Does a Large Minimum Price Variation Encourage Order Exposure?

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ABSTRACT

Does a Large Minimum Price Variation Encourage Order Exposure?

The minimum price variation (tick) affects order exposure. Traders who display their orders risk being front-run. In markets that enforce time precedence, the tick makes front-running expensive. It sets the price of obtaining order precedence through price priority when another trader has time precedence. This paper examines order, quotation, and transaction data from the Paris Bourse and the Toronto Stock Exchange to characterize the relation between tick size and order exposure. The results show that traders display more size when the tick is large and when intraday volatility is small. The topic is particularly timely given recent regulatory interest in reducing tick sizes.

Key words: Minimum price variations, tick, time precedence, order transparency, order display, order disclosure, hidden orders, quotation sizes, electronic exchanges, front-running, order option values.

Does a Large Minimum Price Variation Encourage Order Exposure?

EXCHANGES AND BROKERS that use computer assisted trading systems to arrange trades are successful only if they can encourage traders to offer liquidity in their systems. Traders offer liquidity when they submit standing limit orders that indicate that they are willing to trade. Traders may publicly display these indications or they may only disclose them to the trading system. Without standing limit orders, these systems have no liquidity.

To be successful, trading systems must attract traders who demand liquidity. Liquidity demanders submit their orders to where they expect they will be filled. Where traders can see displayed liquidity, they can easily form these expectations. Where liquidity may be present but undisplayed, they form these expectations through experience generated by trial and error. Since liquidity is easier to find when it is displayed, and since some traders may trade only when they see an opportunity, the sponsors of trading systems want traders to fully display their orders.

Traders who offer liquidity, and especially those who display their offers, expose themselves to various risks. They risk trading with better informed traders (adverse selection). They also risk higher transaction costs if other traders employ front-running trading strategies to profit from the information conveyed by their exposure. Trading systems that force traders to expose their standing orders may drive those orders away.

Trading system designers therefore must balance two sometimes conflicting interests. They need to attract liquidity and they want traders to display that liquidity. If they force traders to display, they may not obtain the liquidity.

To encourage traders to offer liquidity, trading systems provide various facilities that allow traders to limit their order display. Virtually all systems permit traders to cancel orders on demand or at some prespecified time. Fill-or-kill, day, and good-till-canceled order instructions are examples of such facilities. Some systems, such as those used by the Paris Bourse, the Toronto Stock Exchange and Globex, also allow traders to specify only partial display of their orders. These systems hide the remaining size and display it only after the displayed size executes. In these systems, liquidity demanders learn about the undisclosed size only upon the presentation of a qualifying order that executes.

To encourage traders to display their orders (and to encourage order submission), most order-driven trading systems use secondary order precedence rules that reward traders for displaying their orders.[1] Time precedence rules encourage traders to display by giving the first orders submitted at a given price the right to trade first. In those systems that allow traders to partially disclose their orders, a display precedence rule gives precedence to displayed order size over undisplayed size at a given price.

The economic importance of secondary order precedence rules depends on the size of the minimum price variation, known in some markets as the tick.[2] If the tick is small, traders can use price priority to obtain precedence by just slightly improving price. A large tick makes front-running strategies expensive and should therefore encourage traders to expose their orders.

This study examines the empirical relation between order exposure and tick size. Using order data from the Paris Bourse and the Toronto Stock Exchange, the analyses characterize the trader propensities to control their order display. The results show that larger ticks are indeed associated with greater order display. Traders are also less likely to display in volatile stocks. Additional analyses show how the tick affects more general measures of market liquidity.

The results should interest exchanges, brokers, regulators, traders, and academics. Exchanges will be interested because they specify their minimum price variation schedules.[3] Brokers will be interested because traders who wish to control their order exposure often use brokers to hold them hidden. Regulators will be interested because they must estimate the social costs and benefits of regulating tick sizes and of enforcing universal time precedence across exchanges.[4] Traders will be interested because they must decide when and how to expose their orders. Finally, academics should be interested because we understand very little about how tick size and time precedence affect market quality.

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[1] Price priority is usually the first precedence rule. Price priority gives precedence to orders that offer the best prices (the lowest offers and the highest bids).

[2] The minimum price variation is the minimum amount by which prices can differ. All prices must be expressed as an integer multiple of the minimum price variation.

[3] The Toronto Stock Exchange and the American Stock Exchange have most recently changed their minimum price variation regulations.

[4] The Division of Market Regulation of the US Securities and Exchange Commission, for example, suggested in their Market 2000 Study (1994) that smaller minimum price variations be considered for adoption, as did SEC Commissioner Steven Wallman in a September 25, 1996 speech.

The remainder of the paper is organized as follows: Section I provides a deeper discussion of the issues involved, presents hypotheses, and cites related research. Section II describes the data. Section III provides an initial empirical characterization of how traders control their order display. Section IV presents cross-sectional characterizations of the propensity of traders to display orders, and of the relation between tick size and measures of market liquidity. Section V provides a time-series analysis of these issues for a subset of stocks that traded on two tick sizes during the sample period. The paper concludes in Section VI with a short summary and some suggestions for further research.

I. Theoretical Discussion, Testable Hypotheses and Prior Research

A. Economics of the Order Exposure Decision

The main reason traders display orders is to attract other traders. Traders who expose their orders risk that other traders will use this information to their disadvantage. Such traders may try to infer security values from the exposed order flow or they may try to take advantage of trading options implicit in the exposed order flow.

If the market suspects that a trader is well informed, price will move away from him when he exposes his order. Other traders will either front-run his order or they will refuse to supply liquidity to his side without a substantial price concession. This may happen regardless of whether the trader is indeed well informed.

Traders rarely know who is well informed because informed traders do not want to be identified. Traders widely believe that large anonymous traders are well informed. They base this conclusion on the observation that informed trading is most profitable when traders can trade large size with little price impact and on the presumption that large traders will invest more in information than will small traders. Traders also assume that aggressively priced orders may come from informed traders because impatient traders generally issue such orders.

Even if traders are uninformed, their order exposure can still adversely affect their trading costs. Orders provide free trading options to other traders. The value of these options can be extracted by clever traders called quote-matching front-runners.

For example, suppose that a quote-matcher knows that a large order to buy stock is at 20. If she can buy the stock before the large trader, she will acquire a valuable position in the stock.

If stock values subsequently rise, she will profit to the full extent of the rise. If they fall, she may be able to bound her loss by selling to the large order at 20.

In practice, several factors may make it difficult to profit from this strategy. The quote-matcher may be unable to acquire her position without paying a substantial premium over 20. If she does acquire her position, she may be unable to sell out to the large order. The large order trader may cancel the order or adjust it downward to reflect a change in values. Although these (and other) factors make the quote-matcher strategy less profitable, they may not eliminate all potential profits. Quote-matching can be profitable if traders can identify and exploit significant inelasticities in the demand for liquidity.

The profits that quote-matchers make come at the expense of the order exposing traders. Quote-matchers take liquidity that might otherwise have gone to these traders. In the example, if the quote-matcher takes a trade away from the large trader, and if price subsequently rises, the quote-matcher profits are profits that otherwise would have gone to the large trader.

B. Defensive Strategies

Large traders and informed traders limit order exposure to minimize their losses to quote-matching front-runners. Traders control order exposure three ways. They have their agents manage exposure for them, they cancel and resubmit their orders, and they break up their orders.

In automated order matching systems, the system is the traders' agent. In systems that permit partial order exposure, traders specify how their orders should be displayed. Usually, some minimum quantity must be displayed. Liquidity demanders can discover undisplayed size only by committing to trading with it and with all displayed orders at the same price.[5] This mechanism greatly reduces the potential profits from quote-matching strategies by denying information to traders who are not otherwise interested in trading.

In manual trading systems, traders control their order exposure by instructing their brokers to expose only to traders who are likely to be interested in trading. (The instruction is usually implicitly assumed.) A good broker exposes orders only to traders who are likely to fill them, and avoids traders who would front-run them.

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[5] For example, suppose that a trader wonders whether there is undisclosed liquidity to sell at 30. To reveal it, he must place a limit buy order at 30 for more size than is displayed there. If the order trades more than the displayed size, the trader will have discovered the hidden liquidity, but only to the extent of his order size.

Traders can also cancel their orders frequently to control their order exposure. They may cancel their orders manually, or they may instruct their agents to cancel them at some prespecified time. The order cancellation strategy frustrates the quote-matching strategy by making it difficult to identify a trader's true intentions. It also makes the quote-matching strategy more risky by reducing the order option values: When traders cancel their orders frequently, quote-matchers cannot rely upon them to take them out of unprofitable positions.

The final method for controlling order exposure is to break orders into small pieces and distribute the pieces through time and/or across brokers. This strategy makes it difficult for quote-matchers to identify the full order before it executes. Traders who submit orders to completely confidential trading systems such as POSIT do not need to break up their orders. That traders routinely break up their large orders when trading at traditional exchanges suggests that they do indeed worry about how their size is treated on the floor.

C. Implications

Traders consider the advantages and disadvantages of order exposure when they decide how to trade. Exposure is generally advantageous if it does not create profitable front-running strategies. Time-precedence, in conjunction with an economically significant minimum price variation, helps protect exposed orders by making front-running strategies less profitable.

