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Registered trader participation during the Toronto Stock Exchange's pre-opening session

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Abstract

This paper documents order submission strategies during the Toronto Stock Exchange's pre-opening session. I find that the registered trader (RT) actively participates in the market opening despite not being able to set the opening price directly and not having an apparent informational advantage. I find that RT opening trades are profitable, are able to moderate overnight price changes, and may be motivated, in part, by inventory adjustment concerns. I focus on interlisted stocks that simultaneously open for trading under two different mechanisms and show how the comparative levels of pre-trade market transparency of each exchange impacts RT profits and participation.

JEL Classification: G10

Keywords: Registered trader; market transparency; interlisted securities; price discovery.

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1 Introduction

An emerging topic in financial market microstructure is the role of pre-opening sessions and of opening protocols in facilitating price discovery. Financial markets have established a variety of opening protocols designed to incorporate new information efficiently into security prices after the overnight non-trading period. Recent articles by Biais, *et al.* (1999), Madhavan and Panchapagesan (2000), and Cao, *et al.* (2000) have explored price discovery during the pre-opening of the Paris Bourse, the New York Stock Exchange (NYSE), and the Nasdaq Stock Market, respectively. This paper extends this line of research by focusing on the pre-opening session and the market opening of the Toronto Stock Exchange (TSE).

The role of the TSE's designated market maker, the responsible registered trader (RRT), at the market opening is ambiguous. Unlike the NYSE specialist, the RRT cannot set the opening price directly and, because of the high level of pre-trade market transparency on the TSE, the RRT does not have an apparent informational advantage at the market opening. Thus, it is unclear whether the RRT is able to improve upon the efficiency of a transparent, purely automated opening mechanism such as the pre-opening session of the Paris Bourse. The objective of this paper is to investigate the RRT's motivation for submitting orders during the pre-opening session and to determine how these orders impact liquidity and price discovery.

This research is timely because of two trends in financial markets: (i) the development of around-the-clock trading; and (ii) the increase in market fragmentation resulting from new alternative trading venues. At first glance, the trend towards around-the-clock trading appears to make market opening mechanisms obsolete. However, as initial attempts to introduce after-hours trading have demonstrated, trading outside of regular trading hours can be subject to very poor liquidity and significant price volatility. As a result, it is likely that after-hours trading for less frequently traded stocks will not operate as a continuous trading environment, but instead may develop into a series of call auctions, similar to that currently being used by the Arizona Stock Exchange (AZX). The goal of these call auctions is to consolidate liquidity at a single point in time, thereby reducing transaction costs and price volatility. Research into the properties of the mechanisms used to open financial markets, such as the TSE, is of particular interest because of the similarities between market opening mechanisms and these after-hours trading procedures.

This research is also timely because of the trend towards increasing market fragmentation. This trend increases the likelihood that a security will open for trading simultaneously

on different exchanges, each with different opening mechanisms. Market participants will submit their orders to the exchange with lower transaction costs and the optimal level of transparency given the information content of their trades. This will influence the location of price discovery and the relative liquidity of each exchange. This paper examines the interaction between different opening procedures by focusing on interlisted stocks that simultaneously open for trading on the TSE and a U.S.-based exchange.

The paper makes three important contributions to the literature:

1. I show that the RRT actively participates in the market opening and that the RRT's opening trades (i) moderate overnight price changes, (ii) are influenced by the composition of order types submitted during the pre-opening session, and (iii) may be motivated, in part, by inventory adjustment concerns. I find that, on average, the RRT's opening trades are profitable and constitute about one-fifth of the RRT's daily trading profits. The RRT takes advantage of opening order imbalances and thereby appears to provide greater overnight price stability than is possible with a purely automated electronic limit order market (e.g. Paris Bourse).

2. I investigate RRT trading behavior in interlisted stocks that simultaneously open on two exchanges using different opening mechanisms. I argue that the less transparent NYSE opening call auction contributes to higher adverse selection costs for RRTs assigned to NYSE-interlisted stocks. As a result, RRTs assigned to NYSE-interlisted stocks participate less actively and have lower profits at the market opening. In contrast, the more transparent Nasdaq pre-trade period does not create the same adverse selection costs for RRTs assigned to Nasdaq-interlisted stocks.

3. I show that high levels of pre-trade market transparency and poor incentives for early order submission cause most traders to wait until just before the market opening to submit their orders. The last few minutes of the pre-opening session are characterized by rapid inside quote revisions and substantial increases in quoted market depth. This potentially chaotic environment creates disadvantages for market participants with poorer access to trading facilities.

Domowitz and Madhavan (2000) divide market opening mechanisms into three main groups:

1. **Non-differentiated** procedures are systems where the opening trade is undistinguished from subsequent intraday trading in terms of their market protocols (e.g. Nasdaq).

2. **Batch opens** are opening procedures that set the opening price to clear the overnight accumulation of orders and orders submitted for execution at the open (e.g. Paris Bourse).

3. **Intermediated opens** normally involve a form of batch procedure coupled with potential market maker intervention in the process (e.g. NYSE).

Within these groups are many shades of grey. Opening mechanisms vary with regard to the level of pre-trade market transparency, the ability of traders to send messages to other traders, the level of informational parity across market participants, order cancellation policies, price stability rules, method and ease of order entry, and opening trade allocation rules.

The TSE's opening mechanism is best described as a batch open. This description, however, is complicated by the ambiguous role of the RRT at the market opening. While the RRT cannot directly set the opening price — it is determined automatically by the trading system — the RRT can and does submit orders for execution at the market open. The RRT can use these orders to influence the opening price in a predictable manner.

In contrast, the NYSE specialist has much more control over opening prices and has exclusive knowledge of the public limit order book. Typically, the specialist observes the overnight accumulation of market and limit orders and then either: (i) sets a single opening price at which any remaining accumulated order imbalance from market-on-open and public limit orders must be absorbed by the crowd and the specialist's inventory; or (ii) posts a two-sided quote based on the limit order book or his or her own willingness to trade. Madhavan and Panchapagesan (2000), characterizing the low level of pre-trade market transparency on the NYSE with a "black box," show that the opening price set by the specialist is more efficient than the implied market clearing price. Their analysis, however, cannot determine whether the efficiency gain from specialist intermediation would still exist if other market participants had access to information contained in the limit order book. One goal of the present study is to find out whether participation by the RRT improves the efficiency of the open in an environment with a high level of pre-trade market transparency.

The optimal level of pre-trade market transparency is unclear. Experimental studies by Bloomfield and O'Hara (1999,2000) and Flood, *et al.* (1999) suggest that higher levels of market transparency might lead to higher or lower levels of informational efficiency depending on the specific underlying market structure. Of particular relevance to the situation faced by the TSE, Bloomfield and O'Hara (2000) investigate whether transparent markets can survive when faced with direct competition from less transparent markets. The introduction of

the *Market-by-Price* system on the TSE in 1990 dramatically increased the level of pre-trade transparency by allowing market participants to view the depth available at the best five bid and ask prices. Madhavan, *et al.* (2000) find that this increase in pre-trade transparency was detrimental to liquidity and resulted in higher execution costs and increased volatility.

The opening protocols of the Paris Bourse and TSE share several features. Both exchanges operate as continuous electronic limit order markets and have highly transparent pre-opening sessions during which market participants can place, modify, or cancel orders for possible execution at the market opening. Biais, *et al.* (1999) examine the process of price discovery and learning during the Paris Bourse's pre-opening period between 8:30AM and the start of regular trading at 10:00AM. They find that due to the high level of market transparency and the ease with which orders can be canceled, traders are unwilling to submit the most informative orders until just prior to the market opening. This paper documents a similar order submission pattern during the TSE's pre-opening session. Despite these similarities, this paper highlights a very important difference between the Paris Bourse and the TSE: the TSE has an RRT assigned to each stock, but the Paris Bourse does not. I find that the RRT is able to counteract possible opening order imbalances, thereby improving the efficiency of the opening price over what might occur with a limit order market without intermediation.

Price discovery during the TSE's pre-opening session frequently occurs in an environment with overlapping orders. Cao, *et al.* (2000) also find overlapping orders are prevalent in the Nasdaq's pre-trade period, and argue that dealers often use locked market quotes as an important signaling mechanism. They argue that certain dealers consistently show price leadership and use locked inside quotes to signal which direction the price should move. Signaling, however, cannot explain the pattern of overlapping orders on the TSE: Most orders submitted during the pre-opening session are rarely revised or withdrawn prior to the market open.

The paper is organized as follows. The next section describes the institutional features of the TSE. Section 3 describes the data and sample selection criteria. Section 4 describes the patterns of order submission, bid-ask spreads, and market depth during the pre-opening session and during regular trading hours. It also decomposes opening trades across market participant types (retail, institutional, etc.). Section 5 infers which factors influence RRT profits and participation at the market opening. Section 6 concludes.

2 Institutional details

Regular trading hours of the TSE are from 9:30AM to 4:00PM and coincide with the regular trading hours of the major U.S. equity markets. The TSE operates as an electronic limit order market based on the **C**omputer **A**ssisted **T**rading **S**ystem (CATS). The limit order book is transparent. Three alternative services enhance market depth information away from the inside bid-ask quote: (i) *Market-by-price* provides committed tradeable volume at the top five bid and ask prices; (ii) *Market-by-order* provides the top five buy and sell orders; and (iii) *Market-by-broker* is similar to market-by-order, except that it provides aggregate volume for each member firm at one price rather than individual orders.

Since the Paris Bourse's trading system was based on the original version of CATS, the TSE and the Paris Bourse share similar rules. Unlike the Paris Bourse, however, the TSE assigns a specialist, the RRT, to each actively traded stock. Typically, each RRT is assigned to about eight different securities for which the main responsibilities are: (i) to contribute to market liquidity and depth; (ii) to moderate price volatility; (iii) to maintain a continuous two-sided market; and (iv) to fill odd lot and mixed lot orders. The RRT is also responsible to fill eligible market orders and tradeable limit orders up to a specified number of shares, the Minimum Guaranteed Fill (MGF), if the order cannot be filled from the order book.

As partial compensation for these responsibilities, the RRT can choose to "auto-participate" in any immediately executable order less than MGF-size. For eligible orders, the RRT can choose to purchase up to 50% of an incoming sell order and to sell up to 50% of an incoming buy order (these percentages have been recently reduced to 40%). Effectively, this allows the RRT to trade ahead of existing public limit orders. The trading system indicates to other market participants that the RRT is participating on the bid and/or ask side. The RRT's intention to participate must be announced prior to the incoming order being submitted. The RRT's ability to auto-participate cannot be used at the market opening.

A large share of order flow executed on the TSE is *internalized* by member firms. When a member firm receives a customer order, the member firm's "upstairs traders" can hold it for up to 15 minutes before sending the order to the consolidated limit order book. During this time, the customer order may either be traded with a member firm account (as a principal cross) or traded with another customer order of the member firm (as an agency cross). Smith, *et al.* (2000) find that while only 3.33% of trades occur in the upstairs market, these trades represent 56% of the total trading volume executed on the TSE.

Opening Protocols: The TSE holds a pre-opening session from 7:00 to 9:30AM during which market participants may submit market and limit orders for possible execution at the beginning of regular trading at 9:30AM. During this time, the best (highest) bid price and the best (lowest) ask price are updated to reflect new orders and are reported to the public. If there are *overlapping orders*, the system reports a single price, the calculated opening price (COP), that is equal to the price at which the most stock will trade. If there are two or more prices at which the stock volume would be the same, then: (i) the system selects the price that minimizes the post-opening imbalance; or (ii) if there is no imbalance, or if the resulting imbalance is the same at each price, the system selects the price nearest to the previous closing price.

During the pre-opening session, market participants can submit standard limit and market-at-open orders. In addition, there is a special order available to client accounts, an *at-the-opening* (OPG) order, that can participate at the opening price of a security, whatever it might be. In contrast to a market-at-open order, an OPG order does not affect the COP. An OPG order does not necessarily receive a partial or complete fill, whereas a market order is filled completely (or causes a delay, if that is not possible).

Another special order type, a *must-be-filled* (MBF) order, is an order to buy or sell a security which is part of a basket of stocks being bought or sold because of the expiry of an offsetting index-based option or futures contract. In order to qualify, orders must be in response to an expiring options or futures position, and must comprise at least 20 of the securities underlying the TSE 35 Index or at least 70% of the component share capital weighting of the TSE 100 Index. An MBF order must receive a complete fill at the opening price. All MBF orders must be entered into the system by 5:30PM on the day before index option expiration day (index options normally expire on the third Friday of every month). The TSE calculates and advertises large net imbalances expected for index securities at the opening. The intent is to reduce the possibility of a large opening imbalance by providing sufficient time to attract offsetting order flow prior to the open. An MBF order has two important benefits over a standard market order: (i) it is exempt from the short sale rule; (ii) orders may be entered into the MGF facility, even if the trades are non-client orders.

