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Abstract

In 1997, the London Stock Exchange, like NASDAQ, allowed the public to compete directly with dealers in a subset of stocks through the submission of limit orders. However, unlike NASDAQ, for these stocks, London also removed the obligation of dealers to quote firm two-way prices, and became a voluntary dealer network competing with a centralized limit order book. In the context of the important differences between the reforms on London and NASDAQ, this London based study addresses several important questions of academic, regulatory and practitioner interest that could not hitherto be examined through U.S. based studies. First, we investigate how the change from obligatory to voluntary market-making affects the provision of financial intermediation services. In particular, we examine the effect of binding market maker obligations on price-stabilisation, and the effect of binding market maker obligations on the adverse selection losses that market makers make in dealing with informed investors. In this context, we also examine the effect of competition and the contestability of markets in competing and non-competing segments, and analyse how the lack of pre-trade quote-transparency, and the resultant increased search costs, affect trading costs. Second, since a major benefit of the London and NASDAQ reforms was the opportunity afforded to "public" investors to earn the spread by posting limit orders, instead of always paying the spread by demanding liquidity, we analyse how the premium charged by individual or institutional "public" investors for supplying liquidity, and the adverse selection losses they face, are different from those of market intermediaries.

Trading Costs of Public Investors with Obligatory and Voluntary Market-Making: Evidence from Market Reforms

Until recently, the London Stock Exchange (hereafter LSE) and the NASDAQ were the two main equity markets organised as pure competitive dealer markets. In 1997, both these markets underwent significant market reforms through introduction of systems that allowed the public to compete directly with dealers in supplying liquidity by being able to submit binding limit orders. However, the nature of the reform was significantly different. NASDAQ remained a dealer market with individual dealers competing only with the limit orders posted with them by their own customers. On the other hand, LSE became a centralised order book market, reinforced by a co-existing network of voluntary dealers providing additional depth. Unlike NASDAQ, the LSE reform represented a virtually complete shift from a quote-driven dealer-based market to an order-driven limit-order-book-based market.

From the perspective of this paper, the main 1997 reform on NASDAQ was in the handling of public limit orders received by a dealer. Market makers were required to fill public limit orders before they could trade for their own account at the same or a better price, and public limit orders better than a market maker's quote had to be either executed straightaway by the market maker from her own inventory, or displayed on the system. However, NASDAQ remained a dealer market and the system remained completely centred around the individual market-makers. NASDAQ has no centralised limit order book; only the very top of the individual market-maker's queue of limit orders on either side is displayed on the system and hence observed by the rest of the market; other market-makers can potentially

trade at the limit order price or better *without* having to execute the limit order; and market-makers retain the right to refuse to accept customer limit orders[2].

On the other hand, for the stocks that have gone through the LSE reforms process, LSE cannot be considered a "dealer market" as commonly understood. For these stocks, the dealers on LSE are no longer obliged to make a fair and orderly market, and stand ready to buy and sell by quoting firm two-way prices, as they did earlier. The erstwhile market makers have become (short-term) traders. Even though a significant proportion of public trades, about 70%, continues to be executed by dealer firms, the participation of dealers in individual trades has became entirely voluntary, and their quotes are no longer available to public investors through publicly disseminated price-display systems[3]. Instead, both public investors and market intermediaries can only see the completely centralised electronic limit order book, called *SETS*, a name which is aptly descriptive of the new regime since it is an acronym for "Stock Exchange Trading System". This limit order book is completely transparent in as much as all limit orders and all trades can be observed at any time[4]. Even though there are no dealer quotes anywhere on the system, and dealers have no obligations either individually or collectively, an active dealer network also co-exists and competes with SETS. Trades through the dealer network are done through telephone, and reported through the same trade reporting system that reports trades on SETS. However, SETS generates all pre-trade information, and the best limit prices on SETS are the basis for the calculation of all market indices. SETS is the explicitly visible price formation mechanism, though the post-trade publication of prices in the voluntary dealer network also plays an underlying but critically important role in price-setting. Essentially, SETS is at the centre of the system, while the voluntary dealer network is

[2] See Barclay et. al. (1998 p 5 footnote 3)
[3] Neither individual dealer quotes nor best quotes across all dealers (formerly called the "touch") are available.
[4] However, the identity of the party posting the quote becomes known only when a trade is consummated by hitting an existing limit order.

on the periphery, but fulfilling the function of providing the depth that has always been the hallmark of the London equity market[5].

In the context of the important differences between the reforms on London and NASDAQ, this London based study is able to address several important questions of academic, regulatory and practitioner interest, questions that could not hitherto be examined through U.S. based studies[6].

First, we investigate how the change from obligatory to voluntary market-making affects the provision of financial intermediation services. In particular, we examine the effect of binding market maker obligations on price-stabilisation, and the effect of binding market maker obligations on the adverse selection losses that market makers make in dealing with informed investors. In this context, we also examine the effect of competition and the contestability of markets in competing and non-competing segments[7], and analyse how the lack of pre-trade quote-transparency, and the resultant increased search costs, affect trading costs.

Second, since a major benefit of the London and NASDAQ reforms was the opportunity afforded to "public" investors to earn the spread by posting limit orders, instead of always paying the spread by demanding liquidity, we analyse how the premium charged by individual or institutional "public" investors for supplying liquidity, and the adverse selection losses they face, are different from those of market intermediaries[8]. These are likely

[5] The nature and history of the London market reforms and the salient features of post-reform trading relevant to this paper are outlined briefly in Appendix I.

[6] Barclay et. al. (1999) provide a comprehensive documentation of the effects of NASDAQ market reforms on the trading costs of NASDAQ stocks and Bessembinder (1998) compares relative trading costs on NASDAQ and NYSE after the reforms.

[7] See Demsetz (1968) and Baumol, Panzar, and Willig (1982) for work on contestable markets. This work emphasizes that industries with only a few firms (or even just one) can be very competitive if there is a threat of entry by other firms due to low entry and exit costs. In our context, even though a relatively small proportion of public order flow is executed through the centralised order book, the public order flow being executed through the dealer network also benefits from the centralised order book since there is the threat that this order flow can migrate to the centralised order book at virtually zero cost.

[8] In this paper, the term "public" investors always includes both individual and institutional investors or traders. The totality of market participants are deemed to fall into two categories: *public investors* and *market intermediaries*.

to be potentially different because of the extent of access to order-flow information, their relative risk aversion, and the nature of the utility derived from liquidity supply activities. Specifically, market intermediaries have, relative to public investors, significantly greater access to order-flow information since they execute 70% of the overall trading through the voluntary dealer network, and also see the trades and orders in correlated stocks and correlated market sectors. And public investors are likely to be more risk-averse. However, a subset of public investors are "patient traders" intending to execute committed order flow through limit orders to lower trading costs rather than demand immediate execution.

It is important to note that, in addressing all these questions, we are able to distinguish between market intermediaries and (individual or institutional) public investors, the targeted beneficiary of any market reforms. This is because our data distinguishes the trades done by dealers as principals from the trades done by public investors, or agents acting on their behalf. Current (US based) studies have analysed trading costs paid (earned) by liquidity demanders (suppliers) without distinguishing whether the liquidity demander (supplier) was a market intermediary (dealer or broker or floor trader) or a public investor. We analyse trading costs faced by the end-users of the trading system, i.e. the public investors, without confounding our analysis by the costs faced by intermediaries. Unlike U.S. based studies, our trading cost measures are defined and duly signed from the frame of reference of a public investor.

In addition, unlike NASDAQ based studies of reform, we are able to also examine a (control) sample of stocks that were not included in the first phase of reform. Hence, we are able to control for inter-temporal variation in trading costs caused by changes in market wide factors, such as changes in prices, volatility and trading volume. Importantly, this control sample of no-reform stocks helps us to distinguish between different causal explanations for a change in a specific trading cost measure in a particular direction.

Our main findings can be summarised as follows. First, dealers in a trading system with obligatory market-making contracts fulfil an important and useful price stabilisation function even though these contracts are difficult to monitor or enforce. Second, obligatory market-makers posting firm quotes face adverse-selection losses (due to trading with informed traders) that are not different from those faced by voluntary market-makers who do not display quotes but only provide quotes on request. Third, limited pre-trade quote transparency because of non-display of dealer quotes significantly increases trading costs for large trades, allowing dealers to charge higher effective spreads and higher gross revenues for themselves. Fourth, the arguably increased competition arising from the introduction of a limit order book into the London dealer market did not drive down trading costs in competing trade-size segments. Fifth, the introduction of a competing limit order book increased the relative proportion of informed trading and liquidity trading through the dealer network in London. Sixth, public investors supplying liquidity face adverse selection losses that are significantly higher than those faced by (voluntary) market intermediaries, consistent with the expectation that the timely access market intermediaries have to order-flow information is valuable. Finally, even though the effective half-spread charged by public investors supplying liquidity, and the inside half-spread at that time, is significantly higher than that of (voluntary) market intermediaries, the overall net premium charged by public investors for supplying liquidity is *not* significantly different from that charged by these market intermediaries. In both cases, on average, the market participant whose limit order is picked off earns the spread but loses on the post-trade price change, and the market participant who picks off the limit order pays the spread but earns on the post-trade price change.

The rest of this paper is organised as follows. Section I describes the data and the measures of trading costs used in the paper. Section II investigates *reform-related changes* in inside half-spreads to determine the effect of the change from obligatory to voluntary market-

making on price stabilisation. Section III analyses *reform-related changes* in effective half-spreads, realised half-spreads and adverse selection half-spreads for trades executed *in the dealer network,* to draw inferences about the impact of the obligatory clauses within market-making responsibilities, and the effect of increased search costs arising from low pre-trade transparency. Section IV investigates *post-reform* trading *in the order-matching system* to evaluate differences in the premium for liquidity supply services charged by public investors and market intermediaries, and differences in the adverse selection costs faced by them. Finally, our concluding remarks appear in Section V.

I Data and Measures of Trading Costs

In order to examine the effect of LSE changeover from a dealer market to an auction market on the trading costs of public investors, we investigate three periods, each of three months duration. We use data from May 1998 to July 1998 (hereafter labelled '1998') to examine trading costs after the reform. We use two control periods before the market reform: August 1994 to October 1994 (hereafter labelled '1994') and February 1996 to April 1996 (hereafter labelled '1996').[9]

For each of these three periods, we analyse comprehensive time stamped trades', quotes' and limit orders' data provided by the London Stock Exchange. The data for 1994 and 1996 is for the pure dealership market prior to the market reform. The data for 1998 also includes data from the SETS electronic order book. In particular, it includes details of entry and execution of all orders on the electronic order book and execution of all trades off the order book in the SETS stocks. All our trades' data indicates the dealing capacity of the Stock

[9] Our choice of periods is determined entirely by availability of the data from the LSE. Transactions' data from the pre-reform quote driven pure dealership market on the LSE has been used by various researchers to explore several interesting issues relating to trading costs. Reiss and Werner (1995) provide early evidence on the subject; Tonks and Snell (1995) analyse the components of the bid-ask spread; Gemmill (1996) and Board and Sutcliffe (1995) examine the impact of different transparency rules on trading costs; Hansch et. al. (1999) examine the effect of preferencing, internalisation and best execution on trading costs; and Naik and Yadav

Exchange member firm reporting the trade, i.e., whether the firm acted as *principal* or as an *agent* in the particular transaction and whether the firm bought or sold in that trade. Hence, we do not have to use an arbitrary rule to decide if the trade was a public buy or a public sell. More importantly, this enables us to determine whether it was a Stock Exchange member firm or a public customer who was effectively supplying liquidity (and earning spreads) in the trade[10].