These arguments suggest several testable hypotheses:

- For a given tick, traders will expose small orders more than large orders.
- Order exposure in order-driven price-time precedence systems will increase with tick size.
- Traders will allow their orders to stand for longer, and they will cancel their orders less often, when the tick is large relative to price.
- The average trade size will be smaller when the relative tick is small.
- Order exposure will be smaller when volatility is higher (because order option values increase with volatility).

This study tests these implications using Paris Bourse and Toronto Stock Exchange data.

D. Relation to Previous Work

This study is related to several lines of research. Many previous studies examine the empirical relation between tick size, market liquidity, and trading volumes. Harris (1991, 1994), Bacidore (1996), Ahn, Cao and Choe (1996), Crack (1995), Ting and McInish (1995), Hameed and Terry (1995), and Niemeyer and Sandas (1993) respectively analyze data from the New York Stock Exchange, Toronto Stock Exchange, American Stock Exchange, American Stock Exchange, Stock Exchange of Singapore, Stock Exchange of Singapore, and the Stockholm Stock Exchange. These studies all examine market quotes. None examine orders as does this study. Their results generally show that quotation sizes and spreads increase with tick size.

Several studies examine theoretical issues related to those in this study. The first formal characterization of limit order option properties appears in Copeland and Galai (1983). Theoretical discussions of the importance of quote-matcher strategies designed to extract these option values first appear in Harris (1990) and Amihud and Mendelson (1991). Effects of the tick on liquidity supplied by dealers and limit order traders are examined in Chordia and Subrahmanyam (1995), Kandel and Marx (1995), Hollified, Miller and Sandås (1996), and Seppi (1995). Angel (1996) and Anshuman and Kalay (1994) consider whether firms split their stocks to adjust relative tick size and thereby increase liquidity. Regulatory issues involving tick size and time precedence are discussed in Harris (1993) and Hart (1993). Factors affecting the endogenous choice of a tick size are considered in Harris (1991) and Brown, Laux and Schachter (1991).

In some respects this paper is most closely related to two studies by Biais, Hillion and Spatt (1995, 1996). The first analyses how the flow of orders to the Paris Bourse varies by the state of the order book. It does not consider how the trading rules affect order exposure, however. The second paper examines order flow before the market opening call auction. The present study examines only trading in the continuous intraday session.

The title of McInish and Wood's (1995) paper, "Hidden Limit Orders on the NYSE," suggests a close relation to this work. Their study shows that specialists may fail to expose orders, but it does not consider why public traders may choose to not have them exposed. This study examines trader decisions to expose order flow.

II. Data

The data for this study come from the SBF Paris Bourse BDM database and from Toronto Stock Exchange order and trade files. The BDM database contains information about all stock orders, trades and quotes made at the Bourse. Since the CAC automated trading system produces these data, they are quite error-free.[6] The TSE data files provide similar information.

Some familiarity with the TSE and Bourse trading rules and procedures is necessary to understand the design of the empirical study and to interpret its results. This section describes these two markets, the stocks analyzed in the study, and the construction of the order sample.

A. Institutional Background

The Toronto Stock Exchange Computer Assisted Trading System (CATS) uses a pure price-time order precedence hierarchy to arrange trades. CATS allows large traders to partially display their orders. Traders who use this facility must display a minimum of 50 board lots, but they can specify more.[7] At a given price, undisclosed size has less precedence than disclosed size. When the exposed portion (and perhaps some of the hidden portion) of a partially disclosed order executes, the system then exposes more of the remaining undisclosed size. This process continues until the order is completely filled or the remainder is canceled.

Traders who use the TSE can see all displayed size on both sizes of the market, aggregated by price.[8] During the sample period analyzed in this study, the minimum price variation at the Toronto Stock Exchange was 1/8 dollar for all stocks trading above 5 dollars; 5 cents for prices between 3 dollars and 5 dollars, 1 cent between 50 cents and 3 dollars, and ½ cent below 50 cents. The minimum variations recently decreased slightly when the exchange converted to full decimal pricing on April 15, 1996.

The Paris Bourse Cotation Assistee en Continu (CAC) electronic trading system is very similar to (and is in fact derived from) the Toronto CATS system. Like CATS, CAC uses a pure price, exposure, time order precedence hierarchy. The exposed portions of partially displayed orders must be at least 10 times the minimum trading lot. Trading lots vary by stock.

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[6] No reporting problems appear in the data such as those that often afflict manual trading systems. Some trader order submission errors appear, however. For example, some limit orders that cannot be executed upon submission (because their limit prices are inferior to the best opposing quote) have fill-or-kill instructions attached to them that immediately cancel them. Traders either mistakenly coded these orders, or they submitted them when the market was moving faster than they could react.

[7] A board lot varies by stock price. It is 100 shares for stocks trading above $1, 500 shares for stocks trading between $0.10 and $1, and 1000 shares for stocks trading under 10 cents. The TSE occasionally specifies special board lots for stocks that have changed price levels.

[8] The TSE also uses a second computer assisted trading system called the floor system, or CATS 2. TSE stocks trade either trade in CATS or in the floor system, but not in both systems. Unlike CATS, all orders in the floor system must be fully disclosed. The floor system also uses a slightly different time precedence rule. Floor system data are not used in this study.

Market orders submitted to the Paris Bourse are converted to limit orders upon submission to CAC. The limit price is set to price of the best opposing quote. The order is immediately matched at that price, first with the disclosed size, and then with any undisclosed size that may be present. If the liquidity offered at that price is insufficient to completely fill the order, the remainder of the order will stand at that price. Market order traders can submit disclosure instructions and fill-or-kill instructions that apply to the remainder.

The Paris Bourse maintains a block trading facility for its larger and more actively traded stocks. For these "block eligible" stocks, the Bourse computes a bid and ask for a standard block size from data in the displayed order book. The block bid and ask show the prices necessary to execute the standard block size, based only on displayed size. The block eligible stocks include all stocks in the CAC 40 Index and some other stocks with similar trading characteristics.

The minimum price variation at the Paris Bourse varies more with the price level than at the TSE. It is FF0.01 for stocks trading below FF5; 0.05 between 5 and 100; 0.10 between 100 and 500; 1 between 500 and 5000; and 10 above 5000.

B. The Sample Stocks

The Paris Bourse stock sample consists of all 300 French common stocks that traded in the continuous market on more than 25 days of the 41 trading days in the January and February 1995 sample period. This study analyzes only French common stocks to ensure that cross-sectional comparisons do not depend on security type or market of primary listing.[9]

The study examines only orders submitted between 10:00 AM and 5:00 PM while the market was open for continuous trading. The analysis excludes pre-opening orders because they are matched in an opening call auction. Traders who submit to the call auction may employ different order strategies than traders who submit to the continuous trading market.

The Toronto Stock Exchange sample consists of all 170 CATS-traded stocks for which traders submitted at least 50 intraday orders during the November 8, 9, 14-18, 1994 sample

[9] The Paris sample excludes eight continuously traded French stocks that did not trade more than 25 days in the sample period, and approximately 70 continuously foreign stocks. The primary markets for most of the foreign stocks are in their home countries, although some may trade primarily in Paris. Many more French stocks trade in the Bourse's twice daily fixing (call) markets. These stocks are excluded because they are beyond the scope of this study.

period (seven trading days).[10] The TSE was open for continuous trading between 9:30 AM and 4:00 PM during the sample period.

C. Initial Sample Characterizations

Table I provides a summary characterization of the sample stocks. The Bourse stocks are larger and more actively traded then the TSE stocks. Equal-weighted average capitalization in the Bourse sample is 5.8 times larger than in the TSE sample (after adjusting for exchange rate differences). The ratio of value-weighted average capitalizations (3.3) is somewhat smaller. The TSE sample includes proportionally more very small stocks than does the Bourse sample. Within each sample, size also varies considerably. The largest stocks are three to four orders of magnitude larger than the smallest stocks. Since trading activity is highly correlated with firm size, variables that characterize activity show similar variation within and across samples. Bid/ask spreads are likewise inversely correlated with firm size, both within and across samples.

The average relative tick is about 12 times larger at the Toronto Stock Exchange than at the Paris Bourse. As a result, far more ticks separate the best bid and offer at the Bourse than at the TSE. The value-weighted average spread is 12.4 ticks at the Bourse but only 2.1 ticks at the TSE. The relatively small tick size at the Paris Bourse makes it is less costly to step in front of an order there than at the TSE. Accordingly, order exposure should concern traders at the Bourse more than at the TSE.

Figure 1 shows that price levels and tick sizes within both samples vary considerably. Variation in the relative tick is necessary to identify the effect of tick size on order display in the cross-sectional analyses presented below. The figure also shows that the values of the average relative tick size in the two samples hardly overlap. Only 38 TSE stocks have average relative tick sizes smaller than the maximum found in the Paris sample and only 5 Paris stocks have average relative tick sizes greater than the minimum found in the TSE sample. The points that lie along the 45 degree lines in this log-log scatter plot correspond to stocks that traded only on one tick throughout the sample period.