There are few incentives for early order submission during the pre-opening session. During the pre-opening session and regular trading hours, an order can establish priority by either being the *first* order to set a higher bid or lower ask price or being the *only* order remaining on the bid or offer when all competing orders are canceled or filled. The maximum number of shares for which an order may establish priority is 10,000 shares for a security

that is part of the TSE 35 Index, and 5,000 shares for all other securities.

A security will not open for trading if, at the opening time, orders that are guaranteed to be filled cannot be completely filled by offsetting orders or the COP exceeds price volatility parameters set by the exchange. In addition, exchange rule 4–702(2) states that the RRT may delay the opening of a security for trading if: (i) The COP differs from the previous closing price for the security or from the anticipated opening price on another recognized stock exchange where the security is listed, by an amount exceeding ten ticks for securities trading at or above $5.00 and fourteen ticks for securities trading below $5.00; (ii) The opening of another recognized stock exchange where the security is interlisted for trading has been delayed; or (iii) The COP is less than the permitted difference from the previous closing price for the security, but is otherwise unreasonable.

Under normal circumstances, all securities open for trading at exactly 9:30AM. Market orders, better-priced limit orders, and MBF orders are all guaranteed execution at the open (unless flagged by the anti-scooping rule described below). The trading system then allocates trades in the following manner:

1. All possible crosses are executed. Client orders are given priority over non-client orders.
2. Equally to client limit orders at the opening price and OPG orders and to an order for the account of the RRT to a maximum of three times the size of the MGF for that security.
3. Equally to all limit orders at the opening price and OPG orders.

In other words, the TSE trading system automatically executes all possible crosses from the same member firm *ahead* of orders in the limit order book at the opening price. Thus, a limit order at the opening price may have a better chance of being executed if it is submitted through a larger member firm. Partially offsetting this advantage, after all possible crosses are executed, limit orders at the opening price and OPG orders are first allocated on a *per member* basis up to a fixed amount and then allocated on a *pro rata* basis.

Market professionals such as traders employed by member firms and RTs have access to superior market trading facilities, which may enable them to receive market information and submit orders faster than other market participants. During the last few minutes of the pre-opening session, market professionals may be able to submit a limit order that slightly undercuts the current COP and thereby receive a larger opening trade allocation.

To offset this potential advantage, the TSE adopted an *anti-scooping* rule in which any

market orders or better price limit orders entered after 9:28AM for non-client accounts that do not change the calculated opening price are converted to OPG orders. In effect, this rule causes these non-client orders to move to the "back of the line" in terms of opening allocation priority. When the opening is delayed past 9:30, the rule only applies to RRT orders since only the RRT knows the exact time at which the security will open, thereby eliminating the possible timing advantage market professionals normally have over client orders at the open. In effect, the anti-scooping rule eliminates the RRT's potential "last-mover" advantage.

3 Data

Trade and quote data for all TSE-listed securities is obtained from the 1998 TSE Equity History database. Like the widely-used TAQ database produced by the NYSE, the TSE database reports all executed trades and inside quote revisions. Unlike the TAQ database, which only includes records of board lot trades posted on the consolidated tape, the TSE database includes records of trades involving both odd and board lot orders. Trades involving odd lot orders provide important information about the amount of liquidity trade in a particular security and about how small retail orders are handled on the TSE.

Trade and quote records in the TSE database provide more detail than comparable TAQ records. Each trade record details whether the trade involved: special terms, sales delayed, delayed delivery, cash settlement, certificate, non net (trade cannot be settled via normal clearing), do not tender (explicit instructions from client not to tender the stock to an outstanding offer (e.g. take-over)), auto allocation, money market. Each trade record also identifies the member firm(s) involved on both sides of the transaction. Each quote record reveals whether the quote occurred during the pre-opening session or during a trade halt.

For the period January to August 1998, the database also contains markers indicating whether a trade involved an order for a registered trading account or for a non-client account. Trade markers are used, in part, to enforce the *In-House Client Priority Rule* which requires member firms to execute their own clients' orders ahead of any non-client orders at the same price. Non-client orders include orders for the member firm itself (inventory orders) and orders for the accounts of partners, directors, officers and employees of the firm.

In addition, there are optional account identification codes indicating the specific account for which the trade was placed (e.g. an inventory account). Inventory accounts are used by member firms to accumulate a large long or short position in a security for possible use in

an "upstairs" trade with an institutional client. These upstairs trades are executed on the exchange as a "put-through" or cross. Member firms can add to their accumulated position either by trading directly with the limit order book or by internalizing order flow.

The inventory account marker alone does not suggest the direction of institutional trade. The inventory account marker may be used when the member firm is accumulating a position for a institutional client by participating in smaller retail orders that may either have been sent to the consolidated limit order book or that have been internalized by the member firm, but it may also be used when the member firm is actually executing a large cross involving the institutional client. The percentage of trades involving non-client inventory accounts *do* provide a good proxy for the level of institutional trade in a security at a particular time, and hence a good proxy for the level of informed trade in a particular security.

The trade markers and account identification codes can also be used to approximate participation by the RRT. The trade marker "R" indicates trades that involve orders placed by a RT, not necessarily an order placed by the *responsible* RT. RTs can, and do, place orders for securities other than the securities for which they are directly responsible. It is possible, however, to isolate trade records involving the *responsible* RT by restricting attention to trade records with the appropriate member firm field and the alpha-numeric account identification code. Although account identification codes are confidential, it is possible to obtain the relevant codes for the RRT by concentrating on odd lot trade records. Because the RRT has an obligation to fill all odd lot market orders, I can use these trade records to identify uniquely the member firm field and the alpha-numeric account identification code that correspond to the security's RRT. Using this "fingerprint," I can identify orders involving the RRT.

Each RRT must have an approved backup to act as a substitute in times of illness and during scheduled vacations. Because backup RTs do not necessarily use the same trade marker "fingerprint," my reported averages understate the proportion of trade from the RRT and overstate the proportion of trade from "other" RTs. My reported regression results attempt to screen for occurrences when the RRT changes.

3.1 Selection Criteria

At the beginning of the sample period (Jan. 1, 1998), 1,763 different securities were listed on the TSE. Because most of these securities are not actively traded and the trading properties of different security types are not directly comparable, I restrict attention to actively traded common shares of Canadian-based companies. My sample excludes the following securities:

1. Warrants, installment receipts, preferred shares, debentures, limited partnership units, trust units, index participation units, securities trading in U.S. funds, and securities based outside of Canada.

2. Securities that were under suspension by the TSE at any time during 1998.

3. Securities that had a monthly trading volume with a value of less than $100,000 during any month in the sample period.

4. Securities that had a market capitalization less than C$100 million on Dec. 31, 1997.

5. Securities that were added or eliminated from the TSE stock list during 1998.

For convenience, I also exclude any security that changed its symbol during 1998 (either through a name change or a substitutional listing). Employing this selection criteria produces a final sample of 459 securities. As long as I restrict attention to common shares, the results presented in this paper are not sensitive to the security selection criteria.

Table 1 reports the characteristics of the stocks included in the sample. Based on market capitalization at the close of trading on Dec. 31, 1997, I divide the sample into size quintiles. On average, the number of daily transactions, the daily trading volume, the daily dollar value of trading volume, and the number of inside quote revisions increase with firm size. The largest firms (quintile 1) are much larger and more actively traded than firms in the next largest quintile. The table also highlights the important role of interlisted securities on the TSE. In 1998, 58.7% of the total value of trading volume on the TSE was comprised of trading in securities that were also listed on a U.S.-based exchange, and 25% of trading in these stocks occurs in U.S. markets.[1]

During the sample period, many securities listed on the TSE were also listed on the Montreal Exchange (ME). In 1998, the ME accounted for 10.0% of the trading volume in Canadian securities (TSE Review, 1998). In 1999, a major restructuring agreement between the Canadian exchanges consolidated all equity trading in senior equities on the TSE. Because of insufficient data and the diminished importance of the ME in equity trading, this study ignores order flow submitted to the ME. Consequently, my results understate trading volumes for regional Quebec-based firms that tend to trade primarily on the ME and my results may be sensitive to effects caused by brokerage firms that send retail order flow to preferred market makers on the ME. The close linkage of the trading systems used by the TSE and the ME

[1]Source: Toronto Stock Exchange 1998 Annual Report.

Table 1: **Composition of stocks satisfying selection criteria.** Stocks are grouped into quintiles according to their market capitalization on Dec. 31, 1997. Stocks are classified under the category "Changed listing status" if during 1998: (i) they become listed on a U.S. exchange; (ii) there is a change in their *U.S. exchange* trading symbol; (iii) they become delisted from a U.S. exchange; (iv) they change U.S. exchange. The descriptive statistics are reported as averages across all applicable firm-days. The average closing price is based on the last reported normal trade, omitting trading days in which the stock did not trade.

		Size Quintile (1 = largest)				
	Total	5	4	3	2	1
Total sample	459	92	92	92	92	91
Exchange listing status:						
Non-interlisted on U.S. exchange	315	73	76	62	62	42
Interlisted on NYSE	60	0	3	8	13	36
Interlisted on AMEX	19	1	2	9	3	4
Interlisted on Nasdaq	55	17	11	10	10	7
Changed listing status during 1998	8	1	0	3	4	0
Descriptive Statistics:						
Market cap. 12/31/97 (C$M)		127.8	216.9	414.0	942.2	5,908.7
Avg. closing share price (C$)		10.84	14.13	19.45	27.41	45.00
Avg. # of transactions / day		21.0	19.7	27.8	49.1	279.1
Avg. daily trading volume ('000)		60.1	59.0	64.3	124.5	428.5
Avg. daily dollar volume (C$000)		219	332	659	1,853	14,610
Avg. # of inside quote revisions / day		30.2	31.1	43.5	72.7	338.3

ensure that, in general, trades cannot be executed on one exchange if there is a more favorable quoted price on the other exchange.

Internalized Order Flow: A large proportion of trades executed on the TSE originate from a relatively small number of member firms. Table 2 illustrates that the ten most active member firms participated in 52.52% of the TSE's total trade dollar volume over the sample period. The ongoing consolidation of Canada's financial sector suggests that, over time, just a handful of member firms may execute an ever larger proportion of trades on the TSE. This has important potential implications regarding the ability of member firms to "internalize" trade.

Table 2 identifies the share of each member firm's trading dollar volume that was submitted for: (i) a registered trader, employed by the member firm, trading in a stock of responsibility (RRT); (ii) a registered trader, employed by the member firm, trading in a non-assigned stock (ORT); (iii) a non-client (NC); or (iv) a client (C). Two observations stand out:

Table 2: **Top Ten Member Firms by Trading Dollar Volume** Member firm names and their corresponding TSE trading numbers are effective July 6, 1998. The sample period is from January 1, 1998 to June 30, 1998.

		% of Trading Dollar Vol.				% of TSE
Rank	Member Firm (Trading Number)	RRT	ORT	NC	C	$Vol
1	RBC Dominion Securities Inc. (02)	1.42	4.07	32.32	62.20	6.69
2	Nesbitt Burns Inc. (09)	0.41	3.73	43.72	52.15	6.28
3	CIBC Wood Gundy Securities Inc. (79)	0.00	0.00	39.82	60.18	4.90
4	ScotiaMcLeod Inc. (85)	0.09	1.90	32.32	65.69	4.29
5	TD Securities Inc. (07)	0.00	0.01	37.79	62.20	3.83
6	Midland Walwyn Capital Inc. (39)	5.03	7.20	43.92	43.85	3.79
7	First Marathon Securities Ltd. (80)	0.00	3.09	44.67	52.25	3.13
8	Levesque Beaubien Geoffrion Inc. (63)	6.61	18.05	39.70	35.65	2.23
9	Griffiths McBurney & Partners (74)	4.06	12.29	49.53	34.12	2.00
10	Gordon Capital Corp. (81)	0.00	0.00	35.59	64.41	1.67

1. On average about 32% of a member firm's trading dollar volume is from non-client orders. This reflects the importance of "upstairs" trading for TSE member firms.

2. RTs actively trade in stocks that are not directly under their responsibility. For many firms, RT trade in non-assigned securities exceeds RT trade in assigned securities.