Our data covers all stocks, but we confine our analyses to the stocks for which we have data for *each* of the three periods above. These include 76 stocks traded on the new SETS system (hereafter SETS stocks), which we use to examine the impact of market reforms. The data also include a control sample of 76 stocks not traded on SETS (hereafter non-SETS stocks) that we use as a proxy to estimate the extent of longer term inter-temporal market-wide changes over the three sample periods. The non-SETS stocks are chosen on the basis of market value but with a minimum threshold level of average trading volume equal to the tenth percentile of average trading volume across SETS stocks.

In reaching our inferences, we also control for changes in relevant economic factors over the three sample periods. The control economic factors that we use are price volatility, trading volume and the price level since it is well known that the quoted spread is related positively to price volatility and inversely to trading volume and price level[11]. We control for the known changes in these three factors by running regressions in which the dependent variables are the changes in trading cost measures of a stock from 1994 or 1996 to 1998, and

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(1999) investigate differences in the quality of execution offered by different dealers and different brokers. However, the focus of this paper is totally different from earlier research in this area.

[10] We consider only *public* trades in which a public customer (individual or institution), or her agent, trades with a member firm trading as principal. We do not include inter-dealer trades, and the tiny fraction of public trades (less than 2%) in which a public customer (or her agent) trades directly with another public customer (or her agent).

[11] Higher the price volatility, greater the inventory carrying risk and greater the risk faced by liquidity suppliers from dealing with more informed investors. Higher the trading volume, lower the inventory carrying risk faced by liquidity suppliers. Inverse variation with price level arises because of discreteness of prices. Discreteness should be less important in the UK than the US since trades do not necessarily have to be in multiples of tick size, though, in practice, they are generally so.

the independent variables include *inter-alia* the corresponding changes over the period in average daily volatility, average trading volume, and the average price level.

Let p_t^i be the transaction price for the i^{th} trade executed at time t. We define a_t as the lowest ask quote or limit price to sell one second before time t, and b_t as the highest bid quote or limit price to buy one second before time t[12]. We measure best quotes or limit prices *one second before* the execution of the trade since transactions can potentially change the contemporaneous best limit prices in an order driven market. Let m_t be the mid-price of best quotes or limit orders at time t, $m_t = (a_t + b_t)/2$. Let the subscript T denote the particular post-trade reference time used to estimate the "true" value of the stock: in this paper T is taken as t+60. We analyse the following four measures of trading costs[13].

- Inside Half-Spread IS_t

$$IS_t = \frac{(a_t - b_t)/2}{m_t}$$

- Signed Effective Half-Spread ES_t^i for the i^{th} trade[14]

$$ES_t^i = \frac{(p_t^i - m_t)}{m_t} \quad for\ a\ public\ buy$$

[12] For the dealer market in 1994 and 1996, and for non-SETS stocks in 1998, trading cost measures are calculated from the best bid and best ask quotes. For SETS stocks in 1998, these measures are calculated from the best limit orders to buy and sell.

[13] There is no organised data available in London on commissions and so it is not possible to formally analyse changes in commission costs. That said, we believe that there have *not* been any significant systematic changes in commissions as a result of the reform. In the retail sector, the commission has always been, and still is quoted only on the basis of the size of the trade. It does *not* depend on whether the trade is executed through the order book or through the dealer network, and does *not* depend on whether the trade relates to a SETS stock or a non-SETS stock. In the institutional sector, the only available evidence is an internal "study" done by Plexus Group for the London Stock Exchange. They analyse selected institutional clients and break up costs into components in accordance with their proprietary practices. On the basis of the results indicated by them in their April 1999 newsletter to their own clients, and the results presented by them in a SIRIF conference in April 1999, their findings are that the commission for order book trades is slightly higher than the commission for the dealer network, but the difference is only about 3 basis points, and this is insignificant in relation to the total institutional trading costs estimated by them.

[14] The effective half-spread can be different from the inside half-spread because trades can take place both within and outside the inside quotes. The best bid-ask quotes and limit prices are valid only up to a specific trade size. Large buy (sell) trades may have to take place above (below) the ask (bid) price in order to attract liquidity suppliers. In less transparent regimes, large trades can also get significantly better prices than ask or bid prices as dealers implicitly "purchase" the information contained in the order flow (Naik et. al., 1999).

$$ES_t^i = \frac{(m_t - p_t^i)}{m_t} \quad for\ a\ public\ sell$$

- Realised Half-Spread RS_t^i for the i[th] trade[15]

$$RS_t^i = \frac{(p_t^i - m_T)}{m_t} \quad for\ a\ public\ buy$$

$$RS_t^i = \frac{(m_T - p_t^i)}{m_t} \quad for\ a\ public\ sell$$

- Adverse selection Half-Spread PS_t^i for the i[th] trade as $PS_t^i = ES_t^i - RS_t^i$. Thus[16],

$$PS_t^i = \frac{(m_T - m_t)}{m_t} \quad for\ a\ public\ buy$$

$$PS_t^i = \frac{(m_t - m_T)}{m_t} \quad for\ a\ public\ sell$$

Our trading cost measures are signed from the perspective of a public customer. They are positive when the public customer pays the spread to a dealer supplying immediacy in a transaction, and negative when the public customer earns the spread from a dealer seeking immediacy, e.g., when a limit order posted by the customer is picked off by a dealer. In contrast to our use of *duly-signed* effective half-spreads, major US studies (eg Barclay, 1997; Barclay et. al., 1999; Bessembinder, 1997, 1998; Christie and Huang, 1994; Christie et. al., 1994; and Huang and Stoll, 1996) are based on the *absolute value* of the difference between the trade price and the mid-price. This is because the data typically available in the US does not flag trade direction. This absolute value of effective half-spread generically measures the execution costs of "liquidity demanders" on the assumption that a liquidity demander always trades above the mid-price for a buy and below the mid-price for a sell and does not

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Dealers can also offer attractive transaction prices in order to restore their temporary inventory imbalances to normal levels (Hansch et. al., 1998).

[15] The realised half-spread is a measure of trading cost on the assumption that the post-trade mid-price is the "true" value of the stock.

[16] The adverse selection half-spread reflects the post-trade price change. If a subset of public investors have superior information, they will benefit from the post-trade price change, and hence the realised half-spread paid

distinguish between market intermediaries and public investors. By using signed measures, we are able to distinguish the times when public investors act as liquidity suppliers from times when they act as liquidity demanders.

We average instantaneous trading cost measures in two ways: *time-weighted* or *trade-weighted.* Time-weighted measures are calculated as follows. For each of the sample stocks, we take snapshots of the measure every minute for each day in each of the three sample periods: 1994, 1996 and 1998. We then calculate average values of the measure across different stocks and different minute-by-minute periods of the day. The trade-weighted measure is the value-weighted average of the measure *one second before* the execution of every public trade. Our tables are based on time-weighted averaging of inside half-spreads IS_t, and trade-weighted averaging over the relevant trade size categories of the other three spread variables ES_t^i, RS_t^i and PS_t^i. We measure each of the four spread variables in basis points (i.e., one-hundredths of a percentage point).

The inside half-spread, when aggregated across all public trades, determines the revenue that market intermediaries collectively would have *hypothetically* generated if all their public buys were at the ask and all their public sells were at the bid. The signed effective half-spread, when aggregated across all public trades, determines the *actual gross* trading revenue of market intermediaries generated from differences between bid and ask prices. The realised half-spread, when aggregated across all public trades, determines the *actual net* trading revenue of market intermediaries, albeit before consideration of fixed costs. The adverse-selection half-spread, when aggregated across all public trades, represents the part of spread revenue lost due to (adverse) price changes while the asset is being carried in the inventory of the dealer.

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by them will be lower than the effective half-spread by the extent of the adverse selection half-spread.

Table I Panel A reports the distribution of the value of shares traded across different trade size bands in each of the three sample periods. Table 1 Panel B presents the average trade size. Overall, there has been substantial growth in trading volume from 1994 to 1996, but not from 1996 to 1998. For non-SETS stocks, the cross-sectional distribution of trades across different trade size bands has not changed significantly from 1994 to 1996 or from 1996 to 1998. However, for SETS stocks, while the cross-sectional distribution of trades across different trade size bands has not changed significantly from 1994 to 1996, it has changed significantly from 1996 to 1998 (p-value of Chi-square statistic << 0.001). This is because, relative to 1996 or 1994, a substantially greater proportion of trades have taken place in the middle trade size ranges in 1998. This indicates a greater propensity on the part of market participants to split large trades and "work" the order. The average trade size has, as a result, fallen by about half, not just for order book trades but also for trades executed through the dealer network.

II Inside Quoted Spreads in Voluntary versus Obligatory Market Making Systems

Major stock exchanges typically aim to provide investors with a "fair and orderly" market in which liquidity suppliers partially absorb and thereby cushion the impact of order-flow and information shocks. NYSE specifically imposes on specialists *affirmative* obligations to maintain price continuity and provide a fair and orderly market. NASDAQ and LSE have relied on competition between dealers to lead to a fair and orderly market, with affirmative obligations confined to the requirement that the market-makers registered for a security will always stand ready to buy and sell, and accordingly quote firm two-way prices. This requirement has continued for NASDAQ after the reforms, but for the LSE, the 1997 reforms changed the nature of market making from being obligatory to being voluntary, with

no continuing requirement to provide quotes, and quotes not even being available on price-display systems.

In this section, we examine one aspect of "orderly" markets: the extent to which market intermediaries provide stabilization services by cushioning the impact of order-flow and information shocks on the spreads quoted by them. Specifically, we examine if the reform results in a measurable difference in the extent of stabilisation services provided by dealers, i.e. a change in the extent to which inside quoted spreads vary significantly under different market conditions. Since there are no quote stabilization obligations after the reform, the changes in stabilization indicators as a result of the reform gives us an estimate of the practical value of dealer stabilization obligations. This is interesting because it is otherwise difficult to quantify the effectiveness of dealer stabilization obligations in absolute terms, and such quantification indicates what is achievable just through quote-posting obligations without stronger affirmative obligations as on the NYSE.

In the context of the above, we should observe at least two reform-related changes. First, if dealers make no effort to stabilise their quotes (because they do not feel obliged to do so), they will change their quotes more frequently in response to changing economic factors. In particular, they will not quote at all, or widen their quotes without hesitation in order to deter trading, in periods in which they do not wish to trade; and conversely, quote lower spreads more aggressively in periods in which they do wish to trade. This will result in an increase in the cross-sectional *variability* of the inside spread since the quoted spreads of individual dealers, and in individual stocks, will become more volatile. Second, since the quoted bid-ask spread reflects the inventory and adverse-selection risk of dealers, the average quoted spread of individual dealers, and hence the *level* of the inside spread across all dealers, should systematically increase in periods of relatively high uncertainty, and systematically decrease in periods in periods of relatively low uncertainty.