Table II presents the cross-sectional distribution of tick sizes that appear in the sample. A

[10] The TSE provided data for the ten trading days in November 7-18, 1994. The sample does not include data for November 7 because prior day data was required to reconstruct the limit order book. November 10 does not appear in the sample because of a clerical problem that could not be corrected. The next day, November 11, therefore had to be omitted as well.

total of 274 Bourse stocks and 158 TSE stocks traded on only one tick during their respective sample periods. Prices for the other 26 Bourse and 12 TSE stocks appeared in two adjacent price regions so that they traded on two ticks. Time-series analyses of these stocks appear in Section V. No sample stocks traded on more than two ticks.

D. The Order Display Instruction Subsample

This study primarily analyzes orders. Since the purpose is to identify how traders managed their order exposure, these analyses examine only those orders over which traders could specify meaningful display instructions. For convenience, this set of orders will be called the order display instruction subsample.

The order display instruction subsample excludes all market and marketable limit orders that traders should have expected to fully execute upon submission.[11] Traders do not need to control the display of these marketable orders because they do not expect them to stand.[12] The subsample also excludes standing limit orders that are smaller than the required minimum display size since the trader must fully display them. The order display instruction subsample does include marketable orders with expected standing remainders smaller than the minimum display size. Although these remainders are too small to be partially displayed, traders can (and often did) specify fill-or-kill instructions to prevent their disclosure.

This study determines whether traders expected an order to completely fill by comparing the order instructions to contemporaneous quote information. For the Paris database, this information includes only the best quote, and for the block eligible stocks, also the block quote. A marketable order is expected to completely fill if it is smaller than the displayed size offered to it. In addition, limit orders smaller than the standard block size with prices equal or better than the appropriate block quote are also expected to completely fill. If an order arrived when no

[11] A marketable limit order is an order priced so that at least part of it can be executed upon submission. A marketable buy (sell) limit order has a limit price at least as high (low) or higher (lower) than the best offer (bid). In contrast, a standing limit order is an order priced that it cannot immediately be matched with another order.

[12] Traders who wish to fully control their ex ante order exposure can do so by only taking liquidity (issuing marketable orders) and never offering it. It might therefore appear that useful information about order display behavior would be lost by excluding fully marketable orders. Note, however, that in pure order-driven exchanges, all trades must be initiated by a liquidity taker. Liquidity-taking orders that are not expected to leave standing remainders are excluded in this study because it is impossible to determine whether a trader took liquidity because he wanted to control the exposure of his order, or simply because he wanted to complete a trade at an attractive price. Such classifications might be possible with a data set that included trader identifying information. It might also be possible to make some inferences from order timing, but such an analysis is beyond the scope of this study.

quote information was available, it cannot be classified and therefore is excluded from the order display instruction subsample. This classification algorithm unfortunately is based on less information than was available to the Paris traders. They could see displayed size, by price, behind the best quote. This information is indirectly inferred only for the block eligible stocks. For the TSE stocks, the full order book can be quite accurately reconstructed using methods similar to those employed in Kavajecz (1996).[13] The TSE orders were therefore classified using the same information available to the Toronto traders. For both exchanges, the classification uses quotes that stood five seconds before their arrival at the exchange. The quote data are lagged to reflect the latest information that the trader would likely have seen before submitting the order.

The classification algorithm identifies only the worst case execution scenarios that traders could have expected. In practice, marketable orders often discover undisclosed size. Traders may therefore expect that their orders will execute more fully than is apparent from an analysis of disclosed size only. Such expectations may arise through long-term experience, or traders may generate them through current experimentation. Although such expectations undoubtedly affect order submission strategy, this study does not explore the formation of such expectations.

The Paris Bourse order sample includes 1,387,039 observations for the 300 sample stocks. These include 262,998 opening orders and orders submitted before the open, 490 orders that were submitted when no quotes were available, 321,852 orders that reasonably could be expected to fill completely upon submission, and 198,263 standing limit orders that were too small to specify partial display. Of the remaining orders, 46,797 orders were records of prearranged trades entered by brokers or of changed order instructions for which the time of the change is unfortunately not recorded. After excluding these orders, 556,639 orders remained in the order display instruction subsample.

The TSE order display instruction sample includes only 6,059 orders.[14] Fewer orders

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[13] The reconstruction is not perfect, however, because although the data set includes order cancellation instructions, it does not include the time of cancellation. The cancellation times therefore needed to assumed. Cancellation times for partially orders were assumed to be the time of the last fill. Orders that never filled were mostly behind the market and were therefore ignored. The Paris order book cannot be reconstructed because no order cancellation instructions appear in the Bourse database.

[14] The TSE order sample includes 52,737 observations for the 170 sample stocks. These include 5,008 orders entered before sample period; 804 entered on the missing day November 10 that remained open on November 11; 5,847 orders entered before the 9:30 open; 103 untriggered stop orders; 2,853 odd lot orders; 1,664 put-through orders (prearranged crosses); 739 orders submitted when no quotes were available, 10,477 orders that reasonably could be expected to fill completely upon submission; and 19,183 standing limit orders that were too small to

appear because the sample time-period is shorter (7 versus 41 days), because fewer stocks are in the sample (170 versus 300), and because the Paris stocks are on average 5.8 times larger than the TSE stocks. The average numbers of orders per day per stock per billion French francs of capitalization are comparable across the two samples. This ratio is 6.2 for the Bourse stocks versus 4.0 for the TSE stocks. The relatively small size of the TSE sample makes it difficult to obtain high resolution results for this market.

III. Preliminary Characterizations

Table III characterizes order display in the order display instruction subsample. Traders in both markets often restricted order display, especially for orders with large expected remainders. Most notably, traders specified display restrictions far more often at the Paris Bourse than at the TSE where the tick size was much greater. When the remaining size is greater than FF500,000, 74 percent of the Paris orders are not fully disclosed. At the TSE, only 13 percent of equivalent sized orders are not fully displayed.

Not surprisingly, smaller remainders are more fully disclosed in both markets. Two reasons explain why this is so. First, the fixed minimum quantity that traders must display is a larger fraction of remaining size when the remainder is small. Second, traders are probably more willing to display small remainders because their exposure is not as risky to the trader as is the exposure of large remainders. To confirm that the first explanation does not account for the entire result, the analysis was repeated by dropping from the subsample all standing orders with remainders too small to hide, and by computing the fraction of the disclosable remainder (the remainder less the minimum disclosure size) that was displayed. The results (not presented) confirm that small remainders are more often displayed than large remainders.[15]

Panel B of Table III presents results cross-tabulated by relative tick size. As hypothesized, Paris Bourse traders more often restricted order display when the relative tick size was small than large. This relation is not apparent in the Toronto data, probably due to the large tick size and the small sample size.

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specify partial display. After excluding these orders, 6,059 orders appear in the order display instruction subsample.

[15] The results obtained using this alternative method are not emphasized because dropping from the sample small remainders that cannot be partially displayed ignores the fact that they can be completely hidden by issuing a fill-or-kill instruction.

The remaining panels of Table III present results cross-tabulated by variables that traders control. Panel C shows that buy and sell order display tendencies are economically indistinguishable. Panels D and E present cross-tabulation results by order price placement aggressiveness. In Panel D, absolute price aggressiveness is measured by the percentage difference between the order price and the midpoint of the bid and offer quotes.[16] (Aggressiveness is measured as the negative of this quantity for sell orders.) In Panel E, relative price aggressiveness is measured by an index of the order price placement relative to the best bid and offer. The index is $1-2(A-P)/(A-B)$ where A, B and P are respectively the bid, ask and order prices. This index assigns a value of -1 to orders placed at the best bid and a value of 1 to orders placed at the best offer. (Aggressiveness is measured as the negative of this quantity for sell orders.) For both measures of aggressiveness, the order price for a market order is set equal to the best opposing quotation price, which is the price at which the remainder stands when converted to a limit order.

The Paris results show that the relative price measure of order placement aggressiveness explains more variation in order display than does the absolute measure. Traders least display orders that just slightly improve the market and or that very aggressively demand liquidity. They more often display when they place standing orders that substantially improve the market. Traders who just slightly improve the market probably do not display much because quote-matching strategies are most attractive when they are placed in front of precommitted traders who do not aggressively price their orders. Traders who substantially improve the market, but who are unwilling to issue marketable orders, are aggressively searching for someone to fill their orders. They presumably display to allow willing counterparts to easily see their orders. Traders who place very aggressive marketable orders are probably either well informed traders, very impatient traders, or both. They probably avoid displaying because they do not want to telegraph their intentions. Traders who place their orders behind the market do not display as much as those who match the market. The latter probably include many value-motivated traders who are only willing to trade if the price is right. Since their orders will likely stand longer than orders placed

[16] The midpoint employed is a weighted average of the bid and the offer. The size of the bid is used to weigh the offer price and the size of the offer is used to weigh the bid price. This formula, which appears in Lee, Mucklow and Ready (1993) provides a better estimate of value than the unweighted quotation midpoint. Similar results were obtained for the unweighted midpoint.

closer to the market, they may give up substantial option value when displaying their orders (if the orders are not too far from the market).[17] The Toronto results are similar, although less clear due to the small sample size.

