes this is a particularly interesting result. In fact, the average investor in such an environment prefers to show her identity to the dealer rather than make use of the anonymous characteristic of the call.

An interesting feature of our results is the probability of having both markets open or close together. One striking feature is that the both-markets strategy at the close is much more sensitive to market conditions that at the open. Table 10 shows that the event where *both markets open together* is only sensitive to the level of volume and the firm size. When volume is expected to be high traders prefer to trade on the call rather than have orders split orders between the two systems. The same behavior is seen for traders submitted orders for large firms. It appears that the call adds value to the trading community in these two instances since we find that the call-exclusive strategy dominates both the dealership-exclusive strategy and the both-markets strategy. On the other hand, Table 9 shows that it is more likely that the two markets function simultaneously at the close when (a) volume is expected to be high, (b) firm size gets larger, and (c) own returns get higher, while such outcome become less likely when (a) adverse selection is high, (b) dealers' inventory is high, (c) price revision is high, and (b) bid dispersion is high. These results suggest that, although the call-exclusive strategy remains the preferred one when trading volume is high and when firm size is large, the both-markets strategy becomes profitable for some traders indicating that better execution could be obtained by splitting the order flow to both markets. Moreover, the both-market strategy is also dominated by the dealership-only strategy when uncertainty is high at the close (high bid dispersion) or when issues of adverse selection are paramount.

In summary, we can draw a number of firm conclusions. Whether the call auction functions depends on there being a high level of market activity, low adverse selection, low uncertainty, and large market capitalization. The corollary of these findings is that the dealership mode is more likely to operate when market activity is expected to be low, adverse selection is high, uncertainty is high, and for smaller stocks. Our empirical findings lend support to the idea that thick market externalities allow better coordination among traders when there are a large number of potential traders, and when the potential gains from trade are large. With only a small number of potential traders, or when the potential gains are small, the concern that no counterparty can be found becomes self-reinforcing. If a trader is concerned that there could be potentially a limited number of trading partners, she will tend to (a) either not trade at all, or (b) trade on the dealer market, which leads to thin call auction markets.[4]

6.2.2 Robustness

We check the robustness of the endogenous switching model and of the multinomial logit 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 7:50:00 a.m. and 8:00:30 a.m. (4:30:00 p.m. and 4:37:00 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 and the multinomial logit taking into consideration - one at a time - dealership trades up to (a) 8:01:00 a.m., (b) 8:02:00 a.m., and (c) 8:03:00 a.m. for the open analysis, and dealership trades from 4:30:00 p.m. up to (a) 4:38:00 p.m., (b) 4:39:00 p.m., and (c) 4:40:00 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 Tables 8-10.

Next, we test for possible asymmetries between buyer- and seller-initiated orders and we reestimated both the endogenous switching model and the multino-

[4] These co-ordination features are an application of the recent literature on global games [(Morris and Shin (2000)].

mial logit 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 Tables 8-10, the overall outcome is not different than the one presented here.

We also checked for the endogeneity of normalized volume by using predicted volume. Again, the results obtained using predicted volume are similar to the ones obtained using normalized volume. 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 here.

7 Conclusions

This paper investigates the trading patterns at the opening and closing of the London Stock Exchange where traders can choose between a call auction and a dealership to place their orders. Our initial results identified a puzzle in the use of the dealership and auction markets at the opening and close of daily trading: although spreads are wider on the dealership market and higher for smaller stocks, we are more likely to see smaller stocks opening and closing using the dealership system. 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 investors' decisions on the choice of trading venue, and were able to discriminate between two alternative theories of market microstructure. We found little evidence for the adverse selection theories but substantial support for the coordination theories. Our results indicate that traders in smaller stocks prefer trading on the dealership to the call. In the presence of uncertainty traders shy away from the call, and prefer to trade on the dealership in uncertain market conditions. The call is popular on days with higher trading volumes, and when adverse selection measures are low. Our findings suggest is consistent with microstructure theories that take into account the coordination motive for trade based on “thick market externalities” in which the gains from trade depend on the number of other traders who decide to come to the market, rather than the pure asymmetric information theories.

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 auction market functions well for liquid securities, 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.