We accordingly measure the change in quote stabilisation by the reform-related change in the level and variability of the inside half-spread of SETS stocks separately in periods of high uncertainty, and in other periods. We control for corresponding changes in these variables for non-SETS stocks, and also control for changes in price volatility, trading volume and the price level as discussed earlier in Section 1. We note that there exists extensive evidence that there is greater degree of price uncertainty at the open in view of the long non-trading interval that precedes the open (e.g., Stoll and Whaley,1990; Amihud and Mendelson, 1987; Amihud and Mendelson,1991). The resolution of this price uncertainty takes place after commencement of trading. Hence, if dealer quote stabilisation services are valuable, we should observe after the reform, after controlling for all relevant factors, an increase in the *variability* of the inside spread in all periods, an increase in the *level* of the inside half-spread at the open, and a decrease in the *level* of the inside half-spread in periods of relatively lower uncertainty, and in "normal" periods. Hence, we test the following hypotheses:

> *Hypothesis H_{1A}: The variability of the inside half-spread increases after the reform in all hourly trading intervals.*
>
> *Hypothesis H_{1B}: The level of the inside half-spread after the reform increases around the open, but decreases in other hourly intervals.*

To test the above hypotheses, we construct time-series cross-sectional panel datasets for SETS and non-SETS stocks separately for each of the three sample periods. We calculate the mean, median, minimum and maximum values of time-weighted inside half-spreads for each stock over each of the eight different hourly trading intervals within the day[17]. We measure *variability* of the inside spread by the difference between the minimum and the maximum values of the inside half-spread in a given cell. We measure *level* of the inside

[17] The data for inside half-spread that we use for 1998 sample period is from May 1, 1998 to July 19, 1998. This is because the exchange changed the opening on 20 July 1998 from 8.30 am to 9.00 am. The results for the last 10 days of July are virtually identical to the rest of the 1998 period when the hours are measured from the new

spread by either the mean or the median for the cell.

Figures 1, 2, 3 and 4 are plots of the raw (unadjusted) level and variability of the inside spread of SETS and non-SETS stocks. The variability is clearly higher for SETS stocks post-reform, and not for the control sample of non-SETS stocks. For both SETS and non-SETS stocks, the *overall average level* of the inside half-spread behaves similarly – a decline from 1994 to 1998 but no change from 1996 to 1998. However, the *intra-day variation* for SETS stocks is sharply different from that of non-SETS stocks. For non-SETS stocks, there is no qualitatively difference over different hours of the day in any of the three years. There is also no qualitatively difference over different hours of the day for SETS stocks prior to market reform in 1994 and 1996. But there is huge large intra-day variation for SETS stocks after the reform with a massive increase in average inside half-spread immediately after the open, decreasing steadily over the first two hours to reach a level representing a significant decrease in the average inside half-spread for the rest of the trading day[18]. The average inside half-spread of SETS stocks in the first five minutes (first hour) of trading is *more than four times* (about three times) the level over rest of the day[19].

We control formally for changes in trading volume, price level and volatility, and the other economic factors that also affect non-SETS stocks not going through reform, by running the following regression separately for the change from (pre-reform) 1994 to (post-reform) 1998, and a change from (pre-reform) 1996 to (post-reform) 1998:

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opening time.

[18] The change in the intra-day variation of inside half-spreads is not being driven by large changes in the case of a few stocks. The plot is qualitatively similar for *each and every SETS stock*

[19] Trade-weighted inside half-spreads give qualitatively similar results. These trade-weighted average spreads are about 25% to 40% less than the corresponding time-weighted spreads, suggesting that trades are clustered in periods with relatively low inside half-spreads. If trades cluster into periods when spreads are low, the intra-daily variation in the average value of shares traded should be inversely related to the intra-daily variation in the inside half-spread. Consistent with the pattern of intra-daily variation in spreads after the reform, we observe that the average value of shares traded through the order book in the first five minutes as a proportion of the average value of shares traded for a similar interval over the rest of the day is only 0.33, and the average over the first hour is about 0.5, and this increases over the day.

$$\Delta IHS^k = \sum_{t=1}^{8} a_t D_t + \sum_{t=1}^{8} a_t^{SETS} D_t D^{SETS} + (f_1 \Delta V^k + f_2 \Delta P^k + f_3 \Delta SD^k) + (f_1^{SETS} \Delta V^k + f_2^{SETS} \Delta P^k + f_3^{SETS} \Delta SD^k) D^{SETS} + e_t^k$$

where ΔIHS^k is the change in inside half-spread measure (mean, median, or the difference between the maximum and the minimum) for stock k; D_t (t = 1, 2, …, 8) is a dummy variable for the eight hourly intervals within the trading day; D^{SETS} is a dummy variable with a value of one for SETS stocks (undergoing reform) and zero otherwise; ΔV^k is the average change in the volume of trading for stock k; ΔP^k is the average change in price for stock k; ΔSD^k is the change in volatility for stock k; the coefficients a_t (t = 1, 2, …, 8) capture the overall change in the inside half-spread measure in hourly interval t; the coefficients a_t^{SETS} (t = 1, 2, …, 8) capture the change in the inside half-spread measure in hourly interval t for the subset of SETS stocks (undergoing reform); the coefficients f_1, f_2, and f_3 capture the overall change in the inside half-spread measure due to trading volume changes, price level changes, and volatility changes respectively; the coefficients f_1^{SETS}, f_2^{SETS}, and f_3^{SETS} capture the change in the inside half-spread measure due to trading volume changes, price level changes, and volatility changes respectively specifically for SETS stocks (undergoing reform); and e_t^k is a random error term for stock k.

Our results are reported in Table 2. Hypothesis H_{1A} and Hypothesis H_{1B} are both strongly supported. The explanatory power (R-sq) of the regressions is high. For each hourly interval, the variability of the inside half-spread of SETS stocks increases significantly post-reform, both with reference to 1994 and 1996, after controlling for corresponding changes over the same period in non-SETS stocks, and for changes in price volatility, trading volume and price levels. The increase is highest for the first trading hour but remains highly significant (t-statistic > 16) all through the day. The average (median) level of the inside half-

spread increases enormously by 34 (19) basis points for the first trading hour, the hourly interval with the greatest uncertainty. It also increases significantly also for the second hour, but decreases significantly by several basis points for each of the six other hourly intervals in the day.

The results in this sub-section clearly show two things. First, they show that dealers in a trading system with obligatory market-making quotes do fulfil a useful stabilisation function. In particular, in the obligatory market-making London system preceding the market reform, and for the stocks not subject to the reform, they have stabilised quotes by largely absorbing the bid-ask spread (or liquidity) shocks associated with the greater uncertainty immediately after the market opening. Second, our results show that, before the reform, even without NYSE-like affirmative obligations relating to price continuity and orderly markets, a virtually flat inside-spread profile was achieved just through the obligation to post firm two-way quotes[20].

III Effective, Realised and Adverse Selection Half-Spreads in the Dealer Network

i. Development of Hypotheses and Methodology

This section investigates reform-related changes in effective half-spreads, realised half-spreads and adverse-selection half-spreads *in the dealer network* to draw inferences about four key economic questions of regulatory interest that follow from the four factors that can potentially influence reform-related changes in these trading cost measures.

First, *do obligatory market-makers posting firm quotes face adverse-selection losses (due to trading with informed traders) that are greater than those faced by voluntary market-makers who do not display quotes but only provide quotes on request?* We know that dealers posting obligatory quotes provide free options that can be picked by other traders, and hence

[20] The results of Werner and Kleidon (1998) also show that spreads of cross-listed securities trading in London in the pre-reform period vary by a few percent over the course of the trading day. In sharp contrast, our results

these dealers are expected to lose money, on average, in trading with more informed investors (Glosten and Milgram, 1985); and Hansch et. al. (1999) and Sofianos (1995) document evidence consistent with this expectation for obligatory market makers on LSE and NYSE respectively. On the other hand, the post-reform dealers on LSE do not provide these free options through quotes that can be "picked off". They are not obliged to provide quotes on request and not obliged to trade, and can hence be selective about the stocks and trades in which they choose to participate. Do they still continue to lose as much to informed traders[21]?

Dealer quote-related obligations were typically binding (before the reform) only for trade sizes up to the "normal-market size" (NMS) of the particular stock. This means that adverse-selection half-spreads should decrease after the reform for trade sizes up to one NMS and should be unaffected for higher trade sizes. Competition among competing market-makers should arguably keep realised half-spreads unchanged. Hence, dealers should also charge correspondingly lower effective half-spreads for trade sizes up to one NMS since they need to budget for lower losses due to adverse selection.

Second, *does limited pre-trade quote transparency because of non-display of dealer quotes increase trading costs due to higher search costs*? Intuitively, one would expect that dealers will exploit higher search costs to charge higher spreads. On the basis of their theoretical model, Duffie et. al. (2001) conclude that this should indeed be the case. We test this hypothesis. After the LSE reforms, dealer quotes are not disseminated through any real-time price display systems. The competing electronic limit order book does have a high level of transparency with the entire book observable by market participants, but the usable depth of the order book is limited and the majority of trades are executed through the dealer network, and dealer quotes are not on display. In view of the high transparency in SETS, the

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show post-reform variation of several hundred percent over the trading day.

[21] It could also be argued that, conditional on information at the time of the trade, the expected profits of dealers from any inventory they *choose* to hold should be greater than zero for risk averse traders. Bernhardt and Hughson (1997) show that since a limit order book is split against incoming market orders, equilibrium limit

impact of the absence of dealer quotes is unlikely to be felt for trade sizes below the usable depth of the order book. However, for trade sizes above the usable depth of the order book, a public investor would face higher search costs to identify a dealer who can provide the best terms for her trade, and this can potentially enable dealers to charge relatively higher effective spreads. These higher effective spreads should not affect liquidity trading (thereby increasing dealer profits), and should lower informed trading (thereby decreasing dealer losses) since the informed trader needs to have information of potentially higher value before she can trade. Either way, realised spreads should increase. Whether they do or they do not is an empirical issue. We estimated the usable depth of the order book to be about one NMS[22]. This means that if limited pre-trade quote transparency increases trading costs, we should observe, for trades above one NMS in size, higher realised half-spreads, higher effective half-spreads and lower adverse-selection half spreads.

Third, *does competition arising from the introduction of a limit order book into a dealer system drive down trading costs in competing trade-size segments?* The limit order book introduces competition, and should ordinarily be expected to lower trading costs in competing trade-size segments. Since the usable depth of SETS is about 1 NMS, if competition from the limit order book is effective, we should observe lower effective half-spreads for trades below one NMS in size. This increased competition factor should not result in a decrease in adverse selection half-spreads, and hence should also drive down realised half-spreads for trades below one NMS in size. The increased competition factor should not influence any of the trading cost measures for trade sizes in excess of one NMS since the depth of the order book is below one NMS.

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order schedules yield positive expected profits to agents posting them.

[22] We estimated the depth of the limit order book by constructing the order book at fifteen- minute intervals for a sub-set of ten randomly selected stocks for a period of two weeks. We followed the procedure of Kawajeck (1999). Salient descriptive statistics on the estimated depth for each of these stocks is available from the authors on request. It is clear to us that the usable depth in the electronic limit order book SETS is consistently about one NMS. The depth in the dealer network is not quantifiable in the absence of quotes and quote sizes. Hence,

Fourth, *does the introduction of a competing limit order book increase the relative proportion of informed trading through the dealer network*? One of the important benefits of the reform has been the possibility and ease of "patient trading" through posting limit orders (and earning the spread) rather than always demanding liquidity. In this context, after the reform, a large number of institutional traders often break up their (what would have been large) trades into smaller sized trades, and work them through the order book in "patient trading" (Fox, 1999). This patient trading is typically uninformed or liquidity trading since information motivated trades are likely to be executed immediately by demanding liquidity. This means that the introduction of the order book will result in a greater proportion of large sized trades executed through the dealer network to be informed trades than before the reform, since a significant proportion of the uninformed order flow in this category has gone to the order book. Hence, if traders actively manage trading costs through patient trading, we should observe an increase in adverse-selection half-spreads, and consequent increase in effective half-spreads, after the reform for "large trades", i.e. trades larger than 1 NMS. Whether this is the case or not, is an empirical issue.