Panel F presents results cross-classified by order validity instruction. By definition, 100 percent of the remaining size of the fill-or-kill orders is undisplayed. In the Paris sample, the day orders are next most hidden, followed by the until-date orders and finally by the good-till-canceled orders. The ordering of these results is consistent with the expected time to order cancellation. The fill-or-kill orders cancel immediately. The day orders cancel at day-end. The until-date orders cancel on the trader specified date. At the Paris Bourse, the good-till-cancel orders cancel on the last day of the current month for securities that settle on T+3 (cash market settlement) and on the next settlement day for securities that settle monthly. Since order option values increase with their expected validity (time to cancellation) these results suggest that traders attempt to limit their order option values.

Panel G presents results cross-classified by submission time-of-day. At the Paris Bourse, traders hide their orders slightly more during the first and last ten minutes of the trading session than within the session. Since these periods have the greatest intraday price volatility, these results again suggest that traders attempt to limit their order option values. The TSE results are inconclusive, probably because of the small sample size.

The final panel of Table III presents results cross-classified by whether the order was linked to another order in the database. Linkages occur when one order cancels another order or is itself canceled by another order. Such changes typically take place when traders adjust their order instructions. Linked orders are therefore orders that traders closely manage. Traders who do not wish to display their orders probably will choose to adjust them frequently. Moreover, traders who choose to display large orders can protect their order option values by adjusting order prices as the market moves to keep them out-of-the-money. In both markets, the results confirm that traders display less size for linked orders than for not linked orders.

A table (not presented) similar to Table III was also prepared to examine classified means of the fraction of remaining order size that is not disclosed. The qualitative results are almost

[17] The rank ordering of these results may not be completely reliable because are obtained by pooling orders across stocks that differ substantially.

identical to those described above for the fraction of display-restricted orders. For most well populated classification cells, the mean undisclosed remaining size, stated as a percent of the total remaining order size, is about eight-tenths of the corresponding percentage of display-restricted orders (presented in Table III).

IV. Cross-Sectional Analyses

This section presents the results of cross-sectional regression analyses designed to identify factors that affect order display and market liquidity. The presentation is divided into two subsections. The first subsection analyzes dependent variables that characterize order display. These variables are computed from the order display instruction subsample. The second subsection analyzes broad measures of market liquidity. These variables include averages of quotation sizes, bid/ask spreads, daily volumes, daily numbers of trades, daily numbers of quotes, and trade sizes. With one exception noted below, both sets of analyses use the same set of explanatory variables.

All models include the average relative tick as an explanatory variable. The hypotheses advanced in this study suggest that order display will be greater when the tick is large relative to price. A large tick also should be associated with larger trades since traders have less incentive to break up their orders. Its effects on other broader measures of liquidity, however, are not always obvious. The average relative tick is computed by taking the time-weighted average of the current tick divided by the current quotation midpoint.

All models also include a measure of intraday volatility. Order display should be greater for low volatility stocks because volatility increases order option values. Volatility should likewise affect the measures of market liquidity because volatility generally hurts liquidity suppliers. However, since volatility also attracts speculation, its effect on the measures of market activity is ambiguous. Volatility is measured by the root mean squared 30 minute intraday return.[18]

Finally, all models also include market capitalization as a regressor. This variable provides information about the scale of market activity. Log market value is used to shrink market values

[18] The intraday returns are computed from log price relatives using last observed prices. The root mean squared return is used instead of the sample standard deviation because the sample period is far too short to obtain reliable estimates of the expected intraday return, which in any event should be extremely close to zero.

across the stocks.

Notably missing from the list of independent variables are direct measures of market activity and liquidity such as average volumes, spreads, and trade and quote frequencies. Although it is easy to imagine that these variables should be included, this analysis omits them because they are invariably endogenous. Rather than deal with the simultaneous equations problems that their inclusion would create, the analyses instead estimate reduced forms based only on a few exogenous variables.[19] This strategy is more necessary than conservative: Few credible exogenous variables are available to identify simultaneous equations in empirical market microstructure analyses.

The cross-sectional regressions are all estimated using weighted least squares. The observations are weighted by the number of orders used to compute the dependent variables for each stock. This weighting scheme models error term heteroskedasticity. It also gives greatest weight to the large stocks. Given their importance in the market, this characteristic of the analysis probably should be viewed as an advantage rather than as a subject of concern.

A. Cross-Sectional Determinants of Order Display

Four dependent variables are used to characterize trader propensity to control their order display in the various stocks. Each is computed from the order display instruction subsample.

The first three variables provide simple characterizations of the subsample. They are 1) the logit transform of the fraction of orders with remainders that do not fully disclose remaining size, 2) the logit transform of the mean undisclosed remaining size expressed as a fraction of remaining order size, and 3) the logit transform of the mean fraction of linked orders. The regressions use logit transforms of the variables to stretch the [0,1] range of the variables to the full number line. This transformation yields better specified econometric models.[20] These dependent variables are computed for each stock from the entire order subsample, and also from only those orders that had expected remainders of greater than FF200,000. The size-restricted

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[19] To some extent, even these variables are endogenous. Angel (1996), for example, claims that price level is endogenous in the long-run. Volatilties may be endogenous if they include transitory components cause by trading phenomena. Amihud and Mendelsohn (1986) results suggest that even market value is endogenous.

[20] The transformations cannot be done if the variable to be transformed has a value of zero or one. To avoid these problems, the transforms were taken of the Bayesian posterior means of the frequencies. The posterior means were computed using a uniform prior, which is very slightly informative. Untransformed models were also estimated with essentially the same results.

variables probably better represent order display propensities because they only weight those orders where display issues are most pressing.

The last dependent variable is derived from estimates of an econometric model designed to characterize trader decisions to expose their orders. This measure is designed to correct a potential problem that may affect the first three dependent variables: The three simple dependent variables will provide poor cross-sectional measures of the display propensities if average order size and order price placement vary in the cross-section. For example, a high order display restriction rate for a stock may indicate that traders are particularly concerned about order display in that stock. Alternatively, it may simply indicate that traders in that stock submit large orders or place them just slightly into the market. To address this problem, a display propensity index must be created that takes into account order size and price placement. This study constructs such an index using a discrete choice, maximum likelihood logit model: A logit model is first fit to all orders (across all stocks) in the order display instruction subsample. The "dependent" variable of the analysis is the indicator of whether the trader attached instructions to limit the order display. The independent variables are the log order size and the absolute order price aggressiveness variable. Quadratic terms and the cross-product are also included so that the model response function is a second order Taylor series expansion of the unknown true response function. Predicted logits are then computed from the estimated model for each order in the subsample. A second logit model is next estimated for each stock.[21] The only independent variable in this model is the predicted logit from the first model. Its slope coefficient is set equal to 1 and an intercept is estimated for each stock. The estimated intercept measures relative propensity to restrict order display, after accounting for order size and price placement.[22]

The results from the Paris Bourse sample (Table IV) strongly confirm the main thesis of

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[21] The logit model cannot be estimated for those stocks that had no display restricted orders. For these stocks, the index was computed by subtracting the predicted mean logit produced by the first model from the logit of the posterior mean of the restricted display rate.

[22] The cross-sectional weighted average of the intercept should be asymptotically near zero when the weights are given by the number of orders for each stock. This property follows from the fact that the stock specific intercept represents the degree to which the intercept in the common logit model needs to be offset to best characterize the particular stock. These offsets must add up to zero on average. For those stocks where traders more frequently restrict order display (after taking to account the order size and placement), the intercept will be positive. For those stocks where traders restrict display less frequently, the intercept will be negative. Since the logit is a log odds ratio, differences in estimated stock intercepts represent relative differences in trader propensities to display orders rather than absolute differences.

this study. Traders restrict display more when the average relative tick is small. The results are overwhelmingly statistically significant. Not surprisingly, the strongest results come from the models in which the dependent variable is computed only from the larger orders, and from the logit display propensity model.[23]

The Paris results also show that greater volatility is associated with less order display. This evidence suggests that traders are aware of, and attempt to restrict, their order option values.

Finally, traders tend to display more size in larger stocks, and they adjust their orders less frequently in these stocks. These results are probably due to the fact that larger stocks tend to trade more actively. Since the average time that an order stands is probably shorter for large stocks, traders do not need to control their display as much. (Unfortunately, the Paris Bourse database does not permit a direct study of this conjecture because order submission and execution times are not linked.)

Since the relative tick is the primary variable of interest in this study, it is necessary to consider whether its statistical significance might simply be due to variation in the price that appears in its denominator. To address this question, the regression models were all reestimated with the inverse average price level added to independent variable list. The results for the logit index model appear at the bottom of Table IV. The inverse price variable is statistically insignificant and the estimate and the statistical significance of the relative tick coefficient are largely unchanged. Results (not presented) for the other dependent variables are similar.

The results (not shown) for the Toronto Stock Exchange sample are broadly consistent with the Paris results. They are weaker, however, because of the shorter time-series sample and because traders do not restrict order display as much in Toronto as in Paris (presumably because of the differences in tick size).

The regressions were also estimated from both stock samples pooled together. The results (not shown) are similar to the Paris results and statistically more significant. The increased significance is primarily due to the higher relative tick and the lower propensity to restrict display found in the Toronto sample as compared to the Paris sample.