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Table 1: **Descriptive statistics for the securities traded on both the order book and the dealership system on the LSE**

Panel A: Securities used for the Opening Analysis							
	Market Cap		Price	Volume		First Trade	
Quintile	Mean	Median		x1,000		x10	
				OB	Dealer	OB	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		Price	Volume		Last Trade	
	Mean	Median		x1,000		x10	
				OB	Dealer	OB	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: **Volatility of Returns**

	Market Cap		Volatility of Returns (x 100)			
	Mean	Median	Over-night	Open-Close	Open-Open	Close-Close
Top 20%	21951	15022	1.56	2.85	3.12	3.03
Next 20%	5292	5286	2.12	3.06	3.63	3.04
Next 20%	2839	2739	2.30	3.34	3.94	3.64
Next 20%	1396	1298	2.12	3.31	3.54	3.58
Bottom 20%	468	447	3.27	3.96	5.01	4.77

The table reports descriptive statistics for the FTSE 100 and FTSE 250 companies employed for the "Opening" and "Closing" analysis for the period 30 May 2000 - 31 December 2000.

Market capitalization is in GBP million as at 31 December 1999. For each category, the Table provides the mean and median capitalization.

Volatility of Returns is the standard deviation of returns for trades executed on the order book over the period 30 May 2000 - 31 December 2000.

Table 3: **Quoted and effective spreads on both the order book and the dealership system on the LSE**

Capitalization Quintile	Entire Day	Interval 1	Interval 2	Interval 3	Interval 4
PANEL A: QUOTED SPREADS (%) ON THE ORDER BOOK					
Highest	0.534	2.702	2.151	0.554	0.564
2	0.818	3.821	3.241	0.844	0.866
3	1.118	4.072	3.597	1.151	1.165
4	1.374	4.214	3.825	1.546	1.538
Bottom	2.015	4.387	4.118	2.170	2.142
PANEL B: EFFECTIVE SPREADS (%) ON THE DEALERSHIP SYSTEM					
Highest	0.521	2.562	2.108	0.532	0.568
2	0.794	3.724	3.23	0.861	0.869
3	1.072	4.147	3.395	1.161	1.144
4	1.348	4.118	3.751	1.510	1.491
Bottom	1.941	4.225	4.035	2.089	2.058

The table contains descriptive statistics of the trading costs for the FTSE 100 and FTSE 250 companies for the period 30 May 2000 - 31 December 2000.

The quoted spreads (%), reproduced in Panel A, on the order book are the Best Quotes posted to the order book. The effective spreads, reproduced in Panel B, for the dealership is calculated using the Roll (1984) estimator.

In the column "Entire Day" we reproduce the mean quoted (effective) spread for the entire trading day (during the period 08:00 a.m. to 4:30 p.m.). We report the mean quoted (effective) spread in the first five minutes of trading (Interval 1); mean quoted (effective) spread in the first 15 minutes (Interval 2); mean quoted (effective) spread in the last 15 minutes (Interval 3); and the mean quoted (effective) spread in the last five minutes (Interval 4).

Table 4: **Opening procedures on the London Stock Exchange**

Capitalization Quintile	No Open	Call Only	Dealer Only	Both
Highest	7142	2938	3832	375
	[10.15%]	[4.17%]	[5.45%]	[0.53%]
2	7232	2034	4573	228
	[10.28%]	[2.89%]	[6.50%]	[0.32%]
3	7210	1518	4892	178
	[10.25%]	[2.16%]	[6.95%]	[0.25%]
4	7392	1410	5211	76
	[10.50%]	[2.00%]	[7.41%]	[0.11%]
Bottom	7611	1059	5400	72
	[10.81%]	[1.50%]	[7.67%]	[0.10%]

Chi square test for independence = 2660.94
p - value = 0.00

The table reports the number of firm-days for each type of opening procedure for the FTSE 100 stocks which were officially assigned to the limit order book system (SETS) on 1 June 1998. In parentheses we report the % of firm-days for each type of opening for the period 1 June 1998 to 31 December 2000. The column "No Open" reports the number of firm-days where there were no trades at the open neither through the Open Call nor through the Dealership Market; the column "Call Only" reports the number of firm-days where at the open there was trading **exclusively** on the Open Call; the column "Dealer Only" reports the number of firm-days where at the open there was trading **exclusively** on the Dealership Market; and the "Both" column reports the number of firm-days where at the open there was trading on **both** the Open Call and Dealership Market.