The matrix of implications of the four factors above for effective, realised and adverse-selection half-spreads is presented in Table 3. If effective half-spreads increase for trades below one NMS or decrease for trades above one NMS, we have not taken all relevant factors into account. If effective half-spreads do not change for trades below one NMS, factors 1 and 3 above are not important enough, and if they do not change for trades above one NMS, factors 2 and 4 above are not important enough. If effective half-spreads decrease for trades below one NMS with a simultaneous decrease in realised (adverse-selection) half-spreads, then factor 3 (factor 1) is important but not factor 1 (factor 3). If effective half-spreads increase for trades above one NMS, then either factor 2, or factor 4, or both, could be

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the *overall* depth of SETS stocks is also not quantifiable because the limit orders on the book and the dealers trading off the limit order book *together* constitute the depth in the SETS stocks.

important. In this circumstance, if adverse-selection half-spreads decrease, factor 2 is important; if adverse-selection half-spreads increase, then factor 4 is important; and if adverse selection spreads do not change, then both factors are important, particularly if there is a simultaneous increase in realised half-spreads.

ii. Methodology and Results

To address the four questions raised in the previous sub-section, we construct time-series cross-sectional panel datasets for SETS and non-SETS stocks separately over each of the three sample periods. These datasets consist of trade-weighted averages of each of these three trading cost measures, i.e. signed effective half-spreads, realised half-spreads and adverse selection half-spreads. We sort and analyse these measures based on six different trade size bands defined in terms of the "normal-market size" (NMS) of the stock as follows: below 0.125 NMS; from 0.125 NMS to 0.25 NMS; from 0.25 NMS to 0.5 NMS; from 0.5 NMS to one NMS; from one NMS to three NMS; and from three NMS to eight NMS[23]. We control formally for changes in trading volume, price level and volatility, and the other economic factors that also affect non-SETS stocks not going through reform, by running the following regression separately for different spread measures for a change from (pre-reform) 1994 to (post-reform) 1998, and a change from (pre-reform) 1996 to (post-reform) 1998:

$$\Delta Y^k = \sum_{j=1}^{6} b_j D_j + \sum_{j=1}^{6} b_j^{Sets} D_j D^{Sets} + h_1 \Delta V^k + h_2 \Delta P^k + h_3 \Delta SD^k + (h_1^{Sets} \Delta V^k + h_2^{Sets} \Delta P^k + h_3^{Sets} \Delta SD^k) D^{Sets} + x_j^k$$

where ΔY^k is the change in the average effective, realised or adverse-selection half-spread for stock k; D_j (j = 1, 2, …, 6) is a dummy variable for the six trading size bands; D^{SETS} is a

[23] We do not analyse trades above eight NMS in size in view of the special arrangements, called Worked Principal Agreements (described in Appendix 1) for these largest trades.

dummy variable with a value of one for SETS stocks (undergoing reform) and zero otherwise; ΔV^k is the average change in the volume of trading for stock *k*; ΔP^k is the average change in price for stock *k*; ΔSD^k is the change in volatility for stock *k;* the coefficients b_j (j = 1, 2, …, 6) capture the overall change in the average effective, realised or adverse-selection half-spread measure in trade-size band *j*; the coefficients b_j^{SETS} (j = 1, 2, …, 6) capture the change in the average effective, realised or adverse-selection half-spread measure in trade-size band *j* for the subset of SETS stocks (undergoing reform); the coefficients h_1, h_2, and h_3 capture the overall change in the inside half-spread measure due to trading volume changes, price level changes, and volatility changes respectively; the coefficients h_1^{Sets}, h_2^{Sets}, and h_3^{Sets} capture the change in the average effective, realised or adverse-selection half-spread measure due to trading volume changes, price level changes, and volatility changes respectively specifically for SETS stocks (undergoing reform); and x_t^k is a random error term for stock *k.*

We also run a similar regression for the aggregate values over all trade sizes of the different spread measures by running the following regression separately for different spread measures for a change from (pre-reform) 1994 to (post-reform) 1998, and a change from (pre-reform) 1996 to (post-reform) 1998:

$$\Delta Y^k = d + d^{Sets} D^{Sets} + h_1 \Delta V^k + h_2 \Delta P^k + h_3 \Delta SD^k$$
$$+ (h_1^{Sets} \Delta V^k + h_2^{Sets} \Delta P^k + h_3^{Sets} \Delta SD^k) D^{Sets} + z_j^k$$

where the coefficient d captures the overall change in the aggregate effective, realised or adverse-selection half-spread measure in trade-size band *j*; the coefficients d^{Sets} captures the change in the aggregate effective, realised or adverse-selection half-spread measure in trade-size band *j* for the subset of SETS stocks (undergoing reform); and everything else has the same meaning as before.

Table 4 Panel A and Table 4 Panel B reports the results of the regressions. Our focus is on the impact of the reform on our three trading cost measures after incorporation of all relevant controls. Hence, the betas for the subset of SETS stocks, and the delta for the subset of SETS stocks, are the coefficients of interest from the perspective of this paper. In this context, our results can be summarised as follows:

1. For trade sizes less than one NMS, the London reforms have resulted, after controlling for other relevant factors, in no significant change in effective half-spreads, no significant change in realised half-spreads and no significant change in adverse selection half-spreads.
2. For trade sizes greater than one NMS, the London reforms have resulted, after controlling for other relevant factors, in a significant increase in effective half-spreads, and a significant increase in realised half-spreads but no significant change in adverse selection half-spreads.

Looking at matrix of possibilities discussed above, our results hence imply that both factor 2 and factor 4 are important, but not factor 1 and factor 3. Specifically:

1. Obligatory market-makers posting firm quotes face adverse-selection losses (due to trading with informed traders) that are not significantly different from those faced by voluntary market-makers who do not display quotes but only provide quotes on request.
2. Limited pre-trade quote transparency because of non-display of dealer quotes significantly increases trading costs for large trades, allowing dealers to charge higher effective spreads and higher gross revenues for themselves.
3. The arguably increased competition arising from the introduction of a limit order book into the London dealer market did not drive down trading costs in competing

trade-size segments. This could potentially be because trading costs were already at the lowest levels that were economically viable.

4. The introduction of a competing limit order book increased the proportion of informed trading through the dealer network relative to liquidity trading.

IV. Post-Reform Liquidity Supply through the Limit Order Book: Public Investors versus Market Intermediaries

A major benefit of the London and NASDAQ reforms was the opportunity afforded to "public" investors to earn the spread by posting limit orders, instead of always paying the spread by demanding liquidity. In this context, we investigate, for the first time, the behaviour of public investors supplying liquidity. Specifically, we analyse how the premium charged by individual or institutional "public" investors for supplying liquidity, and the adverse selection losses they face, are different from those of market intermediaries. Both of these can be potentially different because of at least three reasons: the extent of access to order-flow information, relative risk aversion, and the nature of the utility derived from liquidity supply activities.

First, market intermediaries have, relative to public investors, significantly greater access to order-flow information since they execute 70% of the overall trading through the voluntary dealer network, and also see the trades and orders in correlated stocks and correlated market sectors, and, this should be valuable (See, for example, Chordia, Roll and Subramanyam, 2001). Hence, market intermediaries should have, relative to public investors, lower adverse selection losses to informed investors.

Second, relative to public investors, market intermediaries have better trading systems, more capital and also dedicated personnel and manpower. Also, as discussed above, public investors are farther from the information in the order flow. All of these factors should

make public investors more risk averse, and need a greater compensation for the risk in liquidity supply activities. This should mean higher realised spreads when public investors supply liquidity.

However, third, many of the public investors engaged in liquidity supply through limit orders are "patient traders", i.e. those investors who are committed to trade a specific amount in a specific direction, but are intending to lower overall trading costs by earning the spread through limit orders rather than pay the spread by demanding immediate execution through market orders. The main effort of these patient traders should arguably be to trade as close to the mid-price, and as quickly as possible, rather than be fully compensated for the normal business risk involved in liquidity supply activities. Hence, the influence of these patient traders should potentially reduce overall average realized spreads when public investors supply liquidity. Whether they do, or do not, is an empirical issue.

Specifically, we investigate two questions:

1. Is the realised spread charged by public investors for supplying liquidity different from that charged by market intermediaries?
2. Do public investors face greater adverse selection losses when they provide liquidity through limit orders relative to the adverse-selection profits they make at the expense of market intermediaries when they demand liquidity through market orders?

To address these two questions, we construct a cross-sectional panel dataset for post-reform trades in SETS stocks executed through the electronic limit order book, separately for cases in which the public investor supplied liquidity and for cases where the market intermediary supplied liquidity. These data consist of trade-weighted averages of each of the four trading cost measures, i.e. inside half-spreads, signed effective half-spreads, realised half-spreads and adverse selection half-spreads. We run the following regressions separately for each of the different spread measures:

$$Y^k = b_{PubInv} D_{PubInv} + x_1^k$$

$$Y^k = b_{PubInv} D_{PubInv} + h_1 V^k + h_2 P^k + h_3 SD^k + x_2^k$$

where Y^k is the average inside, effective, realised or adverse-selection half-spread for stock k; D_{PubInv} is a dummy variable with a value of one for averages for public investors, and zero otherwise; V^k is the log of the average volume of trading for stock k; P^k is the log of the average price for stock k; SD^k is the change in volatility for stock k; the coefficient b_{PubInv} captures the overall change in the average inside, effective, realised or adverse-selection half-spread measure; the coefficients h_1, h_2, and h_3 capture the overall effect on the half-spread measure due to trading volume, price level, and volatility respectively;; and x_j^k is a random error term for stock k in regression j (j = 1,2). The first regression captures the raw differences between public investors and market intermediaries without any controls, and the second regression also controls for the dependence of these spread measures on trading volume, price level and volatility. We also sort and analyse the average inside, effective, realised or adverse-selection half-spread measures based on the same six trade size bands defined in Table 4. The results are not qualitatively different across different trade size bands and are hence not reported for compactness of presentation.

Table 5 Panel A and Table 5 Panel B reports the results of the first and second regressions respectively. From the perspective of the issues addressed in this paper, the results are not qualitatively different with or without controls for trading volume, price and volatility. The main results can be summarized as follows. First, irrespective of whether it is the public investor or the market intermediary who is demanding or supplying liquidity, on average, the market participant whose limit order is picked off, earns the spread but loses on the post-trade price change, and the market participant who picks off the limit order pays the

spread but earns on the post-trade price change. For example, when market intermediaries supply liquidity, they charge about 21 basis points in effective half-spread, but lose about 18 basis points in adverse selection half-spread, leaving a realized spread of about 3 basis points.

Second, public investors supply liquidity when the inside half-spread is significantly higher: about 2 basis points. As a result, they earn a significantly higher effective half-spread (about 2 basis points higher), but lose significantly more than market intermediaries in adverse selection half-spreads (about 3 basis points more), resulting in a realized half-spread about one basis point lower. The significantly higher adverse selection losses faced by public investors are consistent with the expectation that the timely access market intermediaries have to order-flow information is valuable. For example, this could arise from the competitive advantage market intermediaries may enjoy in picking stale limit orders left inadvertently on the system. Even though realized half-spreads are slightly lower for public investors, the difference is not statistically significant, indicating that the overall net premium charged by public investors for supplying liquidity is not too different from that charged by market intermediaries. In this context, the influence of "patient" public investor traders is not significant. The marginal patient public investor appears to be a discretionary liquidity trader rather than an informed investor, and so time or uncertainty of execution are perhaps not as important to her.

Finally, it is clear from Table 5 Panel B that all the factors we have used for controls – trading volume, price level and volatility – significantly influence each of the trading cost measures used by us.