4 Order submission patterns

To understand the RRT's role during the pre-opening session, I first document the typical order submission pattern during this session. Reflecting the similarities between the opening protocols of the TSE and the Paris Bourse, I find that order submission patterns during the TSE pre-opening session are similar to those documented by Biais, *et al.* (1999) for the Paris Bourse. Specifically, order submission is concentrated in the last few minutes prior to the start of regular trading. The high level of market transparency during the pre-opening session discourages traders from submitting their orders early for fear of revealing their information. Also, traders are unwilling to offer free options to the market, and thereby, subject themselves to the likely event that additional information will be revealed to the market prior to the beginning of regular trading hours. As explained in section 3, the TSE provides few incentives to counteract these concerns and thereby promote early order submission.

Figure 1 illustrates the number of inside quote revisions per five minute interval during the pre-opening session and regular trading hours. An inside quote revision is defined as a change in the: (i) inside bid price; (ii) inside ask price; (iii) inside bid size; or (iv) inside ask

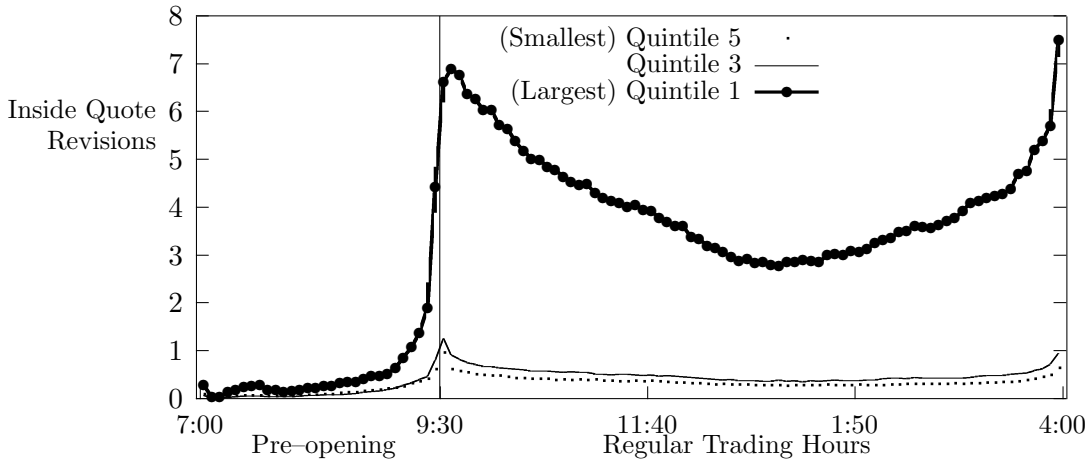

Figure 1: **Average number of inside quote revisions per five minute interval.** Results are calculated at five minute intervals, taking the average number of inside quote revisions during the time interval across all trading days and all stocks in the quintile. An inside quote revision occurs when there is a change in the inside bid or ask price and/or in the inside bid or ask size.

size. The key empirical regularities characterizing the pre-opening behavior and quotes are:

- The number of inside quote revisions accelerates as the opening approaches.
- The U–shaped pattern of inside quote revisions during regular trading hours is consistent with previously observed intraday patterns of order submission.
- On average, the frequency of inside quotes revisions rises with firm size. There is a big difference between the trading activity for firms in the largest size quintile and the corresponding level of trading activity for firms in other size quintiles.

The theoretical model of Medrano and Vives (1998) investigates a price discovery process similar to a pre-opening session and shows that during the beginning of the session an informed trader may deliberately manipulate prices using a contrarian strategy to neutralize the effects of the trades of competitive informed agents. To investigate the possibility of market manipulation, I investigate the percentage of inside quote revisions that indicate that an existing order has been withdrawn. Specifically, an inside quote revision resulting from a withdrawn order is indicated by: (i) an increase in the bid-ask spread; (ii) no change in a positive bid-ask spread but a decrease in either the bid size or the ask size; (iii) no change in a bid-ask spread of zero but a decrease in the minimum of the bid size and the ask size. As reported in table 3, about 95% of all quote revisions lead to an increase in market depth

Table 3: **Percentage of inside quote revisions resulting from a withdrawn order.** These quote revisions are indicated by: (i) an increase in the bid-ask spread; (ii) no change in a positive bid-ask spread but a decrease in either the bid size or the ask size; (iii) no change in a bid-ask spread of zero but a decrease in the minimum of the bid size and the ask size.

	Size Quintile				
Time period	5	4	3	2	1
7:00 - 7:30	4.18%	6.95%	6.62%	6.79%	2.88%
7:30 - 8:00	8.22%	7.80%	6.95%	7.18%	9.03%
8:00 - 8:30	4.35%	6.64%	5.36%	6.30%	7.47%
8:30 - 9:00	3.47%	3.93%	3.44%	3.57%	5.06%
9:00 - 9:30	4.86%	4.96%	5.16%	4.85%	4.82%

and/or an increase in the bid-ask spread. In other words, most orders are "serious" and are submitted with the intention of being executed.

Figure 2 illustrates the average number of inside quote revisions per *one minute* interval during the pre-opening session for securities in the largest size quintile. In the first few minutes, there is a small surge in quote revisions that may be attributed to the submission of new orders that arrived at member firms during the overnight non-trading period. These orders may have been submitted early in the session in an effort to be the first order to set a new price and thereby gain priority in the opening trade allocation. A more likely explanation is that these orders are just small retail orders that were submitted by investors who find it more convenient to trade after normal working hours.

Figure 2 also illustrates that quote revision accelerates every minute up to and including the last minute of the pre-opening session. A large number of traders literally wait until the last minute to submit their orders despite potential communication-related problems that might prevent their timely arrival. The rapid quote revision at the end of the pre-opening session could be advantageous to traders with the ability to take advantage of any favorable opening imbalances. The TSE's anti-scooping rule is designed to compensate for this by penalizing non-client orders submitted during the last two minutes of the pre-opening session.

Figure 3 illustrates the intraday pattern of the percentile bid-ask spread. The percentile bid-ask spread is defined as $\frac{2*(ask-bid)}{bid+ask}$, where bid and ask are the most recent, best bid and ask prices, respectively. The intraday pattern is similar across firm sizes. In general, average spreads are inversely related to firm size (and perhaps more accurately, average trading volumes). Spreads narrow throughout the pre-opening session, with the narrowest spreads of the day occurring just prior to the open. In fact, the spread at the open is zero for a large

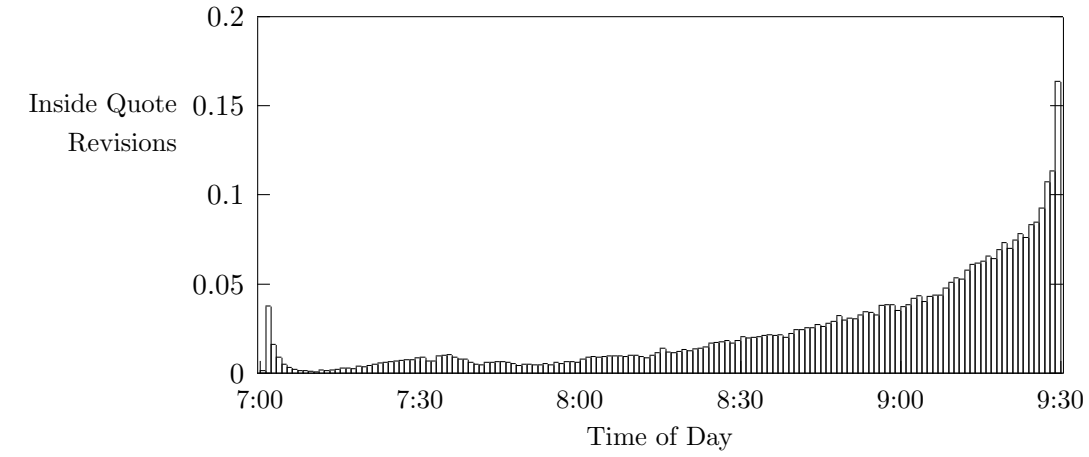

Figure 2: **Average number of inside quote revisions per one minute interval during the pre-opening session for stocks in the largest size quintile.** Results are calculated by taking the average number of inside quote revisions during the time interval across all trading days and all stocks in the quintile.

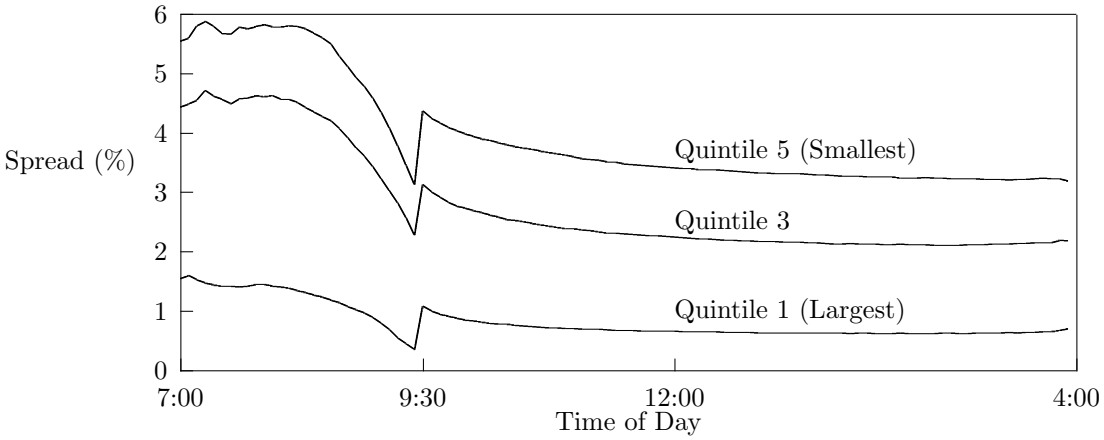

Figure 3: **Intraday pattern of the percentile bid-ask spread.** The percentile bid-ask spread is defined as $2 * (ask - bid)/(bid + ask)$, where bid and ask are the most recent, best bid and ask prices, respectively. Results are calculated at five minute intervals, taking the average across all trading days and all stocks in the quintile.

number of securities with overlapping orders. As regular trading hours begin, spreads widen initially as these overlapping limit orders are executed. During the remainder of the trading day, spreads gradually narrow.

McInish and Wood (1992) and Chan, *et al.* (1995) have analyzed the intraday pattern of bid-ask spreads on the NYSE and the Nasdaq, respectively. McInish and Wood found that the bid-ask spread for NYSE stocks has a crude reverse J–shaped pattern with higher spreads near the beginning and the end of the day. In contrast, Chan, *et al.* find that the bid-ask spread for Nasdaq stocks is relatively stable throughout the day but narrows significantly during the final hour of trading. The pattern observed near the end of the trading day on the TSE differs from the observed pattern on both of these exchanges.

Figure 4 illustrates the intraday pattern of quoted market depth available at the inside quote. When the percentile bid-ask spread is less then 2%, quoted market depth is defined as the average of the quoted size, in dollar terms, available at the inside bid and at the inside ask. Otherwise, quoted market depth is defined as zero. This definition provides an indication of the dollar magnitude of an order which could be executed at the inside quote without incurring large transaction costs from the bid-ask spread. Expressing quoted market depth in dollar terms allows us to compare liquidity across different firms. It is important to note that this measure provides only a proxy for the actual depth available. It does not make any allowances for depth that might exist a single tick size away from the inside quote nor does it account for hidden liquidity available from the upstairs market or from the RRT's MGF requirements.

For all firm sizes, quoted market depth increases throughout the pre-opening session and reaches its highest level of the day at the market open. For smaller firms, quoted market depth during the first hour of the pre-opening session is very low. For example, by 8:00AM the average quoted market depth for firms in size quintiles 5 and 3 has reached just $2,742 and $5,114, respectively.

- These liquidity levels indicate that a relatively small order could alter the pre-opening quotes for small stocks. In sharp contrast, the pre-opening quotes for large stocks have substantial financial backing, with an average quoted market depth of $113,000 by 8:00AM, and are thus less subject to manipulation.