The Opening Period on the London Stock Exchange has gone through various changes over the period under consideration. From SETS's introduction until 20 July 1998, the open was set at 08:30 am (pre-open period 08:20-08:30 am). Between 20 July 1998-20 September 1999, the open was set at 09:00 am (pre-open period 08:50-09:00 am), and after such date the open was set at 08:00 am (pre-open period 07:50-08:00 am).

Table 5: **Closing procedures on the London Stock Exchange**

Capitalization Quintile	No Close	Call Only	Dealer Only	Both
Highest	179	230	167	4036
	[0.78%]	[1.00%]	[0.73%]	[17.60%]
2	223	423	325	3613
	[0.97%]	[1.84%]	[1.42%]	[15.75%]
3	368	504	765	2854
	[1.60%]	[2.20%]	[3.34%]	[12.44%]
4	517	92	1885	2168
	[2.25%]	[0.40%]	[8.22%]	[9.45%]
Bottom	667	46	2433	1444
	[2.91%]	[0.20%]	[10.61%]	[6.30%]

Chi square test for independence = 6162.08
p - value = 0.00

The table reports the number of firm-days for each type of closing procedure for the FTSE 100 and FTSE 250 firms which were officially assigned to the limit order book system (SETS). In parentheses we report the % of firm-days for each type of closing. The period is 30 May 2000-31 December 2000. The column "No Close" reports number of firm-days where there were no trades at the close neither through the Close Call nor through the Dealership Market; the column "Call Only" reports number of firm-days where at the close there was trading **exclusively** on the Close Call; the column "Dealer Only" reports number of firm-days where at the close there was trading **exclusively** on the Dealership Market; and the "Both" column reports number of firm-days where at the close there was trading on **both** the Close Call and Dealership Market.

The Close Period is defined as starting at 4:30 pm until the end of trading on the Close Call which normally occurs around 4:37 pm.

Table 6: **Mean Absolute Differences in the Call and the Dealership Markets**

	Panel A: Opening Using 9:00am prices			Panel B: Closing Using 4:00pm prices		
Market Cap	Call	Dealers	**t-stat**	Call	Dealers	**t-stat**
Highest	0.759	1.281	**8.55**	0.245	0.337	**5.22**
2	1.014	1.315	**7.81**	0.317	0.329	1.57
3	1.301	1.489	**7.29**	0.364	0.453	**4.59**
4	1.436	1.615	**7.02**	0.391	0.364	1.48
5	2.025	2.304	**6.84**	0.439	0.477	1.62
6	2.257	2.618	**6.47**	0.480	0.615	**5.06**
7	2.881	3.042	**5.17**	0.531	0.705	**7.49**
8	3.141	3.181	1.55	0.587	0.788	**8.05**
9	3.755	3.416	2.11	0.704	0.765	**2.59**
Lowest	3.921	3.854	1.48	0.901	0.925	1.25

The table reports the Mean Absolute Difference (in %) of prices generated by the Call Market and the Dealership Market from prices at different periods during continuous trading. Panel A reports the Mean Absolute Differences between the Opening Call's price and the mid-quote on the order book at 9:00 am. Similarly, we also report the Mean Absolute Difference between the Dealership Market's opening trade and the price on the dealership system at 9:00 am. Panel B reports the Mean Absolute Difference (in %) between the prices on the Closing Call and the Dealership Market from the mid-quote on the order book at 4:00 pm and the price on the dealership system sampled at 4:00 pm. The period under consideration is 30 May 2000 - 31 December 2000. The t-statistics of the differences between the Mean Absolute Difference are also reproduced.