V. Conclusions

In 1997, the London Stock Exchange, like NASDAQ, allowed the public to compete directly with dealers in a subset of stocks through the submission of limit orders. However,

unlike NASDAQ, for these stocks, London also removed the obligation of dealers to quote firm two-way prices, and became a voluntary dealer network competing with a centralized limit order book. In the context of the important differences between the reforms on London and NASDAQ, this London based study addresses several important questions of academic, regulatory and practitioner interest that could not hitherto be examined through U.S. based studies. First, we investigate how the change from obligatory to voluntary market-making affects the provision of financial intermediation services. In particular, we examine the effect of binding market maker obligations on price-stabilisation, and the effect of binding market maker obligations on the adverse selection losses that market makers make in dealing with informed investors. In this context, we also examine the effect of competition and the contestability of markets in competing and non-competing segments, and analyse how the lack of pre-trade quote-transparency, and the resultant increased search costs, affect trading costs. Second, since a major benefit of the London and NASDAQ reforms was the opportunity afforded to "public" investors to earn the spread by posting limit orders, instead of always paying the spread by demanding liquidity, we analyse how the premium charged by individual or institutional "public" investors for supplying liquidity, and the adverse selection losses they face, are different from those of market intermediaries.

Our analyses lead to several interesting conclusions. First, dealers in a trading system with obligatory market-making contracts fulfil an important and useful price stabilisation function even though it is difficult to effectively monitor or enforce these contracts. Second, obligatory market-makers posting firm quotes face adverse-selection losses (due to trading with informed traders) that are not different from those faced by voluntary market-makers who do not display quotes but only provide quotes on request. Third, limited pre-trade quote transparency because of non-display of dealer quotes significantly increases trading costs for large trades, allowing dealers to charge higher effective spreads and higher gross revenues

for themselves. Fourth, the arguably increased competition arising from the introduction of a limit order book into the London dealer market did not significantly drive down trading costs in competing trade-size segments. Fifth, the introduction of a competing limit order book did significantly increase the relative proportion of informed trading and liquidity trading through the dealer network in London. Sixth, public investors supplying liquidity face adverse selection losses that are significantly higher than those faced by (voluntary) market intermediaries, consistent with the expectation that the timely access market intermediaries have to order-flow information is valuable. Finally, even though the effective half-spread charged by public investors supplying liquidity, and the inside half-spread at that time, is significantly higher than that of (voluntary) market intermediaries, the overall net premium charged by public investors for supplying liquidity is *not* significantly different from that charged by these market intermediaries. In both cases, on average, the market participant whose limit order is picked off earns the spread but loses on the post-trade price change, and the market participant who picks off the limit order pays the spread but earns on the post-trade price change.

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APPENDIX 1

Brief Description of Market Reforms & Salient Features of Post-Reform Trading

A. *Brief History*

The London equity market had always been a pure dealership quote driven market. All trades were executed through competing dealers who were obliged to make firm two-way prices in the stocks they wished to make a market in. In 1997, the LSE introduced an order driven system for the most liquid stocks while retaining the dealer network in parallel. This reform was the biggest structural change in the history of the LSE[24]. The new order driven system was called SETS, an acronym for *Stock Exchange Trading System.*

Several developments led to the introduction of this major market reform: First, the nineties saw a significant increase in the competitive pressures on the LSE from various directions. Many European exchanges introduced new trading systems to capture the market share in European equities from the LSE, though none of these represented structural changes like LSE's change from a dealership to an order driven market[25]. Second, alternative electronic networks such as Tradepoint established themselves in the UK, and the UK regulatory authorities removed the earlier restrictions on market makers that had prevented them from quoting, on other electronic networks, prices better than those they were quoting on LSE. Thus, these electronic networks had the potential of bringing buyers and sellers together well within the LSE spread. Finally, under Article 15.4 of EU Investing Services Directive, automated order matching systems located anywhere within Europe became potential competitors of LSE[26].

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[24] A set of important changes made by the LSE in October 1986, known as the Big Bang, made transaction prices and quotes more transparent, allowed dual capacity trading, abolished fixed commissions and liberalised the entry of foreign firms. However, the Big Bang retained the pure dealership nature of the market. While quote display systems were computerised, the trade execution function was not automated.

[25] Many European Exchanges introduced changes in their trading systems to make themselves more competitive: TSA by Amsterdam Stock Exchange in 1994; SWX by the Swiss Exchange in 1995; XETRA by Deutsche Borse AG in 1997; and NSC by the Paris Bourse in 1996 (see Demarchi and Foucault, 1998).

[26] This article allowed European markets to enrol remote members in other EU countries without securing

Market participants and researchers started comparing costs of trading the same stocks across different exchanges[27]. Although LSE served well the needs of large domestic institutional investors through its high depth[28], it was widely perceived as a market with high trading costs for small retail investors and this high cost was attributed to the dealership nature of the market[29]. Since LSE and NASDAQ were the two main dealer markets in equities, the controversies created by the collusion allegations on NASDAQ (Christie and Schultz (1994), Christie, Harris and Schultz (1994)) added to the popular perception that LSE market makers were profiting unduly from the dealership system. And amid all these developments, LSE was perceived to be sitting still rather than doing something about the changed market conditions in the nineties.

B. ***Nature of Market Reforms***

In October 1997, the exchange introduced a fundamental shift in the nature of the market by replacing the quote-driven manual trade execution system to an order-driven electronic trade execution system SETS interacting with a network of dealers. In the new order-driven system, buyers and sellers could post limit orders or pick limit orders electronically (through their broker or a member firm), and they could *also* trade with dealers functioning as voluntary liquidity suppliers. Since order-driven systems seem to work better for liquid stocks, the change was introduced initially for the hundred highest market

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permission from the regulatory authorities in that country.

[27] See Pagano and Roell (1990) and De Jong et. al., (1995) for comparison of quoted and inside spreads across LSE and European exchanges. Also see Werner and Kleidon (1996) for the analysis of UK and US trading of British cross-listed stocks.

[28] Large institutional US investors were apparently not happy with the lack of transparency in the London market making system since it appears they were paying higher trading costs relative to domestic institutional traders. This is clear, for example, from the April 1999 newsletter of the *Plexus Group*, and the background note circulated by *Global Investor* for their July 1999 roundtable discussion in London on institutional trading.

[29] The perception of high trading costs in the old dealer type London market is not entirely correct. Although the quoted half-spreads and inside half-spreads on LSE had been relatively high, the overall value-weighted average of effective half-spreads and the overall value-weighted average of realised half-spreads have been documented to be very low (Hansch et al (1999), Naik and Yadav (1999)). However, these effective and realised half-spreads differed significantly across different trade sizes, being large in magnitude for small trades, small in magnitude for medium-to-large trades, and increasing again in magnitude for very large trades.

capitalisation stocks which were part of the FTSE-100 index. This coverage has been extended (albeit very slowly) to other stocks as new stocks have joined the FTSE-100 after quarterly market capitalisation reviews, and in some other special cases.

Relative to the market reforms on the NASDAQ, the reforms on LSE represented a significantly greater move from a quote-driven dealership market to an order-driven auction market. Unlike the NASDAQ, dealers were no longer obliged to quote firm two way prices as they did earlier, and their quotes were no longer available to investors through publicly available price-display systems. Dealers' participation became entirely voluntary, and the functions of price formation and liquidity creation were left to collective market forces. Yet, unlike other order driven markets like Paris and Frankfurt, LSE did not introduce special procedures for the market open. However, an active dealer market did continue to formally exist with limited obligations to interact with the order book.

C. *Expected Benefits*

Compared to the old dealer-market, the LSE expected the order book to result in lower trading costs of public investors because of several reasons. First, the new system would give public investors more choice, thus opening up the potential for a range of different trading strategies[30]. The ability to post limit orders also improved the bargaining power of public investors while negotiating with dealer firms. Second, the public investors were now able to observe the entire order book and have real-time knowledge of prices and quantities of trades executed on the order book. Third, order handling costs were expected to be lower due to automated order execution. Thus, the wider choice, greater transparency and lower order processing costs were expected to significantly improve the competitiveness of

[30] The limit order book gives the public investor an important tool to influence the trading costs. Either the public trader can pay the inside half-spread and guarantee execution immediately, or she can try to earn that effective half-spread by being patient and posting a limit order on the electronic order book. Execution of a limit order is not guaranteed, but if it does execute, she can earn the spread instead of paying it.

the LSE[31].

D. *Salient Features of Post-Reform Trading*

LSE has been and continues to remain the dominant exchange for equity trading within the UK with a market share exceeding 99%. After the introduction of SETS, the new order book, trades in SETS stocks can be done either through the order book or through the dealer network offering dealership services on a voluntary basis. In this section, we provide a descriptive analysis of the contribution of the limit order book to the total trading on the exchange. Similar post-reform statistics for NASDAQ are not available, and hence it is not possible to make definitive direct comparisons.

Markets Analysis, published periodically by the London Stock Exchange[32], provides salient descriptive statistics on London market trading. Several descriptive features highlighted in these statistical charts and reports, and observed by us in our sample, are important from the perspective of this paper. First, on the basis of market value, and also the number of bargains, the relative percentage of trading in SETS stocks taking place through the order book is significant and growing, varying from about 35% in the first month (October/November 1997) to over 50% at the end of 1999. The average daily value traded through the order book in London has been £643 million in 1997, £830 million in 1998 and £1318 million in 1999. The average daily number of order book bargains has been 10,820 in 1997, 14,174 in 1998 and 20,360 in 1999. In our view, the proportion of order flow through SETS is remarkably high in the context of two factors, one historical and one institutional. Historically, both individual/institutional traders have no earlier experience of supplying liquidity through limit orders, and, with about 60% of all order flow in the old system being

[31] There is strong interest among regulators, practitioners, exchange members and market participants in analysing whether these expected benefits have materialised (see London Financial News, 5 October 1998).
[32] After introduction of SETS, these have been published in November 1997, January 1998, March 1999 and November 1999.

preferenced to particular dealers[33], there has also been a tradition of long-standing trading relationships between dealers and individual/institutional traders. Institutionally, a significant proportion of small retail trades of individual public investors are executed through specially designated market intermediaries called *Retail Service Providers* (RSP's) and these RSP's, being part of the dealer network, often execute these trades through the dealer network, albeit at best system prices[34].

Second, in addition to executing all trades in the voluntary dealer network, market intermediaries also play a major role in execution of trades in SETS, the new order book, though they do so voluntarily and are not obliged to do so. About 2% of the trades on SETS are executed directly between two public customers. Market intermediaries trading on their own account are the counter-parties in about 98% of the bargains executed through SETS[35]. Comparable figures are not reported (or even definable) for NASDAQ.

Third, even though a sizeable fraction of *public trades* go through SETS, i.e. about 20% to 25%, this fraction is smaller than the proportion of total trading going through SETS which is about 40% to 50%. This is because the inter-dealer trades that used to be executed anonymously through the (since discontinued) Inter-Dealer-Broker (IDB) order-matching network reserved exclusively for dealers in the old pure dealer market now go through SETS[36]. As a result, the proportion of inter-firm principal-to-principal trades that take place

[33] See Hansch et. al. (1998) for empirical evidence on preferencing from the London market.
[34] When SETS was launched in October 1997, there was a minimum order size of £4000 for a trade to be eligible for trading on SETS since it was intended that these smallest sized retail trades will be executed separately through these *Retail Service Providers* (RSP's). However, this minimum order size has since been removed on 8th June 1998.
[35] A fraction of the business on the order book is "risk-less principal trading", i.e. business carried out in agency capacity but booked as principal for administrative purposes. Though definitive estimates of the extent of such reporting are not available, our discussions with dealers and exchange officials suggest that this fraction is very small: less than 5%. These "risk-less principal trades" should actually be regarded as agency trades, but since they appear in our data as principal trades, we have to classify them as principal trades. However, we cannot think of any reason to expect any correlation between trading costs and the nature of these trades. Hence, irrespective of the number of such trades, the impact on our analyses should only be to reduce the size of the sample of trades we analyse, and not to create any bias.
[36] See e.g. Reiss and Werner (1998, 1999) for a detailed analysis of inter-dealer trading on the LSE under the old dealership system.

through SETS is considerably greater than the proportion of *public* customer trades going through SETS[37]. However, even though the proportion of public trading going through the order book is relatively smaller than the proportion of inter-dealer trading going through the order book, our results show that it has resulted in major changes in the schedule of trading costs actually faced by public investors - both on the order book and in the dealer network. This is not surprising in the context of the work on contestable markets of Demsetz (1968) and Baumol, Panzar, and Willig (1982). This work emphasizes that industries with only a few firms (or even just one) can be very competitive if there is a threat of entry by other firms due to low entry and exit costs. In our context, even though a relatively small proportion of public order flow is executed through SETS, the public order flow being executed through the dealer network also benefits from SETS since there is the threat that this order flow can migrate to SETS at virtually at zero cost.