After peaking at the market open, quoted market depth drops during the first few minutes of trading as overlapping orders are executed. After this initial drop, quoted market depth gradually rises throughout the day. Although the intraday pattern is similar across firm

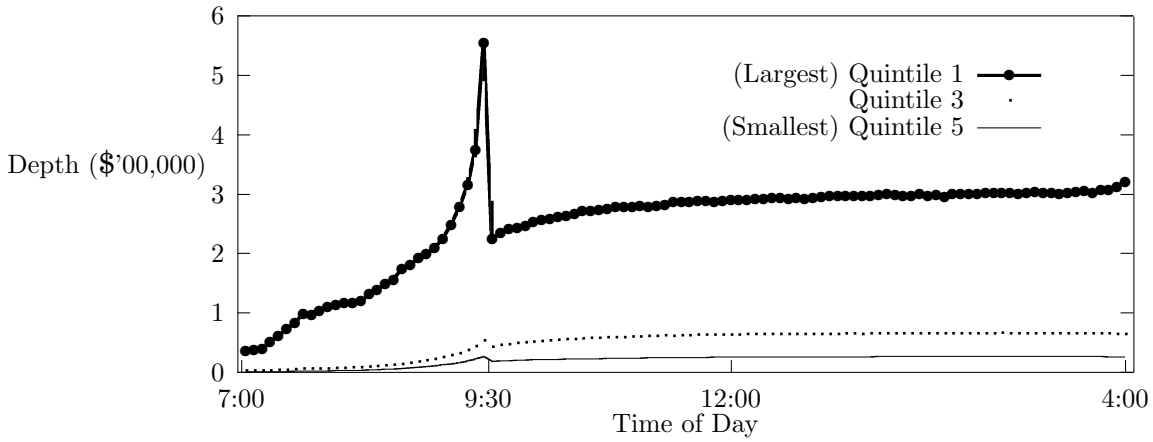

Figure 4: **Intraday pattern of quoted market depth available at the inside quote.** Results are calculated at five minute intervals, taking the average across all trading days and all stocks in the quintile. When the percentile bid-ask spread is less than 2%, quoted market depth is defined as the average of the quoted size, in dollar terms, available at the inside bid and at the inside ask. Otherwise, quoted market depth is defined as zero.

sizes, the difference in magnitudes is stark. Quoted market depth for firms in the largest size quintile averages about $300,000 during the trading day, while the analogous number for firms in the smallest size quintile is about $26,000. From these observed average levels, I infer that the RRT's MGF requirements are relatively more important for smaller firms.

Overlapping Orders: A unique feature of the pre-opening session is the possibility that limit orders may overlap. When the highest bid price exceeds the lowest ask price, a single indicated price (the COP) is posted based on the algorithm described in section 3. As figure 5 illustrates, overlapping orders occur frequently, especially for large stocks, and the likelihood of overlapping orders rises as the market opening approaches.

In the absence of trades, overlapping orders and quotes are a defining characteristic of most pre-opening sessions. Cao, *et al.* (2000) find that locked and crossed inside quotes account for 11.3% and 23.6% of market quotes during the Nasdaq pre-opening session. They argue that Nasdaq dealers use crossed and locked inside quotes to signal to other market makers which direction the price should move. Because these quotes are non-binding, Nasdaq dealers can revise them frequently up until the market open.

- Overlapping orders do not serve a deliberate signaling role on the TSE. Pre-opening quotes on the TSE are driven by orders, not dealer quotes, and these orders are rarely revised prior to the market open.

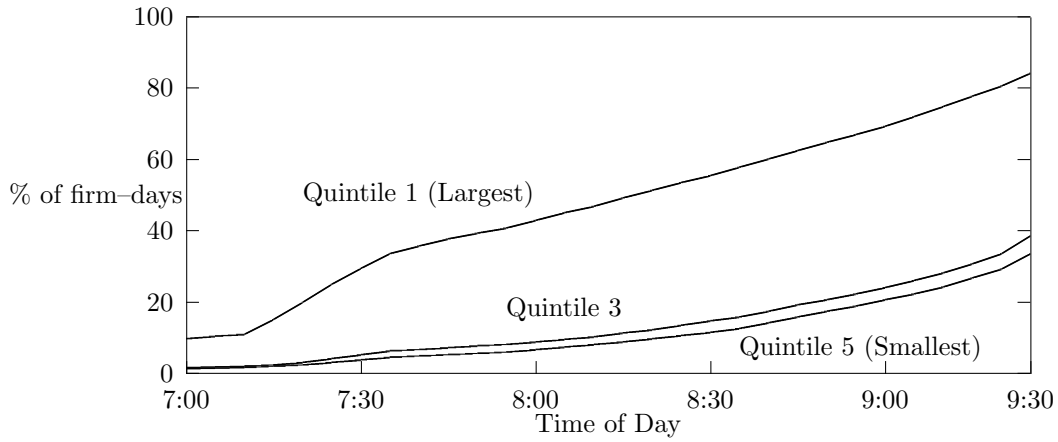

Figure 5: **Overlapping orders.** Results correspond to the percentage of firm-days in the quintile that had a single indicated opening price at the respective time.

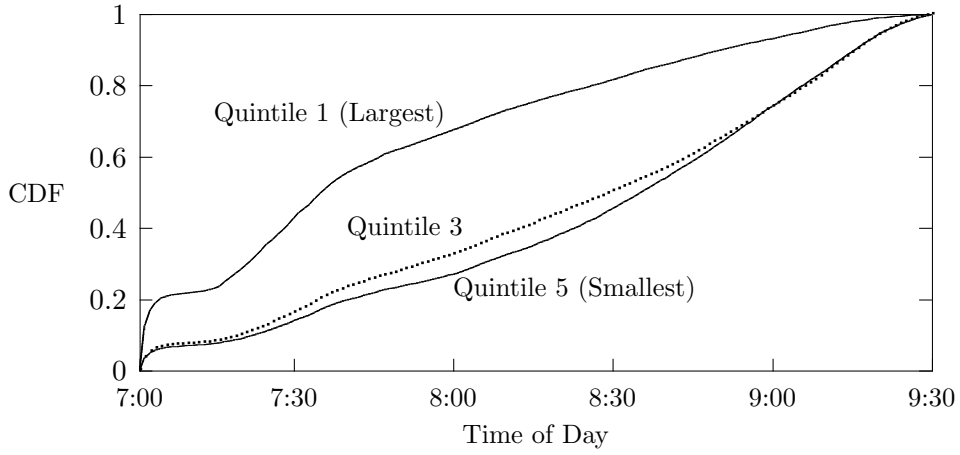

Figure 6: **Empirical CDF of first pre-opening quote revision times.**

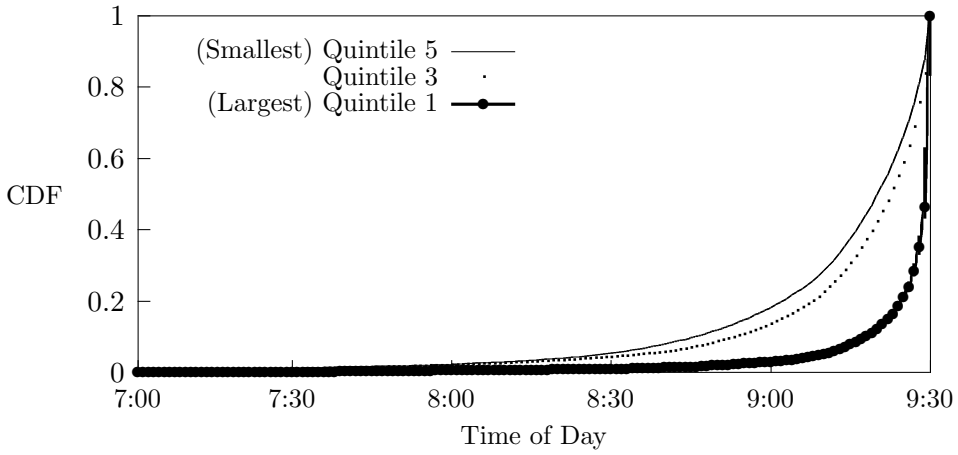

Figure 7: **Empirical CDF of last pre-opening quote revision times.**

Length of pre-opening session: The paucity of quote revisions in the first hour suggests that the market's performance would not be qualitatively affected were the pre-opening session shortened. To investigate this further, I consider the distribution of the times of the *first* and *last* quote revisions.

Prior to the start of the pre-opening session, the system posts a quote reflecting good till canceled orders carried forward from the previous trading session. Because these initial quotes reflect old information, the price discovery process does not begin until there has been a quote revision. Let N_Q and λ_{it} denote the number of securities in quintile Q and the time of the first quote revision for firm i on trading day t, respectively. Then the empirical cumulative distribution function (CDF) of the share of firm-days where the first quote revisions occurred within l minutes of the start of the pre-opening session is defined by

$$\hat{F}(l) = \frac{1}{N_Q T} \sum_{i=1}^{N_Q} \sum_{t=1}^{T} \mathbf{I}\left(\lambda_{it} \leq t\right), \qquad l \in [0, 150] \tag{1}$$

where $\mathbf{I}\left(\lambda_{it} \leq l\right) = 1$ if $\lambda_{it} \leq l$; 0 otherwise. Figure 6 illustrates that approximately 68% of firm-days in the largest size quintile had at least one quote revision prior to 8:00AM. Similarly, about 33% and 28% of firms-days in quintiles 3 and 5, respectively, had at least one quote revision prior to 8:00AM. Thus, the price discovery process appears to begin surprisingly early, despite relatively few incentives to submit orders early in the pre-opening session. As reported by Biais, *et al.* (1999) for the Paris Bourse, however, these early order submissions contain significantly less information than orders submitted closer to the market open.

An empirical CDF for the time of the last quote revision is also estimated. This function

provides an indication of how "fresh" quotes are at the beginning of the trading session and whether there are opportunities for astute investors to exploit "stale" orders at the market open. As figure 7 illustrates, the last quote revision occurs during the last five minutes of the pre-opening session for approximately 79% of firm-days in the largest quintile. In contrast, the last quote revision occurs during the last five minutes for only about 41% and 34% of firm-days in quintiles 3 and 5, respectively.

- The last pre-opening quote for smallest firms is often stale. Overall, while the pre-opening session is relatively active for larger firms, it is not particularly effective at promoting liquidity for smaller firms.

Opening trade volume: The open is characterized by the highest market depth and the lowest bid-ask spreads of the trading day. The ensuing low transaction costs should create a favorable environment for agents to trade. This is verified by table 4 which reports the average daily trade volume, at the "instantaneous" open and during the first five minutes of regular trading hours, as a percentage of total trading volume.

Because the calculation of cross-sectional, time-series averages can be ambiguous, I am explicit here. Let $V_{i\tau}$ and $V_{i\tau}^{O}$ denote the total number of shares of firm i traded, during regular trading hours and at the open, respectively, on trading day τ. Let N and T denote the number of firms and the number of trading days, respectively. Then the average trade volume at the open as a percentage of total daily trading volume for a group of securities is defined as

$$100 \times \frac{1}{N} \sum_{i=1}^{N} \left(\frac{\sum_{\tau=1}^{T} V_{i\tau}^{O}}{\sum_{\tau=1}^{T} V_{i\tau}} \right). \tag{2}$$

In general, smaller firms are less actively traded and have greater informational asymmetries. Thus, the enhanced liquidity provided by the market opening is especially important for smaller firms. This is confirmed in table 4 and is consistent with similar results reported by Madhavan and Panchapagesan (2000) for the NYSE and by Cao, *et al.* (1997) for the Nasdaq.

At the open, market participants trading in interlisted stocks may decide that the opening mechanism of either the TSE or the U.S. exchange will provide better trade execution given the size and the information content of their order. This decision impacts where pre-trade price discovery occurs and how the RRT responds to competitive pressure from U.S. market makers. Although table 4 reports no consistent differences in opening volumes between interlisted and non-interlisted firms, the analysis in section 5 will show that these aggregate volumes conceal potential differences in the information content of the order flow.

Table 4: **Average opening trade volume and the frequency of opening trades.** Opening trades include all trades that occur at the instant the security opens for regular trading (normally at 9:30AM, except when the opening is delayed). Averages are calculated using equation (2).

	Size Quintile (1 = large)				
	5	4	3	2	1
% of total daily trading volume at open ("instantaneous"):					
All securities	2.2	1.6	1.2	1.0	1.5
Non-interlisted	2.1	1.6	1.1	1.1	1.4
NYSE interlisted	NA	1.1	0.9	0.9	1.5
Nasdaq interlisted	2.4	1.9	1.5	0.9	1.7
AMEX interlisted	2.7	1.5	1.8	0.7	1.4
% of total daily trading volume during first 5 min. of regular trading:					
All securities	4.8	4.1	3.3	2.9	2.9
Non-interlisted	4.4	4.1	3.5	3.2	2.8
NYSE interlisted	NA	2.3	1.8	2.2	2.8
Nasdaq interlisted	6.3	4.6	3.8	2.4	3.7
AMEX interlisted	4.1	2.7	3.3	2.7	3.0
% of firm-days with opening trade					
All securities	38.3	38.7	42.7	55.8	88.0
Non-interlisted	35.0	36.3	40.4	53.4	83.4
NYSE interlisted	NA	50.0	38.4	70.3	93.5
Nasdaq interlisted	49.6	51.8	64.7	63.1	85.2
AMEX interlisted	67.1	48.4	46.6	42.1	95.6
% of firm-days with delayed opening trade					
All securities	0.4	0.5	0.6	1.6	3.0
Non-interlisted	0.5	0.6	0.6	0.9	1.6
NYSE interlisted	NA	0.3	0.9	5.3	4.9
Nasdaq interlisted	0.4	0.7	0.3	1.8	2.7
AMEX interlisted	1.2	0.8	0.4	0.8	1.8

The opening of the TSE is the most active period of the trading day. In comparison with the NYSE and the Nasdaq, however, opening trades on the TSE account for a *much lower* percentage of total daily trading volume. Specifically, Madhavan and Panchapagesan (2000) find that, on average, 9.7% and 17.5% of the total daily dollar trading volume of the NYSE occurs at the open and during the first half hour of trading, respectively. Cao, *et al.* (1997) find that, on average, 8.6% of total daily trading volume on the Nasdaq occurs during the first three minutes of trading. In comparison with these exchanges, the TSE's opening mechanism appears to be less effective at attracting order flow.