Table 7: **Weighted Price Contribution on the Call and the Dealership markets**

	Panel A: Call Market				
	Time Periods				
Capitalization Quintile	7:50 am - 7:55 am	7:56 am - end of call	8:00:30 am - 16:29 pm	4:30 pm - 4:37 pm	4:38 pm - 7:50 am
Highest	0.009	0.105*^{A}	0.694*	0.192*^{A}	0.0
4	0.008	0.084*^{A}	0.727*	0.181*^{A}	0.0
3	0.005	0.075*	0.765*	0.155*^{A}	0.0
2	0.006	0.058*^{A}	0.794*	0.142*	0.0
Lowest	0.004	0.049*	0.826*	0.121*	0.0
Overall	0.007	0.074*^{A}	0.762*	0.158*^{A}	0.0

	Panel A: Dealership Market				
	Time Periods				
Capitalization Quintile	7:50 am - 7:55 am	7:56 am - end of call	8:00:30 am - 4:29 pm	4:30 pm - 4:37 pm	4:38 pm - 7:50 am
Highest	0.005	0.081*	0.762*	0.151*	0.001
4	0.006	0.072*	0.771*	0.149*	0.002
3	0.005	0.071*	0.788*	0.135*	0.001
2	0.004	0.068*	0.794*	0.131*	0.003
Lowest	0.002	0.055*	0.816*	0.125*	0.002
Overall	0.0045	0.0695*	0.7861*	0.1380*	0.0017

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 system. Both panels are for the FTSE 100 securities. 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} indicates that the difference between the values for the Call and the Dealership Market is significant at the 10% level.

Table 8: **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:

$$y_{s,i} = \beta_0 + \beta_1 OFI + \beta_2 \Delta P + \beta_3 TBD + \beta_4 MBD + \beta_5 TV + \beta_6 AS + \beta_7 \sigma + \beta_8 \mathrm{Si}\,ze + \beta_9 OD + \beta_{10}\hat{\Phi}_i + \beta_{11} OFI\hat{\Phi} + \beta_{12}\Delta P\hat{\Phi} + \beta_{13} TBD\hat{\Phi} + \beta_{14} MBD\hat{\Phi} + \beta_{15} TV\hat{\Phi} + \beta_{16} AS\hat{\Phi} + \beta_{17}\sigma\hat{\Phi} + \beta_{18}\mathrm{Si}\,ze\hat{\Phi} + \beta_{19} OD\hat{\Phi} + \beta_{20}\phi$$

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.

Table 9: **Impulse sensitivities (in percent) for the close procedure**

		Call Only	Dealer Only	Both	No Crossing
Order Flow Imbalance		**-2.4594***	1.5496	-2.0148	**2.9246***
Price Revision		**3.6461***	**3.7266***	**-7.5541****	0.1815
Bid Dispersion (Close Call)		**-4.8136***	**5.5346****	**-8.0847****	**7.3637****
Order Flow Competition		-0.5593	0.3891	-0.5008	0.6709
Dealers' Inventory		**-2.3556***	**2.9227***	**-4.3264***	**3.7593***
Volume		**9.0554****	**-4.6594***	**5.2731****	**-9.6690****
Adverse Selection		**-3.4402***	**2.7659***	**-3.7233***	**4.3975***
Volatility		**-2.2496***	1.1632	-1.6262	**2.7126***
Firm Size		**3.5531***	**-2.8405***	**3.8174***	**-4.5301***
Market Return		1.6133	-0.8236	0.9282	1.7179
Own Return		**4.1842***	**-2.2649***	**2.6298***	**-4.5491***
News		-0.1059	0.0606	-0.0722	0.1175
Volume*Volatility		-0.5022	-0.4759	0.9759	0.0022
Pseudo R^2	0.0618				