Fourth, there are special arrangements called Worked Principal Agreements (WPA's) for the largest trades, specifically trades above 8 times the *Normal Market Size* (NMS)[38]. The use of WPA's has always remained relatively insignificant. Large trades are either "worked" through the order book by breaking them into smaller trades, or are executed through dealers. Hence, for simplicity, we confine our analyses in this paper to trades below 8 NMS in size. Most of the public trading through SETS is in medium-sized trades up to one NMS in size.

Fifth, the depth of the limit order book at the best bid and ask prices has averaged less than one NMS all through 1997, 1998 and 1999. The maximum depth of the order book has averaged about 6 NMS. However, it is difficult to assert that this is the *true* depth of the

[37] However, the aim of this paper is to analyse the trading costs of public investors, not all liquidity suppliers. Hence, we do not analyse the impact of the reform on inter-dealer trading costs.

[38] NMS, the "normal market size" of a particular stock, is defined as being equal to approximately 2.5% of the average total daily trading volume in that stock over a reference three-month period. Thus, the trade execution difficulty for medium to large trades becomes more comparable across stocks when trade size is expressed in multiples of NMS.

order book because of the existence of substantially greater, albeit non-quantifiable, hidden depth of orders in the dealer network that migrates to SETS as soon as orders on the book get executed. The order book and the dealers trading off the order book *together* constitute *overall* market depth. Therefore the schedule of trading costs actually paid by different sized trades is a more meaningful indicator of true depth than the explicitly visible schedule of limit orders posted on SETS. In this context, we do not explicitly report statistics on the "depth" of the order book. However, for a sub-set of stocks, we use the order history file to construct the demand and supply schedules comprising the order book. We use the order book schedules to analyse whether the extent of visible depth in the order book affects the trading costs of public investors in the dealer network.

Figure 1.

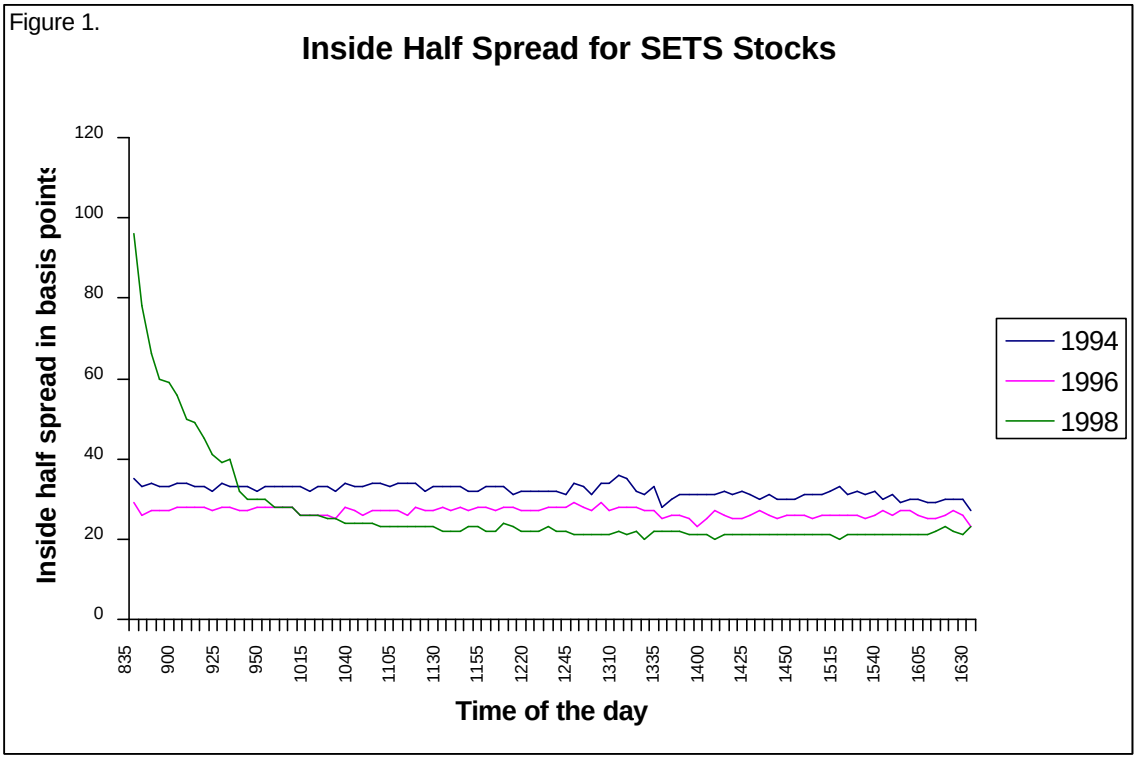

Figure 2.