Both the likelihood of an opening trade and the likelihood of an opening delay increase with firm size. Large NYSE-interlisted firms are much more likely to have an opening delay. Unlike the "automated" opening of the TSE, the NYSE opening is frequently delayed by the NYSE specialist in an attempt to attract order flow from floor traders to offset an opening imbalance. TSE-based trading in these NYSE-interlisted firms is frequently delayed until the NYSE opening call auction is complete.

4.1 Composition of Opening Trades

This section examines the composition of trades that are executed at the beginning of regular trading hours. As explained previously, the TSE trading system automatically executes all possible crosses from the same member firm *ahead* of orders in the limit order book at the opening price. Tables 5–7 demonstrate the importance of this opening trade allocation rule by dividing opening trades between those involving the same member firm on both sides of the trade and those involving two different member firms. Opening trade dollar volume is classified as involving six possible order types: (1) RRT board lot; (2) RRT odd lot; (3) registered trader for non-assigned stocks (ORT); (4) non-client (NC) for inventory accounts; (5) non-client (NC) for non-inventory accounts; (6) client.

Approximately 23.6%, 17.7%, and 16.0% of the dollar volume of opening trades involve the same member firm on both sides of the trade for the largest, middle, and smallest quintile, respectively. The same member firm is more likely to be involved on the both sides of a trade for larger stocks. This order flow represents order flow that could be *internalized* by member firms in a more decentralized opening procedure.

The RRT actively participates in the opening. Approximately 7.6%, 19.6%, and 19.9% of the total trading dollar volume involves the RRT for the largest, middle, and smallest quintile, respectively. The RRT provides much needed liquidity at the open to infrequently

Table 5: **Composition of trades at open by trading dollar volume for firms in largest quintile (Quintile 1).** The reported numbers indicate the percentage of *all* reported opening trades within the subsample of firms and trading days that had the indicated property. By construction, the reported percentages should sum to 100 (allowing for rounding errors). Opening trades include all trades that occur at the instant the security opens for regular trading (normally at 9:30AM, except when the opening is delayed).

Same member firm involved on both sides of trade [23.63%]

		Buy Side					
		RRT			Non-Client		
		Board Lot	Odd Lot	ORT	Inventory	Other	Client
	RRT Board Lot	0.01	0.00	0.00	0.01	0.05	0.17
	RRT Odd Lot	0.00	0.00	0.00	0.00	0.00	0.02
Sell	ORT	0.01	0.00	0.11	0.08	0.20	0.65
Side	Non-Client Inventory	0.01	0.00	0.13	0.50	0.72	1.69
	Non-Client Other	0.03	0.00	0.20	0.36	2.41	2.44
	Client	0.10	0.01	0.58	1.59	1.63	9.92

Different member firms involved on each side of trade [76.37%]

		Buy Side					
		RRT			Non-Client		
		Board Lot	Odd Lot	ORT	Inventory	Other	Client
	RRT Board Lot	0.00	0.00	0.13	0.27	0.30	1.68
	RRT Odd Lot	0.00	0.00	0.00	0.02	0.03	1.20
Sell	ORT	0.12	0.00	0.28	0.64	0.53	2.67
Side	Non-Client Inventory	0.29	0.02	0.63	1.53	1.94	4.41
	Non-Client Other	0.25	0.02	0.54	1.20	13.33	5.13
	Client	1.99	0.87	2.56	4.65	11.71	17.39

Table 6: **Composition of trades at open by trading dollar volume for firms in the "middle" quintile (Quintile 3).** The reported numbers indicate the percentage of *all* reported opening trades within the subsample of firms and trading days that had the indicated property. By construction, the reported percentages should sum to 100 (allowing for rounding errors). Opening trades include all trades that occur at the instant the security opens for regular trading (normally at 9:30AM, except when the opening is delayed).

Same member firm involved on both sides of trade [17.68%]

		Buy Side					
		RRT			Non-Client		
		Board Lot	Odd Lot	ORT	Inventory	Other	Client
	RRT Board Lot	0.05	0.00	0.00	0.03	0.05	0.29
	RRT Odd Lot	0.00	0.00	0.00	0.00	0.00	0.01
Sell	ORT	0.00	0.00	0.02	0.01	0.09	0.85
Side	Non-Client Inventory	0.03	0.00	0.01	0.18	0.11	1.15
	Non-Client Other	0.01	0.00	0.18	0.02	0.10	0.55
	Client	0.59	0.03	1.70	1.30	0.46	9.41

Different member firms involved on each side of trade [82.32%]

		Buy Side					
		RRT			Non-Client		
		Board Lot	Odd Lot	ORT	Inventory	Other	Client
	RRT Board Lot	0.00	0.00	0.10	0.50	0.58	7.43
	RRT Odd Lot	0.00	0.00	0.00	0.02	0.03	0.90
Sell	ORT	0.09	0.00	0.01	0.21	0.09	2.28
Side	Non-Client Inventory	0.45	0.03	0.11	1.00	0.64	5.42
	Non-Client Other	0.38	0.04	0.20	1.07	0.66	4.35
	Client	7.16	0.75	2.17	5.70	4.29	36.17

traded smaller firms. Because the RRT must fill odd lot orders, I decompose the RRT's order flow between that involving board and odd lots. A significant majority (71%, 91%, and 94% for the largest, middle, and smallest quintile, respectively) of the RRT's order flow involves board lot trades, which for the most part, represent voluntary participation.

Because RTs can, and do, place trades for other securities, I examine the level of RT trade in non-assigned securities (denoted ORT). I find that ORT trade accounts for approximately 8.4%, 8.2%, and 6.4% of the total trading dollar volume for the largest, middle, and smallest quintile, respectively. ORT trade is relatively more important for the largest firms and in fact exceeds RRT trade in these securities. Thus, the RRT faces considerable competition for order flow from RTs assigned to other securities. In this sense, it may be more accurate in certain

Table 7: **Composition of trades at open by trading dollar volume for firms in smallest quintile (Quintile 5).** The reported numbers indicate the percentage of *all* reported opening trades within the subsample of firms and trading days that had the indicated property. By construction, the reported percentages should sum to 100 (allowing for rounding errors). Opening trades include all trades that occur at the instant the security opens for regular trading (normally at 9:30AM, except when the opening is delayed).

Same member firm involved on both sides of trade [16.03%]

		Buy Side					
		RRT			Non-Client		
		Board Lot	Odd Lot	ORT	Inventory	Other	Client
	RRT Board Lot	0.02	0.00	0.00	0.06	0.03	0.47
	RRT Odd Lot	0.00	0.00	0.00	0.00	0.00	0.03
Sell	ORT	0.00	0.00	0.00	0.04	0.01	0.34
Side	Non-Client Inventory	0.00	0.00	0.00	0.31	0.08	1.30
	Non-Client Other	0.01	0.00	0.00	0.01	0.23	0.43
	Client	0.38	0.02	0.32	1.33	0.52	10.09

Different member firms involved on each side of trade [83.97%]

		Buy Side					
		RRT			Non-Client		
		Board Lot	Odd Lot	ORT	Inventory	Other	Client
	RRT Board Lot	0.00	0.00	0.09	0.73	0.80	7.41
	RRT Odd Lot	0.00	0.00	0.00	0.01	0.02	0.62
Sell	ORT	0.09	0.00	0.15	0.43	0.39	2.18
Side	Non-Client Inventory	0.41	0.01	0.21	0.62	0.82	3.86
	Non-Client Other	0.65	0.01	0.22	0.86	0.74	5.35
	Client	7.55	0.48	1.89	5.42	5.44	36.39

instances to model the TSE using a multiple dealer environment.

Tables 8 and 9 are designed to establish whether these results are particular to the market opening or are general features of the overall TSE market structure. These results are reported in terms of the number of transactions instead of trading dollar volume. Because the relative proportions of each trade type is similar using these two measures, I am reassured that the results are not being dominated by a single high priced security. There are several observations worth noting:

- The percentage of trades involving two client orders is much higher at the market open than during regular trading hours (e.g. 39.2% versus 21.8% for the largest quintile).

- The percentage of trades involving a non-client inventory account order is much higher during regular trading hours than at the market open (e.g. 29.8% versus 14.9% for the largest quintile). Although crosses receive priority at the open, the respective member firm has little control over the opening price (which is determined automatically by the trading system). In contrast, "put-throughs" that are executed during regular trading hours can be executed at a time when the prevailing price may be favorable.
- Generally, at both the open and during regular trading hours, there is a higher proportion of client orders on the buy side than on the sell side.

5 Registered Trader Participation

Two observations suggest the RRT has little incentive to trade at the market opening. First, the high level of pre-trade market transparency suggests that the RRT does not have a large informational advantage relative to other market participants. Second, the RRT cannot set the opening price directly and must submit orders prior to 9:28AM in order to influence the opening price. Despite these two observations, my previous results demonstrate that the RRT actively participates in trades executed at the market open. This section attempts to solve this puzzle by isolating the factors which contribute to RRT participation at the market opening.

The analysis in this section uses the overnight price change and the likelihood of an opening trade as exogenous factors that influence RRT participation and profits at the market opening. Because the available database contains information about executed trades but not about submitted orders, it is impossible to isolate completely the impact of RRT trades on these variables. To account for this, I assume that, under most circumstances the RRT will wait until the final five minutes of the market opening to submit an order. The RRT has the incentive to delay submitting an order in order to take advantage of economic information and order imbalances that may develop during the pre-opening session. In addition, the RRT's superior access to market trading facilities eliminates incentives to submit an order early because of possible communication related problems. Thus, I assume that overnight price changes calculated using the indicated opening price at 9:25AM can be treated as exogenous. Similarly, the likelihood of an opening trade is indicated by the presence of an overlapping order at 9:25AM, which is also assumed to be exogenous.

In part, the RRT's decision to participate at the market opening depends on whether or not market conditions exist such that there will be an opening trade. A high probability of

Table 8: **Composition of trades at open.** The reported numbers indicate the percentage of *all* reported opening trades within the subsample of firms and trading days that had the indicated property. By construction, the reported percentages should sum to 100 (allowing for rounding errors). Opening trades include all trades that occur at the instant the security opens for regular trading (normally at 9:30AM, except when the opening is delayed).

Quintile 1 (Largest)

		Buy Side					
		RRT			Non-Client		
		Board Lot	Odd Lot	ORT	Inventory	Other	Client
	RRT Board Lot	0.01	0.00	0.10	0.27	0.28	2.89
	RRT Odd Lot	0.00	0.00	0.01	0.21	0.32	11.69
Sell	ORT	0.09	0.02	0.25	0.45	0.44	4.35
Side	Non-Client Inventory	0.22	0.24	0.41	0.89	0.82	5.75
	Non-Client Other	0.23	0.24	0.41	0.77	1.15	5.18
	Client	2.46	8.37	3.31	4.85	4.18	39.15

Quintile 3

		Buy Side					
		RRT			Non-Client		
		Board Lot	Odd Lot	ORT	Inventory	Other	Client
	RRT Board Lot	0.02	0.00	0.08	0.52	0.59	8.46
	RRT Odd Lot	0.00	0.00	0.02	0.17	0.26	6.23
Sell	ORT	0.09	0.01	0.04	0.18	0.12	3.83
Side	Non-Client Inventory	0.36	0.18	0.12	0.61	0.37	5.38
	Non-Client Other	0.34	0.27	0.23	0.50	0.49	4.19
	Client	6.50	5.77	2.71	4.65	3.45	43.25

Quintile 5 (Smallest)

		Buy Side					
		RRT			Non-Client		
		Board Lot	Odd Lot	ORT	Inventory	Other	Client
	RRT Board Lot	0.03	0.00	0.07	0.65	0.64	7.51
	RRT Odd Lot	0.00	0.00	0.03	0.15	0.11	4.44
Sell	ORT	0.10	0.03	0.07	0.36	0.35	3.02
Side	Non-Client Inventory	0.35	0.12	0.13	0.64	0.51	4.98
	Non-Client Other	0.41	0.17	0.19	0.54	0.61	4.86
	Client	5.67	4.82	1.79	5.06	4.42	47.16

Table 9: **Composition of all executed trades during regular trading hours.** The reported numbers indicate the percentage of *all* reported trades during regular trading hours within the subsample of firms and trading days that had the indicated property. By construction, the reported percentages should sum to 100 (allowing for rounding errors).