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[23] A pooled time-series cross-sectional model was also estimated with similar point results. The results are not presented because the statistical significance of the estimates is grossly over-stated when time-series dependencies within each stock are not modeled. It is extremely difficult to properly model such dependencies given the discrete model and the sample size.

B. Cross-Sectional Determinants of Various Liquidity Measures

This subsection presents estimation results for regression models designed to characterize how measures of market liquidity are related to the relative tick. The first measure examined is the log average French franc displayed quotation size.[24] This variable is computed as the time-weighted average of the bid and offer sizes. It should be positively related to the relative tick size if traders display more when the tick is large.

Quotation size by itself, however, can be a misleading measure of order display if comparisons are to be made across stocks with different average spreads. Traders may not offer much size at the market in stocks with narrow spreads whereas they may offer substantial size at the market for stocks with wide spreads. This relation is an expected consequence of adverse selection and does not necessarily indicate anything about trader concerns about front-running.[25]

A more reliable measure of quotation display size that addresses this problem is the ratio of the average quotation size to the relative bid/ask spread. This ratio estimates the rate at which displayed liquidity increases with quotation size. It is computed from the market quote for all stocks in the sample, and where possible, from the block quote for the Paris block eligible stocks.

The next measure examined is the relative bid/ask spread. It is computed as the time-weighted average of the ratio of the quotation spread to the quotation midpoint. The effect of the relative tick on the relative spread is not obvious. If the tick is relatively large, it may prevent dealers from quoting tight spreads for small sizes. Alternatively, a relatively small tick may so reduce the display of size that dealers may be unwilling to quote tight spreads. The first effect probably is the more important since traders often make a market for small size even when they cannot see large orders.

The next liquidity measure examined is the log average daily French franc trading volume. If a small tick increases transaction costs for large traders, trading volume should be small. This effect, if present, will be hard to identify because of the noise in volume and because it is a secondary prediction of the display thesis.

The final two liquidity measures examined are the log average daily number of trades and the log average trade size. These measures are important because they may reveal the extent to

[24] Size is measured in francs instead of shares to permit meaningful comparisons across the stocks.
[25] Easley and O'Hara (1987) provide a model that explains why this may be.

which traders break up their orders to avoid exposing them. If they do, the daily number of trades should be negatively related to the relative tick size and the average trade size should be positively related to the relative tick size.

With one exception, these regressions use the same dependent variables as those reported above for the order exposure variables. The exception appears in the models for the average daily number of trades and the average trade size. These models also include the log French franc minimum lot size as an independent variable. If the minimum lot size is binding on many traders, it will affect these averages.

The Paris results (Table V) show that that relative tick is positively related, as expected, to the absolute and ratio measures of quotation size. The estimates are statistically significant. Volatility in these models also has the expected coefficient sign is also statistically significant. Both effects suggest that traders consider and protect order option values. Not surprisingly, the log market value coefficient is positive and overwhelmingly significant. The addition of inverse price to these models does not affect these results.

The results from the average relative spread model appear exactly as expected for the volatility and firm size variables. Greater volatility is associated with larger spreads and greater size is associated with smaller spreads. The results for the relative tick size depend on whether the inverse price level appears in the model. A large tick appears to be associated with smaller spreads, but the relation is not statistically significant when inverse price appears in the model.

Not surprisingly, log market value is overwhelmingly statistically significant in the log average daily volume model and the log daily average number of trades model. The other variables are much less significant and their estimates behave inconsistently when inverse price is added to the regression.

Finally, estimates for the log average trade size model appear as expected, although they are a bit weak for the relative tick size variable. A large tick is associated with larger trades, as is a large minimum lot size. Greater volatility is associated with smaller trades, possibly because traders are afraid to expose significant size in volatile markets.

Although the inverse price level is statistically significant in many of these regressions, its significance may have more to do with the sample than with any omitted variables. An examination of the average prices reveals why it may be statistically significant. The Paris sample includes a very small number of stocks with prices that are very low compared to the prices of most stocks in the sample. The inverse price level is large for these stocks and near zero for the rest of the sample. The inverse price level therefore acts somewhat like a dummy variable for this small subset of stocks. While this subset of stocks may indeed trade in ways fundamentally different from the rest of the sample, dummy variables invariably will be statistically significant when they identify a small subsample of a much larger sample. It therefore is not obvious that the statistical significance of the inverse price variable is meaningful, especially without any reasonable model of why it should be so.

The Toronto results (not reported) are again essentially similar to the Paris results, but much weaker. The tick size coefficient estimates in the absolute and relative quotation size models are both positive and strongly significant. In the other models, these estimates are all positive, but statistically insignificant.

V. Time-Series Analysis

As noted above in Section C, 26 of the 300 Paris stocks and 12 of the 170 TSE stocks traded in two tick size regimes within the sample period.[26] This section compares their market activity under the two regimes. Although there are few such stocks, the analysis is potentially quite strong: By comparing activity across regimes for the same stock, omitted variable effects presumably will be quite small.

To compare the regimes, two values for each dependent variable analyzed in the preceding section are separately computed. The first value is computed only from those periods when the stock traded on its smaller tick; the second value is computed only from periods when the stock traded on its larger tick. Paired *t*-tests are then used to compare the values of these variables under the different regimes. Although the levels and relative sizes of the transitions vary, the data for all stocks are pooled together to maximize the power of the tests.

The total time during which these stocks traded on one tick versus another varies considerably within the sample. For example, two Paris stocks changed regimes, returned on the same day, and then did not change again. The vast majority of the trades and orders for these two

[26] For some stocks, a single transition from one tick size to another took place as the stock price rose or fell during the sample period. For other stocks, the transition took place multiple times as the stock price repeatedly rose and fell across the transition price. No changes in tick levels in this sample took place because of splits.

stocks therefore are associated with only one tick. The other stocks dwelled for varying amounts of time in their two tick size regimes. The analysis variable means therefore are estimated with varying degrees of error.

To model heteroskedasticity in the differences in the paired means, weighted paired *t*-tests are conducted. Each difference in paired means is weighted by a factor proportional to the variance of the difference. The weighting formula assumes that all observations are drawn from a constant variance distribution.[27] This weighting scheme gives the greatest weight to stocks with many observations under both regimes and least weight to stocks with only a few observations in one regime, regardless of how many observations are in the other regime.

Table VI presents the small and large tick cross-sectional mean values for the order display variables, and the associated paired *t*-tests. The means are weighed by the same weights used to compute the *t*-tests so that they are comparable. The Paris results show that traders exposed less, and adjusted their orders less frequently, when the tick was small than when it was large. The differences are all statistically significant. Not surprisingly, the results are stronger for the order display measures that are computed from only larger orders than from all orders. The strongest statistical results are obtained from the logit index measure, which adjusts for order size and price placement. The Toronto traders also exposed less when the tick was smaller but they adjusted their orders slightly more often. The exposure results are statistically significant but the adjustment results are not.

Table VII presents cross-sectional mean values for several variables that measure liquidity characteristics and other variables of interest in the Paris tick-change sample. Since the mean variable values vary substantially in the cross-section, the *t*-statistics presented in this table test for the paired differences in the logged means rather than for differences in the actual means. This change reduces the heteroskedasticity of the differences. The resulting test therefore examines percentage differences rather than actual differences. In all other respects, the methods are the same as those used in the previous table. The first line shows that the average price did not vary much between the two regimes. The average percentage difference between the two mean prices is only 7.6 percent. Although the associated *t*-statistic appears to be significant, it is meaningless

[27] The weights are given by $1/\left(1/N_L + 1/N_S\right)$.

because the tick regimes depend on the price levels.

The next two lines show that the quote size was substantially bigger for the large tick than for the small tick. The result holds both for size measured in shares and for size measured in French francs. The share results are important because they show that the French franc results are not merely due to the higher stock price associated with the larger tick size. The differences are significant.

The next two lines show that the ratio of quoted size to the bid/ask spread was higher for the large tick than for the small tick. The difference is large and statistically significant for the market quotes. It is large but statistically insignificant for the block quote ratios, for which only four stock observations appear in the sample. These results are consistent with the thesis of this study: Traders appear to offer more liquidity when protected by a large tick.

The next three lines show how spreads varied between the two regimes. The average spread was wider both in relative terms and in absolute terms when the stocks traded on the larger tick. The mean percentage differences are both statistically significant. Not surprisingly, the spread measured in ticks is much smaller for the larger tick. It appears that the smaller ticks allow dealers to quote tighter spreads, albeit for smaller sizes.

The remaining variables that appear in the table – trade size in French francs and in shares, daily number of trades, and daily volume in French francs and in shares – all have statistically insignificant percentage differences. French franc trader size is probably the most important of these variables since it indicates the extent to which large traders break up their trades. It is larger for larger tick sizes, as expected, but the *t*-statistic is only 1.2. The lack of significance is probably due to noise in these variables and to the fact that the expected effects on these variables are all only secondary predictions of the order display argument.

Results (not shown) for a similar analysis of the Toronto tick-change sample are uniformly uninformative. The sample apparently is too small to produce meaningful results.

VI. Conclusion

A. Summary

This study examines cross-sectional and time-series evidence to identify factors that traders consider when displaying their orders. The evidence strongly suggests that traders expose more when the minimum tick is large, when the order is not expected to stand long, and when prices are not volatile. These results suggest that traders recognize and attempt to control the option values associated with their orders.