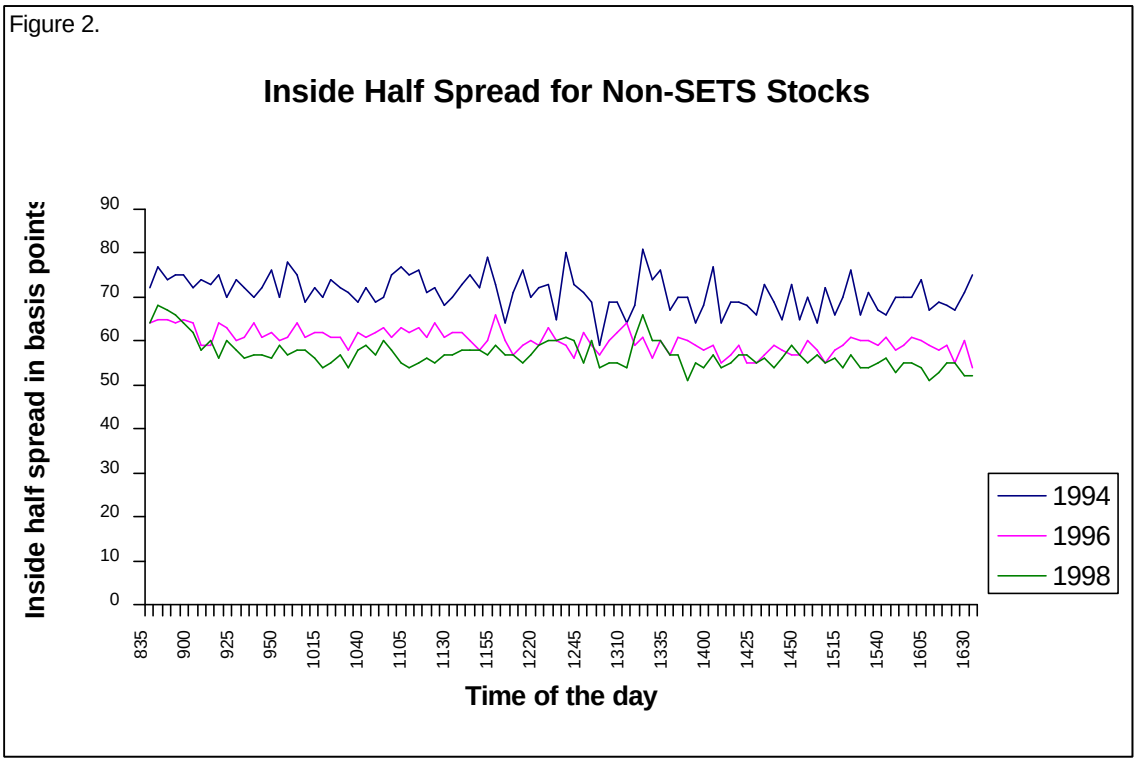

Figure 3

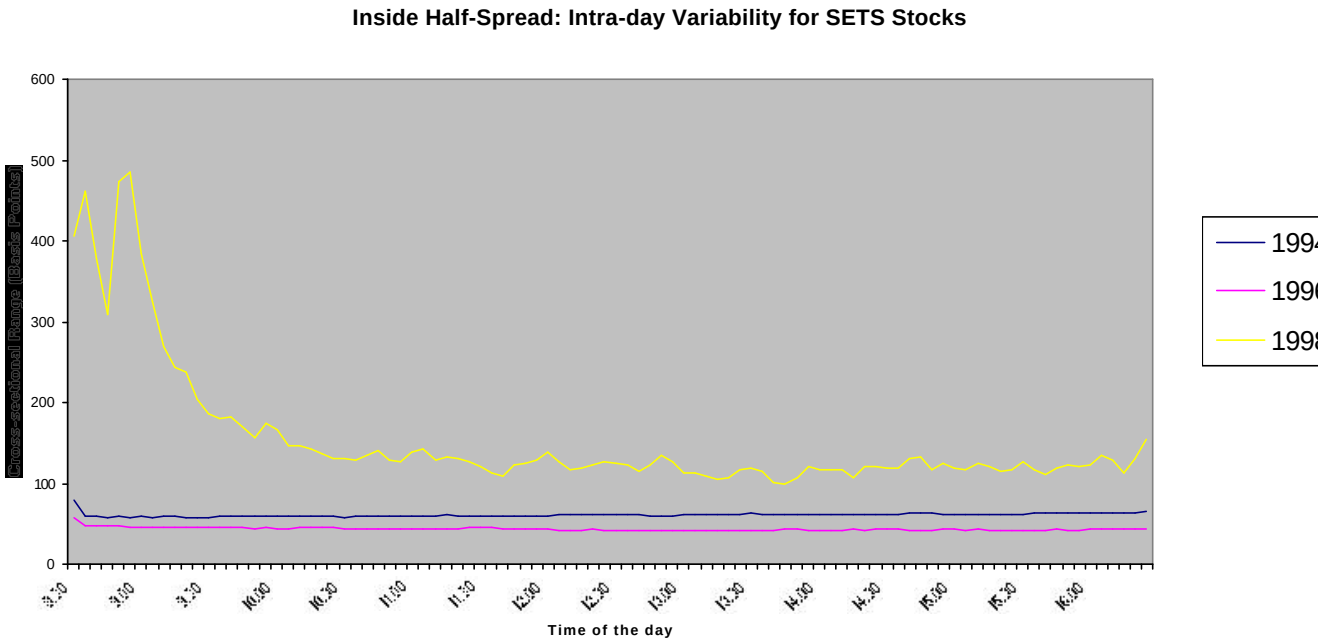

Figure 4

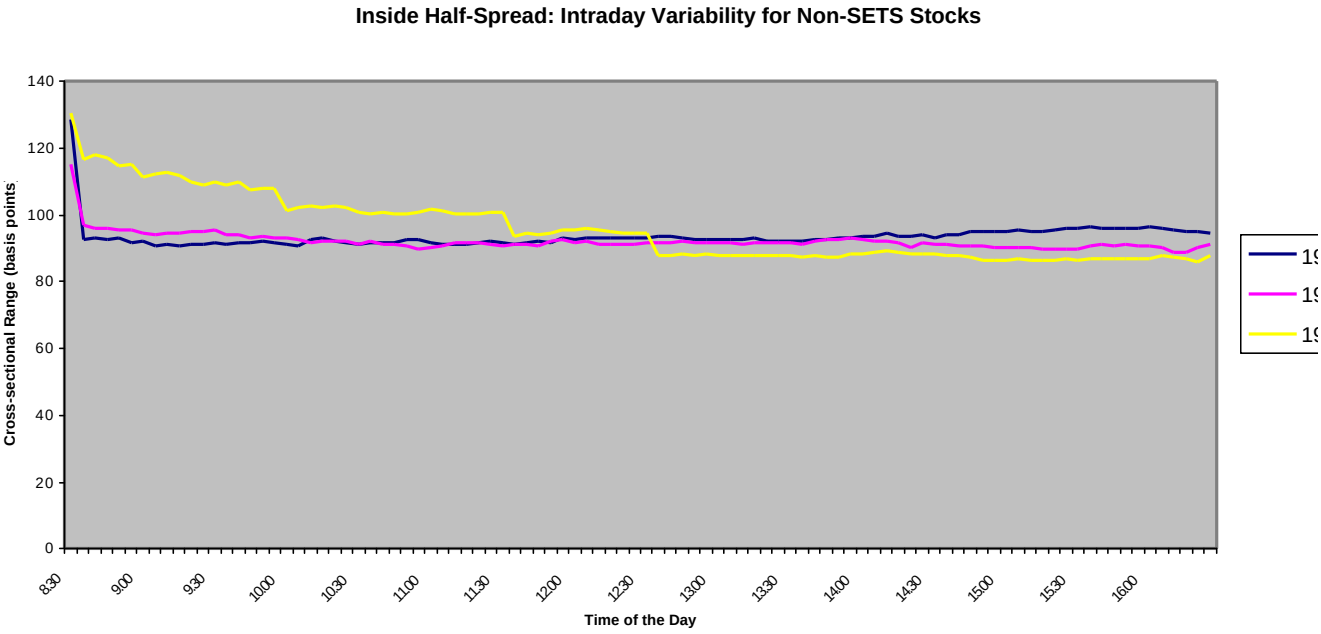

Table I

Value of Shares Traded in Different Trade Sizes

The London Stock Exchange Trading System Reform in 1997 consisted of the introduction of SETS, an electronic order book, interacting with the existing network of competing dealers. This table presents the value of shares traded in different trade size categories in three periods in 1994, 1996 and 1998, each of three months duration. The value of shares traded is reported separately for stocks which underwent trading system reform (SETS stocks), and those which did not (non-SETS stocks). Trade size classifications in London are based on NMS (normal market size) which is approximately 2.5% of the average daily trading volume in the security. Corresponding percentages of the total value of shares traded across different trade sizes are given below the trading value figure. All figures are in Million Pounds Sterling.

	Non-SETS Stocks			SETS Stocks			
Trade size Classification	1994	1996	1998 (Dealers)	1994	1996	1998 (Dealers)	1998 (Order Book)
Trades<0.125NMS	351	520	296	4080	7180	6830	4668
	3.3%	3.7%	2.0%	7.2%	8.4%	9.4%	24%
0.125NMS-0.25NMS	188	271	200	1590	2630	3050	4166
	1.8%	1.9%	1.3%	2.8%	3.1%	4.2%	21.4%
0.25NMS-0.5NMS	265	354	273	2480	3820	4750	4935
	2.5%	2.5%	1.8%	4.4%	4.5%	6.5%	25.3%
0.5NMS-1NMS	433	517	441	4320	6080	6521	3798
	4.1%	3.7%	2.9%	7.6%	7.1%	9.0%	19.5%
1NMS-3NMS	1690	1890	2001	15900	18800	17466	1817
	15.9%	13.4%	13.3%	28.0%	22.1%	24.0%	9.3%
3NMS-8NMS	3240	3430	2123	17600	25500	13060	85
	30.5%	24.3%	14.1%	30.9%	29.9%	18.0%	0.5%
Trades>8NMS	4440	7130	9732	10900	21200	21005	0
	41.9%	50.5%	64.6%	19.2%	24.9%	28.9%	0%
Total	10607	14112	15066	56870	85210	72681	19469

TABLE 2

CHANGES IN INSIDE HALF-SPREADS

This table reports the results of running the following regression separately for a change from (pre-reform) 1994 to (post-reform) 1998, and a change from (pre-reform) 1996 to (post-reform) 1998:

$$\Delta IHS^{k} = \sum_{t=1}^{8} a_{t} D_{t} + \sum_{t=1}^{8} a_{t}^{SETS} D_{t} D^{SETS} + (f_{1}\Delta V^{k} + f_{2}\Delta P^{k} + f_{3}\Delta SD^{k}) + (f_{1}^{SETS}\Delta V^{k} + f_{2}^{SETS}\Delta P^{k} + f_{3}^{SETS}\Delta SD^{k}) D^{SETS} + e_{t}^{k}$$

where:

- ΔIHS^{k} is the change in inside half-spread measure (mean, median, or the difference between the maximum and the minimum) for stock *k*;
- D_{t} (t = 1, 2, …, 8) is a dummy variable for the eight hourly intervals within the trading day;
- D^{SETS} is a dummy variable with a value of one for SETS stocks (undergoing reform) and zero otherwise;
- ΔV^{k} is the average change in the volume of trading for stock *k*;
- ΔP^{k} is the average change in price for stock *k*;
- ΔSD^{k} is the change in volatility for stock *k;*
- The coefficients a_{t} (t = 1, 2, …, 8) capture the overall change in the inside half-spread measure in hourly interval *t*;
- The coefficients a_{t}^{SETS} (t = 1, 2, …, 8) capture the change in the inside half-spread measure in hourly interval *t* for the subset of SETS stocks (undergoing reform);
- The coefficients f_{1}, f_{2}, and f_{3} capture the overall change in the inside half-spread measure due to trading volume changes, price level changes, and volatility changes respectively;
- The coefficients f_{1}^{SETS}, f_{2}^{SETS}, and f_{3}^{SETS} capture the change in the inside half-spread measure due to trading volume changes, price level changes, and volatility changes respectively specifically for SETS stocks (undergoing reform); and
- e_{t}^{k} is a random error term for stock *k*.

TABLE 2 (continued)

CHANGES IN INSIDE HALF-SPREADS

	From 1994 to 1998				From 1996 to 1998			
Change in	Mean	Median	Max - Min		Mean	Median	Max – Min	
a_1	**-4.65** (-3.56)	**-5.56** (-4.55)	8.00 (1.95)		**7.40** (6.98)	**7.47** (7.43)	**11.88** (3.03)	
a_2	**-4.70** (-4.07)	**-5.49** (-5.07)	6.29 (1.73)		**6.59** (7.01)	**6.14** (6.90)	**10.70** (3.08)	
a_3	**-4.61** (-4.08)	**-4.96** (-4.69)	5.55 (1.57)		**5.40** (5.87)	**5.24** (6.02)	**10.35** (3.05)	
a_4	**-5.03** (-4.45)	**-6.28** (-5.94)	5.64 (1.59)		**5.25** (5.72)	**4.39** (5.05)	**11.12** (3.27)	
a_5	**-5.20** (-4.61)	**-6.67** (-6.32)	4.67 (1.32)		**5.13** (5.60)	**4.53** (5.22)	**10.25** (3.02)	
a_6	**-5.07** (-4.51)	**-6.73** (-6.39)	4.57 (1.30)		**5.14** (5.62)	**4.48** (5.17)	**9.37** (2.77)	
a_7	**-4.04** (-3.69)	**-5.77** (-5.62)	3.78 (1.10)		**5.64** (6.33)	**4.46** (5.28)	**10.70** (3.25)	
a_8	**-3.05** (-2.79)	**-4.87** (-4.76)	3.51 (1.03)		**6.30** (7.10)	**5.03** (5.98)	**11.42** (3.48)	
a_1^{SETS}	**33.67** (25.95)	**18.97** (15.63)	**267.24** (65.75)		**35.48** (33.65)	**21.68** (21.71)	**263.94** (67.70)	
a_2^{SETS}	**6.13** (4.92)	-0.79 (-0.68)	**110.21** (28.25)		**8.23** (8.13)	**1.95** (2.04)	**108.34** (28.95)	
a_3^{SETS}	**-2.61** (-2.10)	**-8.21** (-7.06)	**83.61** (21.45)		-0.21 (-0.21)	**-5.24** (-5.48)	**83.28** (22.28)	
a_4^{SETS}	**-5.32** (-4.29)	**-9.87** (-8.49)	**72.25** (18.56)		**-2.58** (-2.56)	**-6.80** (-7.11)	**73.67** (19.73)	
a_5^{SETS}	**-6.35** (-5.11)	**-10.75** (-9.24)	**67.47** (17.33)		**-4.05** (-4.01)	**-8.09** (-8.46)	**70.66** (18.92)	
a_6^{SETS}	**-6.08** (-4.90)	**-10.35** (-8.91)	**62.75** (16.12)		**-4.12** (-4.08)	**-7.97** (-8.34)	**66.31** (17.76)	
a_7^{SETS}	**-4.92** (-3.96)	**-9.84** (-8.47)	**69.78** (17.93)		**-2.92** (-2.89)	**-6.91** (-7.23)	**73.62** (19.72)	
a_8^{SETS}	**-3.26** (-2.63)	**-8.35** (-7.19)	**71.53** (18.37)		-1.86 (-1.84)	**-6.40** (-6.70)	**76.20** (20.41)	
f_1	**2.84** (4.54)	0.88 (1.50)	**12.55** (6.39)		**7.35** (14.44)	**7.29** (15.11)	**13.34** (7.08)	
f_2	**-32.11** (-25.95)	**-27.80** (-24.02)	**-81.09** (-20.93)		**-22.94** (-22.82)	**-20.36** (-21.38)	**-63.05** (-16.96)	
f_3	**10.10** (13.19)	**5.67** (7.91)	**63.58** (26.48)		**10.41** (16.73)	**5.48** (9.30)	**61.36** (26.65)	
f_1 sets	**-20.30** (-26.67)	**-18.66** (-26.21)	**-28.38** (-11.91)		**-8.25** (-13.35)	**-6.12** (-10.45)	**-12.82** (-5.61)	
f_2 sets	**-38.04** (-24.36)	**-38.35** (-26.26)	**-47.24** (-9.66)		**-24.76** (-19.52)	**-28.78** (-23.96)	**-36.01** (-7.68)	
f_3 sets	**31.27** (28.55)	**26.19** (25.56)	**54.76** (15.96)		**19.04** (21.40)	**14.90** (17.68)	**42.74** (12.99)	
Adjusted Rsquare	50.5%	50.0%	44.0%		37.4%	36.3%	41.5%	

Table 3

Effective Half-Spreads, Adverse-Selection Half-Spreads and Realized Half-Spreads

Matrix of Possibilities

	Effective Half-Spread	Effective Half-Spread	Adverse-Selection Half-Spread	Adverse-Selection Half-Spread	Realized Half-Spread	Realized Half-Spread
	Trade Size less than one NMS	Trade Size more than one NMS	Trade Size less than one NMS	Trade Size more than one NMS	Trade Size less than one NMS	Trade Size more than one NMS
Voluntary vs Obligatory Market-Making	↓	No Change	↓	No Change	No Change	No Change
Absence of Quotes	No Change	↑	No Change	↓	No Change	↑
Competition	↓	No Change	↑	No Change	↓	No Change
Patient Trading	No Change	↑	No Change	↑	No Change	No Change