Quintile 1 (Largest)

		Buy Side					
		RRT			Non-Client		
		Board Lot	Odd Lot	ORT	Inventory	Other	Client
	RRT Board Lot	0.02	0.00	0.55	1.19	0.73	7.15
	RRT Odd Lot	0.00	0.00	0.01	0.23	0.24	5.68
Sell	ORT	0.53	0.01	0.79	1.55	0.97	4.91
Side	Non-Client Inventory	1.10	0.34	1.41	3.13	1.64	9.00
	Non-Client Other	0.74	0.20	0.98	1.85	1.24	5.30
	Client	5.55	4.20	4.16	8.42	4.41	21.78

Quintile 3

		Buy Side					
		RRT			Non-Client		
		Board Lot	Odd Lot	ORT	Inventory	Other	Client
	RRT Board Lot	0.04	0.00	0.36	1.03	1.03	10.17
	RRT Odd Lot	0.00	0.00	0.01	0.15	0.17	2.93
Sell	ORT	0.37	0.01	0.15	0.43	0.37	3.37
Side	Non-Client Inventory	0.89	0.21	0.29	1.01	0.77	6.21
	Non-Client Other	0.95	0.20	0.34	0.81	0.75	4.80
	Client	9.67	2.96	3.00	6.63	4.53	35.40

Quintile 5 (Smallest)

		Buy Side					
		RRT			Non-Client		
		Board Lot	Odd Lot	ORT	Inventory	Other	Client
	RRT Board Lot	0.02	0.00	0.26	0.74	1.22	9.39
	RRT Odd Lot	0.00	0.00	0.01	0.08	0.13	1.70
Sell	ORT	0.30	0.02	0.27	0.62	0.67	3.29
Side	Non-Client Inventory	0.63	0.12	0.53	1.11	1.16	5.78
	Non-Client Other	1.05	0.17	0.56	1.21	1.32	5.98
	Client	9.06	2.38	2.85	6.41	6.29	34.65

an opening trade is signaled to the RRT by the existence of an overlapping order during the pre-opening session. To isolate the factors that lead to an opening trade, I estimate the probit model:

$$E\left(Overlap_{it}\right) = F\left(\begin{array}{c} \alpha_0 + \alpha_1 \left|\Delta P_{it}\right| + \alpha_2 DVol_i + \alpha_3 \left(D_i^{ny} \cdot DVol_i\right) \\ \\ +\alpha_4 \left(D_i^{nz} \cdot DVol_i\right) + \alpha_5 \left(D_i^{ax} \cdot DVol_i\right) \end{array}\right) \tag{3}$$

where $F(\cdot)$ is a probit function, $\Delta P_{it} = \ln\left(P_{i,t}^{O}/P_{i,t-1}^{C}\right)$, and the variables are defined as:

1. $Overlap_{it}$ equals one if security i has an overlapping order at 9:25AM on trading day t.
2. D_i^{ny}, D_i^{nz}, and D_i^{ax} are dummy variables indicating whether the stock i is interlisted on the NYSE, Nasdaq, and AMEX, respectively.
3. $P_{i,t}^{O}$ indicates the average of the inside bid and ask prices posted at 9:25AM for stock i on trading day t.
4. $P_{i,t-1}^{C}$ indicates the closing transaction price for stock i on trading day $t-1$.
5. $DVol_i$ indicates the average daily dollar volume traded for firm i (in '00,000,000s).

The motivation for this model is as follows. Larger overnight price changes generally contribute to greater differences in investor stock valuations. Thus, I expect that the probability of an overlapping order, and thus the likelihood of trade at the market opening to be increasing in the size of overnight price changes. I also expect that the probability of an overlapping order (and an opening trade) rises with the stock's average daily trading volume. Finally, I add dummy variables to isolate the impact of average daily trading volume for interlisted stocks. The presence of alternative opening mechanisms may result in interlisted stocks having a higher or lower probability of an overlapping order in comparison with non-interlisted stocks with the same average daily trading volume. All else equal, interlisted stocks may have a lower probability of an overlapping order (and an opening trade) if market participants prefer to send their opening orders to the U.S.-based exchange or if they prefer to wait until after the two exchanges have opened. The behavior of traders in these stocks depends, in part, on the relative level of pre-trade market transparency of each exchange.

Other results, not shown here, suggest that adding dummy variables for interlisted stocks as separate terms in the estimated models produces unclear results. In part, this is because of the significant positive correlation between a stock's average daily trading volume and whether or not the stock is interlisted.

Table 10: **Estimation results: Probit model of the probability of an overlapping order at 9:25AM.** Standard errors are reported below the coefficient estimates in parenthesis. Statistical significance at the 0.05 and 0.01 levels is indicated by * and **, respectively. LLF denotes the value of the log likelihood function. Number of observations: All: 57375; Q1: 11375; Q2–Q5: 11500.

	$\lvert\Delta P\rvert$	$DVol$	$(D^{ny} \cdot DVol)$	$(D^{nz} \cdot DVol)$	$(D^{ax} \cdot DVol)$	α_0	LLF
All	0.114	1.98	-0.498	1.10	0.205	-0.636	-32796
	$(0.00416)^{**}$	$(0.0325)^{**}$	$(0.0405)^{**}$	$(0.0891)^{**}$	$(0.0892)^{*}$	$(0.00874)^{**}$	
Size quintile:							
Q1	0.140	1.11	-0.203	0.929	0.443	-0.139	-4031.6
	$(0.0171)^{**}$	$(0.0432)^{**}$	$(0.0402)^{**}$	$(0.127)^{**}$	$(0.0898)^{**}$	$(0.0319)^{**}$	
Q2	0.167	2.70	-0.406	0.461	-1.11	-0.801	-7077.3
	$(0.0112)^{**}$	$(0.0900)^{**}$	$(0.0987)^{**}$	$(0.148)^{**}$	$(0.229)^{**}$	$(0.0242)^{**}$	
Q3	0.140	4.87	1.90	-0.987	8.75	-0.979	-6888.3
	$(0.00929)^{**}$	$(0.176)^{**}$	$(0.624)^{**}$	$(0.217)^{**}$	$(0.714)^{**}$	$(0.0230)^{**}$	
Q4	0.0906	7.01	-2.71	4.63	0.325	-0.879	-6934.3
	$(0.00798)^{**}$	$(0.385)^{**}$	$(0.492)^{**}$	$(0.595)^{**}$	(0.646)	$(0.0232)^{**}$	
Q5	0.103	6.39	—	4.62	34.0	-0.826	-6991.6
	$(0.00788)^{**}$	$(0.401)^{**}$		$(0.625)^{**}$	$(9.94)^{**}$	$(0.0210)^{**}$	

From the estimation of this probit model, I save the computed conditional probability of an overlapping order at 9:25AM (the Inverse Mill's Ratio) for each security i and trading day t as IMR_{it}. This variable provides a very good indication about whether or not there will be an opening trade and is used as an explanatory variable in my subsequent analysis of RRT participation and RRT profits at the market opening.

Table 10 reports the estimation results. As expected, the probability of an overlapping order at 9:25AM rises with the size of the overnight price change and the average daily dollar trading volume of the security. For the regression involving all firms and for regressions involving quintiles 1,2,and 4, NYSE-interlisted stocks are significantly less likely to have an overlapping order at 9:25AM than a non-interlisted stock with the same average daily dollar trading volume. In contrast, for the regression involving all firms and for most quintile regressions, AMEX- and Nasdaq-interlisted stocks are significantly more likely to have an overlapping order at 9:25AM than a non-interlisted stock with the same average daily dollar trading volume. The differences between NYSE- and Nasdaq-interlisted stocks can be explained by the relative levels of pre-trade market transparency on the NYSE and the Nasdaq.

The less transparent NYSE opening call auction attracts order flow from informed traders who do not want to reveal their information in the highly transparent TSE pre-opening session. As a result, the TSE opening price will tend to be less efficient, causing liquidity based trades to either be sent to the NYSE or to wait until after differences between the TSE opening price and the NYSE opening price are resolved. Because the Nasdaq pre-trade period is more transparent, the same incentives do not exist. The results for AMEX-interlisted stocks are a bit puzzling. Because both the NYSE and AMEX use a non-transparent opening call auction, I would expect them to have similar results. The observed difference may just be an artifact of the relatively small number of AMEX-interlisted firms or it may be due to other differences in the characteristics of firms that choose to list on the AMEX instead of the NYSE.

In addition to the probability of an opening trade, the RRT's decision to participate in the market opening might be motivated by the following factors:

1. **Desire to moderate overnight price changes:** The performance of RRTs is evaluated, in part, on their ability to maintain price stability. To promote price stability, I expect that the RRT attempts to moderate overnight price changes by assuming an offsetting opening position. In general, I expect the probability of RRT participation to increase with the size of the overnight price change.

2. **Competitive response to the presence of competing U.S. market makers and alternative opening mechanisms:** In order to attract order flow away from U.S. exchanges, the RRT may increase participation at the open for interlisted stocks in an attempt to moderate price volatility and improve liquidity. This effect is not clear, however. In a study of interlisted stocks on the NYSE, Bacidore and Sofianos (2000) find that the NYSE specialist actuals participates *less* actively during regular trading hours for Canadian-based stocks compared with similar U.S.-based stocks. The RRT may reduce participation in interlisted stocks if information revelation and price discovery tends to occur on another exchange.

3. **Composition of order flow:** The RRT may be more likely to participate at the market opening when the composition of opening order flow contains more liquidity-motivated trades. As explained previously, non-client, inventory account orders provide a good proxy for the level of institutional trade in a security. On the one hand, large institutional orders may create opening imbalances that the RRT can profitably take advantage of. On the other hand, the RRT may be less likely to participate if institutional trading

corresponds to a higher level of informed trade. Adverse selection concerns are generally higher for less widely-held, smaller firms.

4. **Index option expiration days:** On the expiration of index-based option and futures contracts, traders normally purchase an offsetting quantity of the underlying securities using the MBF order described earlier. On the one hand, large volumes and possible order imbalances on expiration days may result in higher levels of RRT participation. On the other hand, large volumes may result in a more "accurate" price and thereby reduce the need for RRT participation.

The role of each of these incentives is estimated using the probit model:

$$E\left(PARTIC_{it}\right) = F\left(\begin{array}{c} \alpha_0 + \alpha_1 D_{it}^{ex} + \alpha_2 \left|\Delta P_{it}\right| + \alpha_3 \left|INV_{it}\right| + \alpha_4 Instit_{it} + \alpha_5 DVol_i \\ +\alpha_6 \left(D_i^{ny} \cdot DVol_i\right) + \alpha_7 \left(D_i^{nz} \cdot DVol_i\right) + \alpha_8 \left(D_i^{ax} \cdot DVol_i\right) + \alpha_9 IMR_{it} \end{array}\right) \quad (4)$$

where $F(\cdot)$ is a probit function. The variables ΔP_{it}, D_i^{ny}, D_i^{nz}, D_i^{ax}, $DVol_i$, and IMR_{it} are as defined before and:

1. $PARTIC_{it}$ equals one if the RRT participated in a board lot trade at the market open; equals zero otherwise. I restrict attention here to board lot trades in order to identify the factors contributing to *voluntary* RRT participation at the open. In the absence of order flow data, the RRT's involvement in an opening trade provides a reasonable proxy for the RRT's decision to participate in the pre-opening session. This is because the RRT is likely only to submit orders with a high probability of execution.

2. D_{it}^{ex} is a dummy variable that equals 1 on index expiration days for stocks included in the TSE 35 Composite Index; 0 otherwise. Because only large stocks are included in the TSE 35 Composite Index, the dummy variable is only included in the regression involving all firms and the regression for quintile 1.

3. INV_{it} indicates the *net* total dollar volume (number of shares purchased minus number of shares sold) of all trades for stock i on trading day $t-1$ involving the RRT.

4. $Instit_{it}$ indicates the percentage of opening trade volume, excluding RRT trade volume, on trading day t for stock i involving a non-client order for an inventory account.