The results demonstrate that the minimum price variation has important effects on order exposure. The current regulatory initiatives to lower tick sizes therefore may be misguided if order exposure is desirable. Also, attempts to compel traders to display their orders may decrease market liquidity.

B. Directions for Future Research

The effects of tick size on measures of market liquidity like volumes and spreads are harder to measure than are the effects on order exposure. Larger samples will need to be examined to identify a relation, if any, among these variables.

This study examines only unconditional measures of order exposure. Traders undoubtedly condition their order exposure decisions on current market conditions such as the width and depth of the market quote. An analysis of how traders condition their decisions would greatly broaden our understanding of order exposure.

It should be possible to directly identify the activities of quote-matching traders. A characterization of this behavior would broaden our understanding of the environment risks that traders face when offering liquidity.

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Table I

Characteristics of the Cross-Sectional Stock Samples

The Paris sample consists of all 300 French common stocks that traded in the Paris Bourse continuous market on more than 25 days of the 41 trading days in January and February 1995. The TSE sample consists of all 170 common stocks that traded in the Toronto CATS system for which traders submitted at least 50 orders during the November 8, 9, 14-18, 1994 sample period. Common stock capitalization is as of December 31, 1994 for the Paris stocks and as of August 31, 1994 for the TSE stocks. For the TSE stocks, the daily root mean squared return is calculated for the period January 1, 1994 -- October 31, 1994. All other statistics are computed over the sample period. A Canadian dollar was worth approximately 3.8 French francs at the end of 1994.

Variable	Market	Equal-Weighted Mean	Value-Weighted Mean	Minimum	Maximum
Common Stock Capitalization	Paris	7293	32768	16	98584
(Millions of FF and CAN$)	TSE	331	2585	1	9585
Daily Root Mean Square Return	Paris	1.58	1.50	0.44	13.18
(Percentage)	TSE	3.32	1.96	0.78	19.10
Average Daily Trading Volume	Paris	8.06	43.70	0.01	138.16
(Millions of FF, CAN$)	TSE	0.17	0.53	0.004	3.33
Average Trade Price	Paris	607	632	8	6450
(FF, CAN$)	TSE	8	17	0.1	47
Average Tick Size	Paris	0.50	0.543	0.05	10.00
(FF, Cents)	TSE	7.8	11.8	0.5	12.5
Average Tick Size	Paris	7.9	7.7	2.1	58.7
(Percentage Basis Points of Price)	TSE	115.3	88.8	26.3	361.1
Number of Sample Days with	Paris	40	41	26	41
Trades	TSE	6.6	6.9	3	7
Average Daily Number of	Paris	87	382	2	1378
Continuous Session Orders	TSE	31	47	7	395
Average Daily Number of	Paris	74	336	1	1000
Continuous Session Trades	TSE	17	28.3	1.5	256
Average Spread	Paris	9.0	4.1	0.1	136.1
(FF, Cents)	TSE	18.8	22.5	0.7	170.5
Average Spread	Paris	1.24	0.53	0.13	4.84
(Percentage of Price)	TSE	2.88	1.46	0.61	11.79
Average Spread	Paris	34.9	12.4	1.3	190.7
(Number of Ticks)	TSE	3.8	2.1	1.0	35.3

(Continued)

Variable	Market	Equal-Weighted Mean	Value-Weighted Mean	Minimum	Maximum
Average Bid Size	Paris	94	242	4	836
(Thousands of FF and CAN$)	TSE	33	100	1	343
Average Ask Size	Paris	105	248	6	745
(Thousands of FF and CAN$)	TSE	43	111	1	794
Average Trade Size	Paris	64.5	116	0.8	233
(Thousands of FF and CAN$)	TSE	9	18	0.9	67

Table II

Cross-Sectional Frequency Distribution of Tick Sizes that Appear in the Samples and Associated Cross-Sectional Average Prices and Relative Tick Sizes

The Paris sample consists of all 300 French common stocks that traded in the Paris Bourse continuous market on more than 25 days of the 41 trading days in January and February 1995. The Toronto Stock Exchange sample consists of all 170 common stocks that traded in the Toronto CATS system for which traders submitted at least 50 orders during the November 8, 9, 14-18, 1994 sample period. No sample stock traded on more than two ticks.

Paris Bourse					Toronto Stock Exchange				
		Number of Tick Sizes Used					Number of Tick Sizes Used		
Price	Tick	1 only	2 Sizes		Price	Tick	1 only	2 Sizes	
Region (FF)	Size (FF)	Unique Tick	Smaller Tick	Larger Tick	Region (Cents)	Size (cents)	Unique Tick	Smaller Tick	Larger Tick
Panel A: Number of Stocks									
5-100	0.05	17	6		0-0.50	0.5	8	3	
100-500	0.10	156	19	6	0.50-3	1	43	4	3
500-5000	1	99	1	19	3-5	5	15	5	4
>5000	10	2		1	>5	12.5	92		5
All	All	274	26	26	All	All	158	12	12
Panel B: Average Trade Price (FF, CAD$)									
5-100	0.05	50	94		0-0.50	0.5	0.3	0.5	
100-500	0.10	295	469	106	0.50-3	1	1.5	2.7	0.6
500-5000	1	1103	4801	523	3-5	5	4.1	4.7	3.2
>5000	10	5929		5310	>5	12.5	13.8		5.3
All	All	611	549	608	All	All	8.9	2.9	3.7
Panel C: Average Tick (Percentage Basis Points of Price)									
5-100	0.05	17.4	5.3		0-0.50	0.5	207	104	
100-500	0.10	4.0	2.2	9.4	0.50-3	1	82	37	180
500-5000	1	11.6	2.1	19.1	3-5	5	122	107	157
>5000	10	17.0		18.5	>5	12.5	116		232
All	All	7.6	2.9	16.9	All	All	112	76	192

Table III

Restricted Order Display Frequency Distributions

This table presents statistics that characterize all orders that could not be fully executed upon submission and which are large enough that the trader could specify a meaningful disclosure instruction. The Paris sample includes all 300 French common stocks that traded in the Paris Bourse continuous market on more than 25 days of the 41 trading days in January and February 1995. The Toronto Stock Exchange sample includes in all 170 common stocks that traded in the CATS system for which traders submitted at least 50 orders during the November 8, 9, 14-18, 1994 sample period. Remaining size is the portion of the order that cannot be expected to fully execute with certainty upon submission. Undisclosed remaining size arises when the trader instructs that it not be disclosed, or when the trader issues a fill-or-kill instruction. A linked order either adjusted another order or was canceled by another order. Percentages greater than zero but less than 0.5 are indicated by "+0."

	Orders with Some Undisclosed Remaining Size (Percent)					Number of Orders Per Cell				
Remaining Order Size (1,000 FF)	0-10	10-50	50-200	200-500	>500	0-10	10-50	50-200	200-500	>500
Panel A: Full Sample										
Paris	5	9	19	37	74	20792	66394	168905	164844	135704
Toronto	1	1	3	4	13	899	2039	2067	736	318
Panel B: Cross-Classified by Relative Tick Size (in basis points)										
<u>Tick Size</u>						Paris Bourse				
2-5	6	8	18	42	79	11044	37628	106872	95718	71666
5-10	4	11	27	42	74	6944	15875	30726	25991	24994
10-20	9	10	16	24	65	2027	9939	29161	42217	38267
210-50	7	9	8	22	50	576	2230	2016	892	769
50-100	3	4	30	38	38	182	720	128	26	8
>100	5	100	+0	n/a	n/a	19	2	2	0	0
						Toronto Stock Exchange				
2-5	n/a	n/a	n/a	n/a	n/a	0	0	0	0	0
5-10	n/a	n/a	n/a	n/a	n/a	0	0	0	0	0
10-20	n/a	n/a	n/a	n/a	n/a	0	0	0	0	0
20-50	+0	+0	5	3	3	155	344	387	73	36
50-100	1	1	5	2	8	263	652	464	160	182
>100	1	1	1	4	25	481	1043	1216	503	100

(Continued)

Panel C: Cross-Classified by Side

Remaining Order Size (1,000 FF)	Orders with Some Undisclosed Remaining Size (Percent) 0-10	10-50	50-200	200-500	>500	Number of Orders Per Cell 0-10	10-50	50-200	200-500	>500
Side						Paris Bourse				
Buy	7	9	19	38	74	8592	32685	84573	83349	67016
Sell	4	9	19	36	74	12200	33709	84332	81495	68688
						Toronto Stock Exchange				
Buy	1	1	2	4	12	485	1013	1029	324	134
Sell	+0	1	4	3	14	414	1026	1038	412	184

Panel D: Cross-classified by order price aggressiveness, as measured by the signed distance between order price and the quotation mid-point ($P/M-1$ for buy orders; $1-P/M$ for sell orders)