TABLE 4

CHANGES IN EFFECTIVE, REALISED AND ADVERSE-SELECTION HALF-SPREADS

PANEL A: RESULTS FOR DIFFERENT TRADE SIZE BANDS

This table reports the results of running the following regression separately for different spread measures for a change from (pre-reform) 1994 to (post-reform) 1998, and a change from (pre-reform) 1996 to (post-reform) 1998:

$$\Delta Y^k = \sum_{j=1}^{6} b_j D_j + \sum_{j=1}^{6} b_j^{Sets} D_j D^{Sets} + h_1 \Delta V^k + h_2 \Delta P^k + h_3 \Delta SD^k + (h_1^{Sets} \Delta V^k + h_2^{Sets} \Delta P^k + h_3^{Sets} \Delta SD^k) D^{Sets} + x_j^k$$

where:

- ΔY^k is the change in the average effective, realised or adverse-selection half-spread for stock *k*;
- D_j (j = 1, 2, …, 6) is a dummy variable for the six trading size bands defined in terms of the "normal-market size" (NMS) of the stock as follows: below 0.125 NMS; from 0.125 NMS to 0.25 NMS; from 0.25 NMS to 0.5 NMS; from 0.5 NMS to one NMS; from one NMS to three NMS; and from three NMS to eight NMS;
- D^{SETS} is a dummy variable with a value of one for SETS stocks (undergoing reform) and zero otherwise;
- ΔV^k is the average change in the volume of trading for stock *k*;
- ΔP^k is the average change in price for stock *k*;
- ΔSD^k is the change in volatility for stock *k;*
- The coefficients b_j (j = 1, 2, …, 6) capture the overall change in the average effective, realised or adverse-selection half-spread measure in trade-size band *j*;
- The coefficients b_j^{SETS} (j = 1, 2, …, 6) capture the change in the average effective, realised or adverse-selection half-spread measure in trade-size band *j* for the subset of SETS stocks (undergoing reform);
- The coefficients h_1, h_2, and h_3 capture the overall change in the inside half-spread measure due to trading volume changes, price level changes, and volatility changes respectively;
- The coefficients h_1^{Sets}, h_2^{Sets}, and h_3^{Sets} capture the change in the average effective, realised or adverse-selection half-spread measure due to trading volume changes, price level changes, and volatility changes respectively specifically for SETS stocks (undergoing reform); and
- x_t^k is a random error term for stock *k*.

TABLE 4 (continued)

CHANGES IN EFFECTIVE, REALISED AND ADVERSE-SELECTION HALF-SPREADS

PANEL A: RESULTS FOR DIFFERENT TRADE SIZE BANDS (continued)

	From 1994 to 1998			From 1996 to1998		
Change in	Effective Half-Spread	Realised Half-Spread	Adverse-Selection Half-Spreads	Effective Half-Spread	Realised Half-Spread	Adverse-Selection Half-Spreads
b_1	**-8.79** (-3.54)	4.44 (0.44)	-13.23 (-1.33)	**-4.30** (-2.39)	-19.17 (-1.77)	14.87 (1.39)
b_2	**-9.65** (-3.88)	-1.48 (-0.15)	-8.18 (-0.82)	**-6.98** (-3.88)	6.49 (0.60)	-13.48 (-1.26)
b_3	**-11.23** (-4.52)	3.64 (0.36)	-14.86 (-1.50)	**-8.98** (-4.99)	1.31 (0.12)	-10.29 (-0.96)
b_4	**-18.59** (-7.48)	-19.29 (-1.90)	0.69 (0.07)	**-12.41** (-6.90)	-7.95 (-0.73)	-4.46 (-0.42)
b_5	**-24.27** (-9.76)	-13.56 (-1.33)	-10.71 (-1.08)	**-19.71** (-10.96)	-17.54 (-1.62)	-2.18 (-0.20)
b_6	**-29.48** (-11.86)	**-32.71** (-3.21)	3.22 (0.32)	**-25.23** (-14.02)	**-31.68** (-2.92)	6.44 (0.60)
b_1^{Sets}	1.33 (0.34)	1.10 (0.07)	0.23 (0.01)	0.89 (0.31)	15.02 (0.86)	-14.13 (-0.82)
b_2^{Sets}	1.00 (0.26)	2.39 (0.15)	-1.38 (-0.09)	1.14 (0.40)	-3.53 (-0.20)	4.67 (0.27)
b_3^{Sets}	1.22 (0.31)	-0.79 (-0.05)	2.01 (0.13)	1.63 (0.57)	1.13 (0.07)	0.51 (0.03)
b_4^{Sets}	6.78 (1.73)	21.81 (1.36)	-15.02 (-0.96)	4.33 (1.50)	15.79 (0.91)	-11.46 (-0.67)
b_5^{Sets}	**11.60** (2.95)	17.82 (1.11)	-6.22 (-0.40)	**10.42** (3.61)	11.00 (0.63)	-0.57 (-0.03)
b_6^{Sets}	**15.07** (3.83)	**29.26** (1.98)	-14.19 (-0.90)	**14.99** (5.19)	**31.61** (1.98)	-16.61 (-0.97)
h_1	-1.14 (-0.69)	-0.76 (-0.11)	-0.37 (-0.06)	**4.09** (2.39)	11.85 (1.15)	-7.76 (-0.76)
h_2	**-12.79** (-3.94)	-20.51 (-1.54)	7.72 (0.59)	**-10.61** (-3.65)	-15.02 (-0.86)	4.41 (0.25)
h_3	3.65 (1.77)	4.50 (0.53)	-0.85 (-0.10)	2.21 (1.67)	10.15 (1.27)	-7.94 (-1.01)
h_1^{Sets}	**-13.69** (-7.35)	-3.91 (0.51)	-9.77 (-1.31)	**-6.33** (-3.63)	-18.13 (-1.72)	11.80 (1.13)
h_2^{Sets}	**-8.94** (-2.41)	-29.42 (-1.94)	20.48 (1.38)	**-11.87** (-3.77)	32.49 (1.71)	**-44.36** (-2.36)
h_3^{Sets}	**22.17** (8.39)	-5.74 (-0.53)	**27.91** (2.64)	**15.41** (7.63)	19.96 (1.64)	-4.54 (-0.38)
Adjusted R-square	37.8%	4.8%	1.6%	33.9%	2.3%	2.3%

TABLE 4 (continued)

CHANGES IN EFFECTIVE, REALISED AND ADVERSE-SELECTION HALF-SPREADS

PANEL B: AGGREGATE RESULTS

This table panel reports the results of running the following regression separately for different spread measures for a change from (pre-reform) 1994 to (post-reform) 1998, and a change from (pre-reform) 1996 to (post-reform) 1998:

$$\Delta Y^k = d + d^{Sets} D^{Sets} + h_1 \Delta V^k + h_2 \Delta P^k + h_3 \Delta SD^k$$
$$+ (h_1^{Sets} \Delta V^k + h_2^{Sets} \Delta P^k + h_3^{Sets} \Delta SD^k) D^{Sets} + z_j^k$$

- ΔY^k is the change in the average effective, realised or adverse-selection half-spread for stock *k*;
- D^{SETS} is a dummy variable with a value of one for SETS stocks (undergoing reform) and zero otherwise;
- ΔV^k is the average change in the volume of trading for stock *k*;
- ΔP^k is the average change in price for stock *k*;
- ΔSD^k is the change in volatility for stock *k;*
- The coefficient d captures the overall change in the aggregate effective, realised or adverse-selection half-spread measure in trade-size band *j*;
- The coefficients d^{Sets} captures the change in the aggregate effective, realised or adverse-selection half-spread measure in trade-size band *j* for the subset of SETS stocks (undergoing reform);
- The coefficients h_1, h_2, and h_3 capture the overall change in the inside half-spread measure due to trading volume changes, price level changes, and volatility changes respectively;
- The coefficients h_1^{Sets}, h_2^{Sets}, and h_3^{Sets} capture the change in the average effective, realised or adverse-selection half-spread measure due to trading volume changes, price level changes, and volatility changes respectively specifically for SETS stocks (undergoing reform); and
- z_j^k is a random error term for stock *k*.

	From 1994 to 1998			From 1996 to1998		
Change in	Effective Half-Spread	Realised Half-Spread	Adverse-Selection Half-Spreads	Effective Half-Spread	Realised Half-Spread	Adverse-Selection Half-Spreads
d	**-26.44** (-10.55)	**-29.84** (-2.80)	3.39 (0.34)	**-21.97** (-10.55)	-15.23 (-1.44)	-6.74 (-0.63)
d^{Sets}	**14.21** (2.90)	28.17 (1.35)	-13.96 (-0.72)	**13.19** (3.37)	1.45 (0.07)	11.74 (0.59)
h_1	-2.02 (-0.63)	-4.93 (-0.36)	2.91 (0.23)	1.91 (0.59)	5.74 (0.35)	-3.83 (-0.23)
h_2	-10.41 (-1.66)	-17.04 (-0.64)	6.62 (0.27)	-7.88 (-1.43)	3.51 (0.13)	-11.40 (-0.40)
h_3	1.03 (0.26)	9.87 (0.58)	-8.83 (-0.56)	0.37 (0.15)	16.65 (1.30)	-16.27 (-1.27)
h_1^{Sets}	**-13.66** (-3.80)	-16.32 (-1.07)	2.66 (0.19)	-6.39 (-1.93)	**-43.43** (-2.58)	**37.04** (2.19)
h_2^{Sets}	0.77 (0.11)	-0.58 (-0.02)	1.35 (0.05)	-1.90 (-0.32)	**63.20** (2.08)	**-65.11** (-2.14)
h_3^{Sets}	**21.05** (4.12)	15.46 (0.71)	5.59 (0.28)	**14.94** (3.90)	0.27 (0.01)	14.67 (0.75)
Adjusted R-square	37.8%	7.8%	2.6%	27.7%	9.5%	10.4%

TABLE 5

POST-REFORM LIQUIDITY SUPPLY IN THE ELECTRONIC ORDER BOOK

DIFFERENCES BETWEEN MARKET INTERMEDIARIES AND PUBLIC INVESTORS

REGRESSIONS WITH CONTROLS FOR TRADING VOLUME, PRICE AND VOLATILITY

We run the following regression separately for each of the different spread measures:

$$Y^k = b_{PubInv} D_{PubInv} + h_1 V^k + h_2 P^k + h_3 SD^k + x_2^k$$

where Y^k is the average inside, effective, realised or adverse-selection half-spread for stock *k*; D_{PubInv} is a dummy variable with a value of one for averages for public investors, and zero otherwise; V^k is the log of the average volume of trading for stock *k*; P^k is the log of the average price for stock *k*; SD^k is the change in volatility for stock *k;* the coefficient b_{PubInv} captures the overall change in the average inside, effective, realised or adverse-selection half-spread measure; the coefficients h_1, h_2, and h_3 capture the overall effect on the half-spread measure due to trading volume, price level, and volatility respectively;; and x_2^k is a random error term for stock *k.* The regression captures the differences between public investors and market intermediaries after controlling for the dependence of these spread measures on trading volume, price level and volatility.

	Inside Half-Spreads	Effective Half-Spread	Realised Half-Spread	Adverse-Selection Half-Spreads
Constant	**215.91** (25.82)	**225.25** (24.89)	**121.63** (6.86)	**103.89** (6.20)
b_{PubInv}	**1.94** (2.52)	**1.68** (2.01)	-1.30 (-0.79)	**3.07** (1.99)
h_1	**-10.54** (-25.73)	**-10.97** (-24.74)	**-6.31** (-7.27)	**-4.67** (-5.70)
h_2	**3.84** (5.78)	**4.27** (5.94)	2.23 (1.58)	2.02 (1.51)
h_3	**7.52** (6.50)	**8.39** (6.70)	3.79 (1.55)	**4.60** (1.99)
Adjusted R-square	47.5%	45.8%	6.6%	5.0%

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