The probit model is estimated for all stocks and across each size quintile. Table 11 reports the estimation results. I find that the probability of RRT participation at the open:

- Rises with the size of the overnight price change;

Table 11: **Estimation results: Probit model of voluntary RRT participation at the market opening.** Standard errors are reported below the coefficient estimates in parenthesis. Statistical significance at the 0.05 and 0.01 levels is indicated by * and **, respectively. LLF denotes the value of the log likelihood function. Number of observations: All: 57375; Q1: 11375; Q2–Q5: 11500.

		Size Quintile				
	All Firms	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
D^{ex}	0.294	0.225	—	—	—	—
	$(0.0935)^{**}$	$(0.0929)^{*}$				
$\lvert\Delta P\rvert$	0.103	0.114	0.143	0.134	0.128	0.141
	$(0.00457)^{**}$	$(0.0117)^{**}$	$(0.0111)^{**}$	$(0.0109)^{**}$	$(0.0101)^{**}$	$(0.00979)^{**}$
$\lvert INV\rvert$	0.166	0.0583	0.173	0.344	0.775	0.830
	$(0.00746)^{**}$	$(0.00830)^{**}$	$(0.0210)^{**}$	$(0.0391)^{**}$	$(0.0783)^{**}$	$(0.0928)^{**}$
$Instit$	0.168	0.123	0.0660	0.0508	0.0604	0.0937
	$(0.0181)^{**}$	$(0.0295)^{**}$	$(0.0356)^{*}$	$(0.0470)^{*}$	(0.532)	$(0.0404)^{*}$
$DVol$	0.367	0.111	1.86	3.75	5.84	4.72
	$(0.0126)^{**}$	$(0.0139)^{**}$	$(0.0982)^{**}$	$(0.176)^{**}$	$(0.534)^{**}$	$(0.458)^{**}$
$(D^{ny} \cdot DVol)$	-0.243	-0.0602	-0.845	-0.309	-5.77	—
	$(0.0128)^{**}$	$(0.0132)^{**}$	$(0.0923)^{**}$	(0.816)	$(0.567)^{**}$	
$(D^{nz} \cdot DVol)$	0.474	0.411	-1.85	-2.40	3.32	4.79
	$(0.0410)^{**}$	$(0.0436)^{**}$	$(0.173)^{**}$	$(0.274)^{**}$	$(0.708)^{**}$	$(0.759)^{**}$
$(D^{ax} \cdot DVol)$	0.707	0.498	-0.973	6.06	-2.48	69.5
	$(0.0502)^{**}$	$(0.0516)^{**}$	$(0.259)^{**}$	$(0.770)^{**}$	$(0.714)^{**}$	$(11.7)^{**}$
IMR	0.863	0.624	0.935	0.919	0.949	0.937
	$(0.00969)^{**}$	$(0.0259)^{**}$	$(0.0209)^{**}$	$(0.0221)^{**}$	$(0.0239)^{**}$	$(0.0223)^{**}$
α_0	-1.29	-0.706	-1.42	-1.80	-1.97	-1.84
	$(0.0105)^{**}$	$(0.0225)^{**}$	$(0.0310)^{**}$	$(0.0328)^{**}$	$(0.0387)^{**}$	$(0.0329)^{**}$
LLF	-23789	-6975	-4996	-3854	-3284	-3441

- Is significantly higher on index expiration days than on regular trading days;
- Is increasing in the share of opening trades involving a non-client, inventory account order (this suggests that the RRT is often more concerned about taking advantage of possible order imbalances than the information content of the opening trades);
- Rises with the size of the RRT's inventory imbalance from the previous trading session.

I also find that an RRT assigned to a NYSE-interlisted stock is significantly less likely to participate at the open than an RRT assigned to a non-interlisted stock with the same average daily trading volume. This result is significant across all of the regressions. The less transparent NYSE opening mechanism increases the RRT's potential adverse selection costs and thus appears to make the RRT more hesitant to participate in NYSE-interlisted stocks. In contrast, I find that, for the regression involving all firms, an RRT assigned to either a AMEX- or Nasdaq-interlisted stock is significantly more likely to participate at the open than an RRT assigned to a non-interlisted stock with the same average daily trading volume. The magnitude and sign of this effect, however, varies across the regressions for each quintile. Again, the results for AMEX-interlisted stocks should be interpreted with caution given the relatively few AMEX-interlisted stocks in each quintile.

What motivates the direction of RRT trade?: The RRT's performance is evaluated, in part, based on whether his/her trades improve price stability. Exchange rule 4-605(1) states that at least 70% to 80% of RRT trades in their stocks of responsibility shall be stabilizing or neutral trades. Exchange rule 4-605(2), however, provides an exemption from these stabilization requirements for RRTs dealing in all U.S.-based interlisted issues and in those Canadian-based interlisted issues in which more than 25% of the trading occurred on exchanges in the U.S. or on Nasdaq in the preceding year. The RRT's performance impacts whether he/she is assigned responsibility for more desirable stocks in the future.

The RRT may also use the open as an opportunity to re-adjust any inventory imbalance from the previous trading day. The high level of market depth at the open provides an ideal environment to adjust his/her position without unnecessarily disturbing the market. To investigate how overnight price changes and the RRT's inventory imbalance impact the RRT's net opening trade position, the regression model is estimated:

$$RTOPEN_{it} = \alpha_0 + \alpha_1 \Delta P_{it} + \alpha_2 INV_{it} + \alpha_3 IMR_{it} + \varepsilon_{it} \tag{5}$$

for $i = 1, \ldots, N$ and $t = 1, \ldots, T$, with the following assumptions on the error process: $E\left(\varepsilon_{it}^2\right) = \sigma_i^2$, $E\left(\varepsilon_{it}\varepsilon_{jt}\right) = \sigma_{ij}$, $\varepsilon_{it} = \rho_i \varepsilon_{i,t-1} + v_{it}$, $E(v_{it}) = 0$, $E(v_{it}v_{jt}) = \phi_{ij}$, $E(v_{it}v_{js}) = 0$ for $t \neq s$, and

Table 12: **Factors affecting the direction of RRT opening trades.** The regression model is given by (5), where cross-sectional correlation is allowed for regressions for individual quintiles, but cross-sectional independence is assumed for the regression using all firms. Standard errors are reported below the coefficient estimates in parenthesis and statistical significance at the 0.05 and 0.01 levels is indicated by * and **, respectively. Number of observations: All: 57375; Q1: 11375; Q2–Q5: 11500.

	ΔP	INV	IMR	α_0	R^2
All firms	-8.35	-0.0377	-0.0181	-0.00327	0.011
	$(0.334)^{**}$	$(0.00948)^{**}$	(0.0109)	(0.00712)	
Quintile 1	-10.96	-0.0466	-0.0557	0.00977	0.11
	$(0.301)^{**}$	$(0.00468)^{**}$	$(0.0121)^{**}$	(0.00794)	
Quintile 2	-18.87	-0.420	-0.258	0.0344	0.20
	$(0.430)^{**}$	$(0.0210)^{**}$	$(0.0123)^{**}$	$(0.00975)^{**}$	
Quintile 3	-38.4	0.376	0.0587	0.135	0.26
	$(0.602)^{**}$	$(0.0721)^{**}$	$(0.0169)^{**}$	$(0.0146)^{**}$	
Quintile 4	-15.2	-2.19	0.00593	-0.0210	0.20
	$(0.306)^{**}$	$(0.104)^{**}$	(0.0128)	$(0.0103)^{**}$	
Quintile 5	-26.8	-1.67	-0.478	-0.173	0.23
	$(0.492)^{**}$	$(0.186)^{**}$	$(0.0215)^{**}$	$(0.0169)^{**}$	

$E(\varepsilon_{i,t-1}v_{jt}) = 0$. The variable $RTOPEN_{it}$ denotes the RRT's net opening position for firm i on trading day t as a share of the security's average daily trading volume (scaled by 100,000). The variables ΔP_{it}, INV_{it}, and IMR_{it} are as defined before. *A priori*, I expect that $\alpha_1 < 0$ if the RRT is moderating price volatility and $\alpha_2 < 0$ if the RRT uses the open as an opportunity to re-adjust his inventory position.

I allow for cross-sectional correlation when estimating the model for each quintile. When estimating the model using the entire sample of firms, however, I must assume cross-sectional independence ($E(\varepsilon_{it}\varepsilon_{jt}) = 0 \; \forall i \neq j$). This assumption is necessary because the total number of firms exceeds the number of trading days.

As reported in table 12, the estimate of α_1 is significant and negative for all regressions. The estimate of α_2 is significant and negative for all regressions, except for the quintile 3 regression. From these observations, I conclude that the RRT's opening trades moderate overnight price changes and are motivated, in part, by inventory re-adjustment concerns.

Table 13: **Average RRT profits at the market opening and during regular trading hours.** Profits are reported in dollars per trading day. Opening trades include all trades that occur at the instant the security opens for regular trading (normally at 9:30AM, except when the opening is delayed).

	Size Quintile				
	5	4	3	2	1
Trades at the market opening	8.52	7.66	16.61	24.51	62.56
Trades during regular trading hours	56.83	56.16	86.66	156.17	385.94

RRT Profits: I now consider whether the RRT's opening trades are profitable and whether their profitability is influenced by the presence of competing U.S. market makers. Because it is impossible to calculate the RRT's exact trading profits from the available data, I make the following assumptions to construct a reasonable estimate. I assume that RRT begins each trading day with an accumulated position of zero in all stocks of responsibility. Let K_i denote the number of trades for security i involving the RRT during the trading day. Let n_{ki} denote the number of shares of security i sold (negative values indicate purchases) at trade number $k \in [1, K_i]$ and let P_{ki} denote the corresponding transaction price. I estimate the gross profit of the RRT from trading in security i on a particular trading day as:

$$\pi_i = \sum_{k=1}^{K_i} P_{ki} n_{ki} - P_{K_i} \sum_{k=1}^{K_i} n_{ki}. \tag{6}$$

Let $I(k)$ be an indicator function which equals 1 if transaction k occurred at the market open, 0 otherwise. I estimate the gross profit of the RRT's opening trades for security i as follows:

$$\pi_i^O = \sum_{k=1}^{K_i} P_{ki} n_{ki} I(k) - P_{K_i} \sum_{k=1}^{K_i} n_{ki} I(k). \tag{7}$$

Table 13 reports that average RRT profits at the market opening and during regular trading hours are positive and are increasing in the size of the firm under responsibility. Opening trades contribute about one-sixth of the RRT's daily trading profit. These results imply that a typical RT responsible for 10 securities (2 from each size quintile) will have gross profits of about $373,847 a year (over 252 trading days).

To investigate the factors influencing the profitability of the RRT's opening trades on a day-to-day basis, I estimate the regression model:

$$\pi_{it}^O = \left(\begin{array}{c} \alpha_0 + \alpha_1 D_{it}^{ex} + \alpha_2 \left|\Delta P_{it}\right| + \alpha_3 Instit_{it} + \alpha_4 DVol_i + \alpha_5 (D_i^{ny} \cdot DVol_i) \\ \\ +\alpha_6 (D_i^{nz} \cdot DVol_i) + \alpha_7 (D_i^{ax} \cdot DVol_i) + \alpha_8 IMR + \varepsilon_{it} \end{array} \right) \tag{8}$$

for $i = 1, \ldots, N$ and $t = 1, \ldots, T$, with the following assumptions on the error process: $E\left(\varepsilon_{it}^2\right) = \sigma_i^2$, $E\left(\varepsilon_{it}\varepsilon_{jt}\right) = \sigma_{ij}$, $\varepsilon_{it} = \rho_i \varepsilon_{i,t-1} + v_{it}$, $E(v_{it}) = 0$, $E(v_{it}v_{jt}) = \phi_{ij}$, $E(v_{it}v_{js}) = 0$ for $t \neq s$, and $E(\varepsilon_{i,t-1}v_{jt}) = 0$. The variables $Instit_i$, ΔP_{it}, D_i^{ny}, D_i^{nz}, D_i^{ax}, D_{it}^{ex}, and $DVol_i$ are defined as before and π_{it}^O indicates the estimate of total profit from the RRT's opening trades for firm i on trading day t using equation (7).

The motivation for this model is as follows. I include the dummy variables for interlisted stocks in order to establish whether the presence of competing market makers and alternative opening mechanisms impacts the RRT's ability to profitably trade. I include the dummy variable for index expiration days in order to establish if the RRT is able to profitably take advantage of opening imbalances caused by the large number of MGF orders submitted on index expiration days. I include the overnight price change variable in order to determine whether the RRT can take advantage of potential price over-reaction resulting from news released during the overnight non-trading period. The average daily dollar volume variable captures the expectation that RRT profits should be increasing in trading activity. The $Instit$ variable establishes whether or not the RRT profits depend on the level of institutional activity in the security at the open. Finally, IMR accounts for the simple fact that RRT cannot have trading profits at the open if there is no opening trade.