Aggressiveness	0-10	10-50	50-200	200-500	>500	0-10	10-50	50-200	200-500	>500
						Paris Bourse				
Low- -2%	1	4	23	44	71	5164	12915	9761	6309	5861
-2 - -1%	1	7	26	46	75	2184	6701	11788	10825	9573
-1 - -0.5%	+0	6	20	42	75	1689	6611	18982	19865	17380
-0.5 - -0.2%	1	4	15	37	75	1340	7231	32886	35859	30126
-0.2 - 0.2%	10	11	17	32	73	6047	23634	82906	84176	65683
0.2 - 0.5%	15	19	36	58	81	1791	4593	7698	5220	4914
0.5 - 1%	11	18	38	64	78	1073	2448	2967	1689	1396
1 - 2%	7	13	38	61	68	752	1310	1249	668	477
2 - High	3	10	26	49	52	752	951	668	233	294
						Toronto Stock Exchange				
Low- -2%	1	2	4	3	23	136	401	387	124	30
-2 - -1%	5	2	1	7	15	37	185	227	104	47
-1 - -0.5%	+0	2	5	3	8	25	124	203	70	49
-0.5 - -0.2%	+0	1	4	3	10	15	68	149	60	50
-0.2 - 0.2%	+0	+0	2	4	7	180	420	385	162	75
0.2 - 0.5%	1	+0	2	1	16	148	279	255	68	32
0.5 - 1%	+0	+0	2	1	26	137	254	251	93	19
1 - 2%	+0	1	1	5	15	117	171	139	38	13
2 - High	+0	+0	1	6	33	104	137	71	17	3

(Continued)

Panel E: Cross-Classified by Order Price Aggressiveness, as Measured by the Relation Between Order Price and the Best Bid and Ask Quotes

Remaining Order Size (1,000 FF)	Orders with Some Undisclosed Remaining Size (Percent) 0-10	10-50	50-200	200-500	>500	Number of Orders Per Cell 0-10	10-50	50-200	200-500	>500
(Ask=1, Bid=-1 for Buy Orders; Bid=1, Ask=-1 for Sell Orders)										
Aggressiveness						Paris Bourse				
P < -1	+0	3	15	34	71	9527	26352	54815	61052	55338
P = -1	1	5	14	31	73	898	5434	26106	31322	24991
-1< P < -1/3	3	9	19	45	84	1122	9767	38860	30922	20357
-1/3<P < 1/3	1	4	10	22	68	660	3023	10452	13258	9435
1/3< P < 1	2	4	10	28	62	261	701	1051	716	625
P = 1	16	22	35	49	77	5198	14294	26565	19381	16329
P > 1	5	10	26	49	77	3126	6823	11056	8193	8629
						Toronto Stock Exchange				
P < -1	4	2	4	5	19	84	292	388	123	57
P = -1	2	1	3	3	9	66	220	417	205	124
-1< P < -1/3	+0	2	7	4	33	57	191	148	25	3
-1/3<P < 1/3	+0	2	2	7	19	45	210	262	124	57
1/3< P < 1	+0	+0	2	+0	n/a	115	166	98	15	0
P = 1	+0	+0	2	2	9	507	922	730	238	75
P > 1	+0	+0	+0	+0	+0	25	38	24	6	2

Panel F: Cross-Classified by Order Validity Instruction

Validity						Paris Bourse				
Fill or Kill	100	100	100	100	100	1009	3704	10684	10777	13587
Day order	1	6	14	33	71	6699	37055	144777	147719	119269
Until date	+0	+0	6	23	62	1123	3230	1046	469	407
G-T-C	+0	1	7	17	52	11961	22405	12398	5879	2441
						Toronto Stock Exchange				
Fill or Kill	100	100	100	100	n/a	1	2	2	1	0
Day order	+0	1	2	4	10	749	1695	1699	589	262
Until date	3	2	5	5	31	120	235	226	44	13
G-T-C	+0	+0	1	2	28	29	107	140	102	43

(Continued)

Panel G: Cross-Classified By Order Submission Time

Time	Paris Bourse

Remaining Order Size (1,000 FF)	Orders with Some Undisclosed Remaining Size (Percent) 0-10	10-50	50-200	200-500	>500	Number of Orders Per Cell 0-10	10-50	50-200	200-500	>500
First 10 minutes	7	11	23	40	77	1050	3555	8246	8041	6559
9:10-13:30	5	8	20	40	76	11042	33888	75976	70475	55907
13:30-16:50	6	9	18	34	71	8099	26705	77066	77585	64002
Last 10 minutes	6	12	22	39	75	601	2246	7617	8743	9236
					Toronto Stock Exchange					
First 10 minutes	+0	1	2	+0	11	35	112	129	53	18
9:40-13:30	1	1	3	4	14	537	1278	1277	436	208
13:30-16:50	1	1	3	3	7	286	574	583	216	82
Last 10 minutes	+0	+0	+0	6	30	41	75	78	31	10

Panel H: Cross-Classified by Whether the Order was Linked to Another Order

Status					Paris Bourse					
Linked	5	10	19	41	80	1556	15024	78169	81298	68727
Not Linked	5	9	19	34	68	19236	51370	90736	83546	66977
					Toronto Stock Exchange					
Linked	+0	1	3	6	24	180	517	540	210	93
Not Linked	1	1	2	2	8	719	1522	1527	526	225

Table IV

Cross-Sectional Regressions of Order Disclosure Indicators

This table presents weighted least squares cross-sectional regression estimates. The dependent variables are various statistics that characterize order disclosure for each stock. They are computed from all orders that could not be fully executed upon submission and which are large enough that the trader could specify a disclosure instruction. The observations are weighted by the number of orders used to compute the dependent variables for each stock. Remaining size is the portion of the order that cannot be fully executed with certainty upon submission. A linked order either adjusted another order or was canceled by another order. The logistic model intercept measures the relative propensity of traders to attach disclosure instructions to their orders, after taking into account order size and price placement. The relative tick is the average of the minimum price variation divided by price. Volatility is measured by the root mean squared 30 minute intraday transaction return. The sample consists of all 300 French common stocks that traded in the Paris Bourse continuous market on more than 25 days of the 41 trading days in January and February 1995. Estimate *t*-statistics are in parenthesis.

Dependent Variable Order Sample	Intercept	Relative Tick	Volatility	Log Market Value	Inverse Price	R^2	N
Logit transform of the fraction of orders that do not fully disclose remaining size							
All orders	-0.10 (-0.60)	-3.13 (-7.9)	0.38 (1.65)	-0.13 (-4.50)		26.7	300
Orders > FF200,000	1.33 (6.4)	-5.98 (-12)	1.16 (4.20)	-0.34 (-10.0)		60.7	298
Logit transform of the mean undisclosed remaining size expressed as a fraction of remaining order size							
All orders	-0.58 (-4.09)	-3.11 (-9.4)	0.39 (2.08)	-0.10 (-4.35)		31.1	300
Orders > FF200,000	0.59 (3.48)	-5.05 (-13)	1.01 (4.49)	-0.28 (-10)		62.4	298
Logit transform of the mean fraction of linked orders							
All orders	-0.13 (-1.09)	-2.39 (-8.6)	0.13 (0.79)	0.03 (1.43)		21.2	300
Orders > FF200,000	-0.08 (-0.73)	-2.67 (-11)	0.53 (3.83)	0.04 (2.61)		30.4	298
Logistic model intercept measure of hidden order usage							
All orders	0.81 (4.91)	-5.38 (-14)	1.41 (6.5)	-0.35 (-13)		73.7	300
All orders	0.88 (5.2)	-5.85 (-12)	1.31 (5.8)	-0.36 (-14)	5.02 (1.59)	73.9	300

Table V

Cross-Sectional Regressions of Stock Liquidity Indicators

This table presents weighted least squares cross-sectional regression estimates. The dependent variables are various statistics that characterize liquidity for each stock. They are computed from order and transaction time-series. The observations are weighted by the number of quotes, trades, or days used to compute the dependent variables for each stock. The relative tick is the average of the minimum price variation divided by price. Volatility is measured by the root mean squared 30 minute intraday transaction return. The sample consists of all 300 French common stocks that traded in the Paris Bourse continuous market on more than 25 days of the 41 trading days in January and February 1995. The regression involving block statistics has only 52 observations because only 52 stocks are block eligible. Estimate *t*-statistics are in parenthesis.