The table shows the impulse sensitivities for the four different states in the closing procedure on the London Stock Exchange. The impulse sensitivities are obtained from the multinomial logit procedure and shocking the mean of one variable each time with one standard deviation while leaving the values of other variables unchanged. Order Flow Imbalance is calculated as the imbalance between buy and sell volume of orders submitted every minute during the pre-close algorithm and weighted by the time elapsed from the beginning of the auction. Price revisions measures the absolute price revisions from the start of the pre-close algorithm until its end. Bid Dispersion is measured as the standard deviation of the volume-weighted bids submitted during the pre-close algorithm. Order Flow Competition is the concentration of orders submitted during the pre-close algorithm and is measured by the Herfindahl Index. Dealers' Inventory is the net position of each dealer's buy and sell trades from the day's open of trading until the close at 4:30 pm. Volume is the normalized Sterling-Volume during the last hour of continuous trading (from 3:30pm to 4:30pm). Adverse Selection is measured as the level of the adverse selection component of the actual bid-ask spread from the order book in the last hour of continuous trading using the Booth, Lin and Sanger (1995) methodology. Volatility is calculated as normalized standard deviation of returns in the last half hour of continuous trading. Firm Size is measured as the market capitalization on 31 December 1999. Market Return is the open-to-close returns of the FTSE 100 Index. Own Return is the security's open-to-close returns for each day. News is a dummy variable and takes a value of 1 when significant news is issued by a firm. Volume* Volatility is an interactive variable between the normalized Sterling volume and the normalized standard deviation of returns. **, and * denote significance at 0.01, and 0.05 levels respectively. The period covered is 30 May 2000 to 31 December 2000.

Table 10: **Impulse sensitivities (in percent) for the open procedure**

	Call Only	Dealer Only	Both	No Crossing
Order Flow Imbalance	**-3.0342***	**7.5747****	-0.4745	**-4.0660***
Price Revision	**1.7626***	-1.4309	-0.9111	0.5795
Bid Dispersion (Open Call)	**-3.5851***	**8.6444****	-0.4387	**-4.6205***
Bid Dispersion (Close Call)	-0.0834	0.2620	-0.0345	-0.1440
Order Flow Competition	0.9663	0.1375	-0.8683	-0.2355
Dealers' Inventory	**-4.9826***	**7.0033****	1.3996	**-3.4202***
Volume	**8.3367****	**-9.5115****	**-3.2106***	**4.3854***
Adverse Selection	**-1.6004***	**3.3601***	0.0026	**-1.7622***
Volatility	**-1.7378***	**2.5409***	-0.3950	**-2.4081***
Firm Size	**5.9691****	**-7.8049****	**-1.9013***	**3.7371***
Market Return	0.6392	**-1.6287***	0.1137	0.8758
Own Return	**4.2700***	**-5.3422***	-1.4568	**2.5290***
News	-0.1123	0.3064	-0.0281	-0.1440
Volume*Volatility	-0.4335	-0.6044	0.6074	0.4306
Pseudo R^2 0.0425				

The table shows the impulse sensitivities for the four different states in the opening procedure on the London Stock Exchange. The impulse sensitivities are obtained from a multinomial logit procedure and shocking the mean of variable each time with one standard deviation while leaving the values of other variables unchanged. Order Flow Imbalance is calculated as the imbalance between buy and sell volume of orders submitted every minute during the pre-open algorithm and weighted by the time elapsed from the beginning of the auction. Price revisions measures the absolute price revisions from the start of the pre-open algorithm until its end. Bid Dispersion (Open Call) is the standard deviation of the volume-weighted bids submitted during the pre-open algorithm. Bid Dispersion (Close Call) is the standard deviation of the volume-bids submitted during the previous day's Close Call. Order Flow Competition is the concentration of orders submitted during the pre-open algorithm and is measured by the Herfindahl Index. Dealers' Inventory is the net position of each dealer's buy trades and sell trades from the previous day's open until the previous close at 4:37 pm. Volume is the normalized Sterling-Volume during the first hour of continuous trading (8:00:31 am - 9:01 am). Adverse Selection is measured as the level of the adverse selection component of the actual bid-ask spread on the order book in the first hour of continuous trading using the Booth, Lin and Sanger (1995) methodology. Volatility is measured as the returns' normalized standard deviation in the first half hour of continuous trading. Firm Size is the market capitalization on 1 June 1998. Market Return is the previous day's close-to-close returns of the S&P 500 Index. Own Return is the security's close-to-close returns for each day. News is a dummy variable, taking a value of 1 when significant news is issued by a firm. Volume* Volatility is an interactive variable between the normalized Sterling volume and the normalized standard deviation of returns. **, and * denote significance at 0.01, and 0.05 levels respectively. The period covered is 1 June 1998 to December 2000.