I employ the same estimation approach and assumptions about price changes as used in the previous regression analysis. In particular, cross-sectional correlation is allowed for regressions for individual quintiles, but cross-sectional independence is assumed for the regression using all firms. The estimation results reported in table 14 are summarized as follows:

- The magnitude of overnight price changes has a significant positive impact on RRT profits at the open across all regressions. Often, when bad (good) news is announced during the overnight non-trading period, a flood of sell (buy) orders arrives during the pre-opening session. Without RRT intermediation, this opening imbalance would cause a price over-reaction at the open. The RRT, recognizing the imbalance, can take an offsetting position which will be profitable when the price partially reverts back during the trading session. In this manner, the RRT moderates price volatility at the open.

- The average daily trading volume has a significant positive impact on RRT profits at the open for all regressions: higher trade volumes lead to higher RRT profits.

- The percentage of opening trade volume involving non-client inventory account orders is insignificant for the regression involving all firms. The quintile regression results

Table 14: **Factors affecting the profitability of RRT opening trades.** The regression model is given by (8), where cross-sectional correlation is allowed for regressions for individual quintiles, but cross-sectional independence is assumed for the regression using all firms. Standard errors are reported below the coefficient estimates in parenthesis and statistical significance at the 0.05 and 0.01 levels is indicated by * and **, respectively. Number of observations: All: 57375; Q1: 11375; Q2–Q5: 11500.

		Size Quintile				
	All Firms	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
D^{ex}	34.9	499	—	—	—	—
	(26.6)	(20.8)**				
$\|\Delta P\|$	1.82	42.4	10.3	6.60	4.38	3.72
	(0.128)**	(0.847)**	(0.223)**	(0.122)**	(0.0793)**	(0.0753)**
$Instit$	0.769	28.8	-14.3	8.20	-23.1	-8.80
	(0.909)	(2.49)**	(1.23)**	(0.952)**	(0.826)**	(0.622)**
$DVol$	15.0	21.3	21.1	86.6	84.6	92.6
	(2.10)**	(2.94)**	(2.62)**	(4.32)**	(5.69)**	(7.33)**
$(D^{ny} \cdot DVol)$	-1.12	-12.7	-38.0	-105	-56.5	—
	(2.96)	(2.44)**	(4.60)**	(10.4)**	(8.29)**	
$(D^{nz} \cdot DVol)$	17.4	53.3	-13.8	-36.3	40.8	-14.4
	(7.54)*	(5.32)**	(5.19)**	(12.7)**	(29.0)	(12.1)
$(D^{ax} \cdot DVol)$	36.1	17.8	1.40	-4.18	-289	889
	(10.6)**	(7.72)*	(16.3)	(25.5)	(48.3)**	(172)**
IMR	6.34	21.6	22.9	16.6	12.5	9.57
	(0.277)**	(1.12)**	(0.402)**	(0.256)**	(0.196)**	(0.209)**
α_0	1.73	-20.1	12.3	-0.773	-0.142	-0.361
	(0.248)**	(1.81)**	(0.745)**	(0.256)**	(0.203)	(0.245)**
R^2	0.015	0.25	0.30	0.37	0.37	0.27

suggest that institutional trade has a non-linear impact on RRT profits at the open. For firms in quintiles 1 and 3, institutional trade has a significant, positive impact on RRT profits. RRTs responsible for larger firms are able to take advantage of order imbalances resulting from larger institutional trades. For firms in quintiles 2, 4, and 5, institutional trade has a significant, negative impact on RRT profits. RRTs responsible for smaller firms appear to be negatively affected by the higher adverse selection costs associated with institutional trade.

- The dummy variable for index expiration days is significant for the quintile 1 regression, but insignificant for the regression involving all firms. The lack of significance for the regression involving all firms may be due to the less complex specification of the error term. The quintile 1 regression suggests that index expiration days have a significant, positive impact of about $500 to RRT profits from opening trades for stocks listed in the TSE 35 Composite Index.

- For a given average daily dollar trading volume, RRT profits for NYSE-interlisted stocks are significantly lower for all of the quintile regressions. The same consistent pattern does not exist for AMEX- and Nasdaq-interlisted stocks. Again, the results for AMEX-interlisted stocks should be interpreted with caution. In general, these results support the argument that the less transparent opening call auction of the NYSE contributes to higher adverse selection costs for the RRT and thereby causes the RRT to participate less actively and to have lower profits in NYSE-interlisted firms.

The coefficients for interlisted stocks in the previous regression analysis of RRT profits are highly sensitive to the regression specification. This is because, on a day-to-day basis, RRT profits in interlisted stocks could be relatively more volatile, with large positive profits some days and large negative profits other days. Because a *linear* regression model cannot properly capture this effect, I now focus on the impact of alternative opening mechanisms on *average* RRT opening profits. I estimate the OLS regression model

$$\bar{\pi}_i^O = \alpha_0 + \alpha_1 DVol_i + \alpha_2 \left(D_i^{ny} \cdot DVol_i\right) + \alpha_3 \left(D_i^{nz} \cdot DVol_i\right) + \alpha_4 \left(D_i^{ax} \cdot DVol_i\right) + \alpha_5 Volatile_i + \varepsilon_i \quad (9)$$

where D_i^{ny}, D_i^{nz}, D_i^{ax}, and $DVol_i$ are as defined previously, $\bar{\pi}_i^O$ denotes the average profit of RRT opening trades for security i, and $Volatile_i$ is proportional to the variance of returns based on daily closing prices for security i during 1997 (obtained from Datastream).

Table 15 reports the estimation results. The estimated coefficients for the historic price volatility and for the average daily dollar trading volume of Nasdaq- and AMEX-interlisted

Table 15: **Regression results: Factors influencing average RRT profits from opening trades.** Reported standard errors are based on a heteroskedasticitity-consistent covariance matrix and are reported below the coefficient estimates in parenthesis. Statistical significance at the 0.05 and 0.01 levels is indicated by * and **, respectively. Number of observations: 459.

$DVol$	$(D^{ny} \cdot DVol)$	$(D^{nz} \cdot DVol)$	$(D^{ax} \cdot DVol)$	$Volatile$	α_0	R^2
48.5	-28.1	71.6	0.688	-3.37	11.5	0.33
$(8.24)^{**}$	$(9.36)^{**}$	(77.6)	(20.8)	(147)	$(3.77)^{**}$	

stocks are statistically insignificant from zero. As expected, RRT profits are increasing in average daily dollar trading volume. Also, RRT profits are significantly lower for a NYSE-interlisted stock compared with a non-interlisted stock with the same average daily dollar trading volume. This is consistent with my previous results and with the hypothesis that the less transparent NYSE opening call auction reduces the RRT's ability to trade profitably at the market opening. Specifically, informed trade tends to be submitted to the less transparent exchange, thereby reducing the RRT's informational advantage, and hence the RRT's ability to exploit profitably this information. As well, over time, the more efficient NYSE opening price attracts order flow to the NYSE, reducing the probability of a TSE-based opening trade for NYSE-interlisted stocks, and thereby reducing the RRT's potential to capture profits in these stocks.

Sensitivity analysis: I perform a number of additional regressions to determine how sensitive these results are to the model specification. First, I explore various specifications of the interlisted firm dummy variables. A large number of interlisted firms only actively trade on one exchange. To focus on stocks with liquid markets both in the U.S. and Canada, the regression analysis was repeated using dummy variables for interlisted firms with between 33% and 66% of their total order flow on a U.S. exchange. These estimation results were consistent with the results presented here. I also consider models that substitute the $Instit$ variable with a variable that is defined as the percentage of RRT trades for which the counterparty to the trade involved a non-client inventory account order. Similar results were obtained.

Price efficiency gain from RRT trade: The combination of two observations suggest that RRT participation improves the efficiency of the opening price: (i) the RRT's opening trades tend to be profitable; (ii) the RRT trades against the direction of overnight price changes. Since RRT trades generally tend to be small, I would like to establish whether or not RRT opening trades have an economically meaningful effect on price efficiency. To quantify this effect, it is necessary to estimate the impact of RRT trades on the opening price. This is a

Table 16: **Price efficiency gain from RRT opening trade.** A price efficiency gain (loss) from RRT trade is indicated by a variance ratio (VR) less (greater) than one. The number of firms that have variance ratios statistically different from one at the 0.05 confidence level is indicated in parenthesis.

	Efficiency Gain ($VR < 1$)		Efficiency Loss ($VR > 1$)	
Size Quintile	No. of Firms	No. Signif.	No. of Firms	No. Signif.
1	86	(0)	5	(0)
2	89	(5)	3	(0)
3	90	(6)	2	(0)
4	89	(13)	3	(0)
5	89	(19)	3	(1)

difficult problem. Even if I had complete order flow data, it would be impossible to determine how market participants would have traded in the absence of RRT trade.

To estimate the potential efficiency gain from RRT participation, I perform the following "back-of-the-hand" calculation. I assume that the larger the percentage of opening trade involving the RRT, the larger the price impact of RRT trades. Specifically, I suppose that when net RRT opening trades account for less than 25% of opening trade volume, the RRT has no impact on the opening price; when net RRT opening trades account for between 25%-50% of opening trade volume, the RRT has an impact on the opening price equal to two tick-sizes ($0.10) in the net direction of his/her trades; and when net RRT opening trades account for between 50%-100% of opening trade volume, the RRT has an impact on the opening price equal to four tick-sizes ($0.20) in the net direction of his/her trades. Then, for each firm, I calculate the following variance ratio (VR) across all trading days:

$$VR = \frac{\text{var}\left[\ln\left(P^f\right) - \ln\left(P_0\right)\right]}{\text{var}\left[\ln\left(P^f\right) - \ln\left(P^*\right)\right]}$$

where P^f is the 11:00AM price based on the midpoint of the posted bid and ask prices; P_0 is the observed opening price; and P^* is the estimated opening price in the absence of RRT trade. The results are reported in table 16. The basic pattern is robust to using different times of day to calculate P^f and to using more or less conservative estimates of the impact of RRT trades. Although almost all firms exhibit a price efficiency gain from RRT trade, the gain is statistically significant for only 43 of 459 firms. As expected, more smaller firms have statistically significant price efficiency gains from RRT trade than larger firms. From these results, I conclude that the RRT's contribution to opening price efficiency is positive, but economically and statistically "small". RRT participation is more important for improving the

opening price efficiency of smaller firms. It is important to note that these estimates are meant only to be illustrative and will tend to understate the potentially important role of the RRT during extremely volatile market conditions.

6 Conclusion

Prior to this study, the role of a market maker, such as the RRT, in the opening price discovery process of a highly transparent financial market was not well understood. The detailed transactions database for the TSE provides an ideal opportunity to examine this environment.

Unlike the NYSE specialist, the RRT cannot set the opening price directly and does not have exclusive knowledge of the limit order book. Despite this, I demonstrate that the RRT actively participates in the TSE's pre-opening session. I show that the RRT's opening trades are profitable, tend to moderate overnight price changes and may be motivated in part, by a desire to rebalance his/her inventory.

I investigate RRT trade in interlisted stocks that simultaneously open on different exchanges using different opening mechanisms. I argue that the less transparent NYSE opening call auction contributes to higher adverse selection costs for RRTs assigned to NYSE-interlisted stocks. As a result, these RRTs participate less actively and have lower profits at the market opening. In contrast, the more transparent Nasdaq pre-trade period does not create the same adverse selection costs for RRTs assigned to Nasdaq-interlisted stocks.

I also highlight some of the shortcomings of the TSE's pre-opening session that may contribute to the observed relatively low levels of liquidity at the TSE market opening in comparison with levels on the NYSE and Nasdaq. In particular, poor incentives for early order submission cause quote revisions to be concentrated in the final minutes of the session. This creates disadvantages to market participants with limited access to trading facilities. It also results in pre-opening quotes with little financial backing that can be easily manipulated.

These problems have prompted new initiatives by the TSE to examine whether the efficiency of its opening mechanism can be improved. In particular, the TSE has entered into an agreement with OptiMark Technologies, Inc. to replace the pre-opening session with a new electronic opening call auction. I provide valuable insights into which features of the existing pre-opening session can be improved. More generally, this paper contributes to the new, and expanding, literature on what characteristics of pre-opening sessions and opening protocols efficiently facilitate price discovery after the overnight non-trading period.

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