Intercept	Relative Tick	Volatility	Log Market Value	Inverse Price	Log Min Display Size	R^2	N
Log Average Inside Quote Size (Thousand FF)							
4.56	4.72	-1.51	0.33			81.2	300
(35)	(18)	(-8.6)	(16)				
4.23	6.37	-1.09	0.36	-15.18		84.1	300
(33)	(19)	(-6.4)	(18)	(-7.4)			
Log Ratio of Average Inside Quote Size to Average Relative Spread (Thousand FF/Percent)							
5.16	4.95	-2.90	0.69			89.8	300
(29)	(14)	(-12)	(24)				
5.04	5.59	-2.74	0.70	-5.89		89.9	300
(27)	(11)	(-11)	(24)	(-1.96)			
Log Ratio of Block Quote Size to Average Block Relative Spread (Thousand FF/Percent)							
14.48	3.80	-5.09	0.51			91.2	52
(40)	(8.0)	(-11)	(8.2)				
14.59	3.51	-5.26	0.49	2.83		91.1	52
(37)	(5.7)	(-9.9)	(7.8)	(0.73)			
Average Relative Spread (Percent of Price)							
0.71	-0.65	0.91	-0.21			71.9	300
(7.1)	(-3.19)	(6.8)	(-13)				
0.61	-0.15	1.04	-0.20	-4.52		72.5	300
(5.9)	(-0.56)	(7.4)	(-12)	(-2.70)			

(Continued)

Intercept	Relative Tick	Volatility	Log Market Value	Inverse Price	Log Min Display Size	R^2	N
Log Average Daily Volume (Million FF)							
0.86	2.77	0.25	1.15		0.18	73.5	300
(2.06)	(2.68)	(0.68)	(22)		(4.10)		
0.93	0.11	-0.16	1.15	28.36	0.22	74.3	300
(2.27)	(0.08)	(-0.43)	(22)	(3.19)	(4.79)		
Log Average Daily Number of Trades							
-5.59	2.48	0.99	0.86		0.02	64.4	300
(-16)	(2.94)	(3.26)	(20)		(0.68)		
-5.48	-1.67	0.34	0.86	44.14	0.08	68.6	300
(-17)	(-1.62)	(1.13)	(21)	(6.4)	(2.18)		
Log Average Trade Size (Thousand FF)							
3.61	0.07	-1.41	0.17		0.13	59.8	300
(18)	(0.22)	(-6.6)	(6.4)		(8.3)		
3.61	1.49	-1.13	0.19	-10.43	0.10	61.5	300
(18)	(3.06)	(-5.0)	(7.1)	(-3.69)	(5.7)		

Table VI

Mean Order Disclosure Characteristics, Classified by Tick Size, for Stocks that Traded on Two Different Tick Sizes During the Sample Period

This table presents cross-sectional means of various statistics that characterize order disclosure for each stock. The statistics are computed from all orders that could not be fully executed upon submission and which are large enough that the trader could specify a disclosure instruction. The paired *t*-statistics are for testing whether the differences in the paired means are zero. They are computed by weighting each difference by a constant proportional to the expected variance of the difference. The cross-sectional means are computed using the same weights. Remaining size is the portion of the order that cannot be fully executed with certainty upon submission. A linked order either adjusted another order or was canceled by another order. The logistic model intercept measures the relative propensity of traders to attach disclosure instructions to their orders, after taking into account order size and price placement. The samples consist of the 26 Paris stocks and the 12 Toronto stocks that traded on two different ticks during their respective sample periods. The Paris subsample of orders larger than FF200,000 includes orders from only 23 stocks because three stocks had no qualifying orders. No results are reported for the Toronto logistic model analysis because traders did not specify any order disclosure restrictions for seven of the 12 stocks.

	Tick Size		
Variable and Order Subsample	Smaller Tick	Larger Tick	Paired *t*-statistic
Mean percentage of orders with some undisclosed remaining size			
All Paris orders	42.6	37.1	-3.5
Only Paris orders larger than FF200,000	62.3	53.4	-5.0
All Toronto orders	3.4	1.4	-2.2
Mean undisclosed remaining size as a percentage of remaining order size			
All Paris orders	32.6	29.0	-2.6
Only Paris orders larger than FF200,000	49.0	41.7	-4.7
All Toronto orders	2.1	1.1	-1.7
Mean percentage of linked orders			
All Paris orders	49.6	38.8	-4.7
Only Paris orders larger than FF200,000	55.8	44.8	-4.9
All Toronto orders	25.8	29.7	1.0
Logistic model intercept measure of hidden order usage			
All Paris orders	0.61	0.20	-6.3

Table VII

Mean Liquidity Characteristics, Classified by Tick Size, for Stocks that Traded on Two Different Tick Sizes During the Sample Period

This table presents cross-sectional means of various statistics that were computed for each stock from order and trade time-series. The subsample consists of the 26 stocks from the main sample that traded on two different ticks during the sample period. The main sample consists of all French common stocks that traded in the Paris Bourse continuous market on more than 25 days of the 41 trading days in January and February 1995. The paired *t*-statistics are for testing whether the percentage differences in the means are zero. They are computed by weighting each difference by a constant proportional to the expected variance of the difference, which is based on the numbers of time-series observations used to compute the two statistics ($1/(1/N_S+1/N_L)$). The cross-sectional means are weighted by the same weights. The mean ratio of average block quote size to average block relative spread is computed from only four stocks because the subsample included only four block-eligible stocks. The daily volume statistics are computed only from days on which only one tick was used. The means for these variables include only 22 stocks because four of the subsample stocks did not trade for a full day on a second tick.

	Tick Size			
Variable	Smaller Tick	Larger Tick	Paired *t*-statistic	N
Average Price (FF)	515	559	6.91	26
Average Inside Quote Size (Thousand FF)	162	334	6.73	26
Average Inside Quote Size (Shares)	372	685	5.77	26
Ratio of Average Inside Quote Size to Average Relative Spread (Thousand FF/Percent)	1382	2121	3.68	26
Ratio of Average Block Quote Size to Average Block Relative Spread (Thousand FF/Percent)	2678	2975	0.93	4
Average Relative Spread (Percent Basis Points)	66	58	2.29	26
Average Spread (Ticks)	28	4	-18.25	26
Average Spread (FF Centimes)	331	375	4.32	26
Average Trade Size (Thousand FF)	104	108	1.20	26
Average Trade Size (Shares)	239	236	-0.26	26
Average Daily Number of Trades	48	37	-0.57	22
Average Daily Volume (Million FF)	5	4	-0.26	22
Average Daily Volume (Thousand Shares)	11	8	-0.03	22

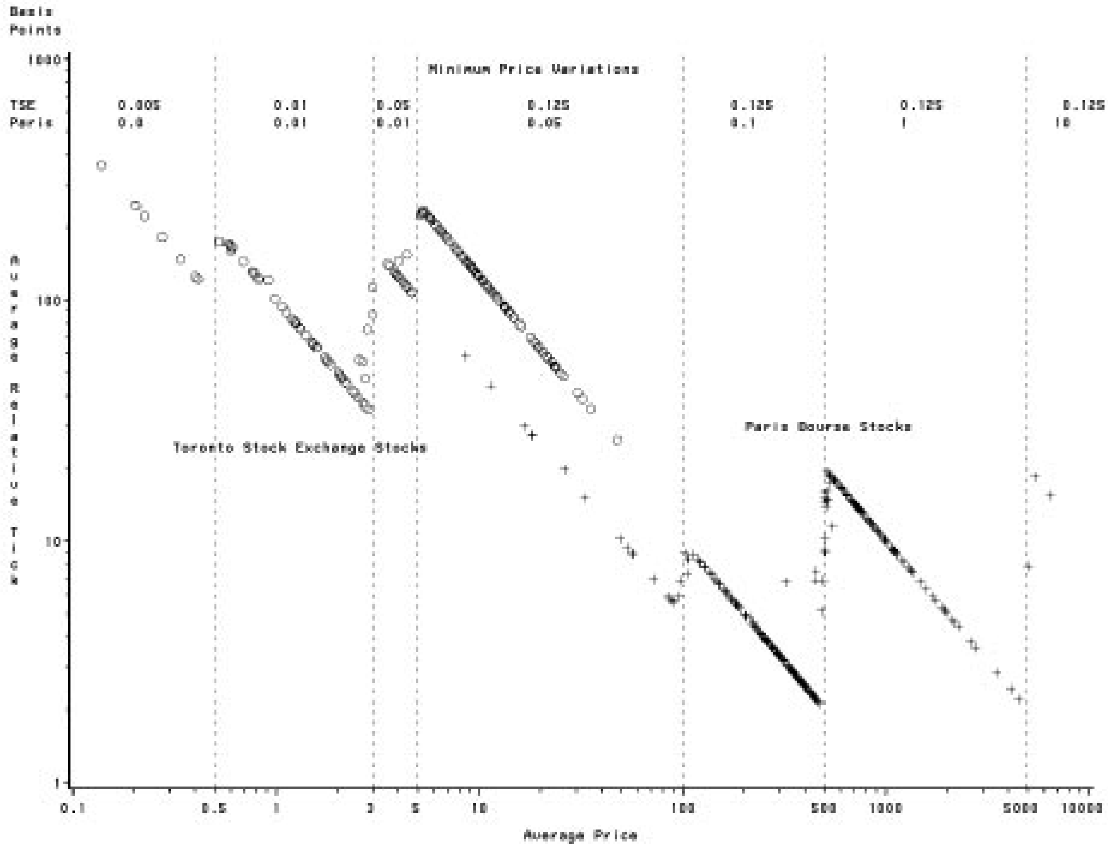

Figure 1. Logarithmic Scatter Plot of Average Relative Tick Size on Average Price. The average relative tick size is the time-series average of the ratio of the exchange minimum price variation to the trade price. It is expressed in basis points. The average price is expressed in local currency units (Canadian dollars for the TSE stocks and French Francs for the Paris Bourse stocks). Most points lie along 45 degree lines because most stocks traded on only one minimum price variation during the sample period. This figure shows that the relative minimum price variation was much greater for the TSE stocks than for the Paris stocks. Only 38 TSE stocks have average relative tick sizes smaller than the maximum found in the Paris sample and only 5 Paris stocks have average relative tick sizes greater than the minimum found in the TSE sample.