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Trading and Liquidity on the Tokyo Stock Exchange: A Bird's Eye View

BRUCE N. LEHMANN and DAVID M. MODEST*

ABSTRACT

The trading mechanism for equities on the Tokyo Stock Exchange (TSE) stands in sharp contrast to the primary mechanisms used to trade stocks in the United States. In the United States, exchange-designated specialists have affirmative obligations to provide continuous liquidity to the market. Specialists offer simultaneous and tight quotes to both buy and sell and supply sufficient liquidity to limit the magnitude of price changes between consecutive transactions. In contradistinction, the TSE has no exchange-designated liquidity suppliers. Instead, liquidity is provided through a public limit order book, and liquidity is organized through restrictions on maximum price changes between trades that serve to slow down trading. In this article, we examine the efficacy of the TSE's trading mechanisms at providing liquidity. Our analysis is based on a complete record of transactions and best-bid and best-offer quotes for most stocks in the First Section of the TSE over a period of 26 months. We study the size of the bid-ask spread and its cross-sectional and intertemporal stability; intertemporal patterns in returns, volatility, volume, trade size, and the frequency of trades; and market depth based on the response of quotes to trades and the frequency of trading halts and warning quotes.

THE TRADING MECHANISM FOR equities on the Tokyo Stock Exchange (TSE) stands in sharp contrast to the primary mechanisms used to trade stocks in the United States. In the United States, exchange-designated specialists have affirmative obligations to provide continuous liquidity in the market and to maintain a (private) limit order book with the public's limit orders. On the TSE, exchange-designated intermediaries (*saitori*) log limit orders and match them to incoming market orders but provide no market-making services. In the United States, specialists offer simultaneous and tight quotes to both buy and sell. On the TSE, public limit orders constitute the available bids and offers. In the United States, specialists supply sufficient liquidity to limit the magnitude of price changes between consecutive transactions.¹ On the TSE, the market mechanism places limits on the magnitude of consecutive price

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¹With rare exceptions such as October 19 and 20, 1987.

changes, and liquidity is organized through temporary trading halts that advertise the need for additional liquidity and smooth quote adjustments between transactions. In the United States, there are specialized trading venues for large and small orders, retail and institutional customers, and other reflections of spatial fragmentation. In Tokyo, trading in listed equities is largely consolidated on the TSE, and the only other venues—the regional exchanges—are organized in exactly the same manner.²

In this article, we examine indicators of the quality of liquidity on the TSE. Our analysis is based on a complete record of transactions and *best-bid* and *best-offer* quotes for most stocks in the First Section of the TSE over a period of 26 months. We examine several indicators of market liquidity: the size of the bid-ask spread and its cross-sectional and intertemporal stability; intertemporal patterns in returns, volatility, volume, trade size, and the frequency of trades; and market depth based on the response of quotes to trades and the frequency of trading halts and indicative quote revisions.

The article is organized as follows. Section I presents a description of the institutional structure of trading on the TSE. In particular, we describe the role of the *saitori* in overseeing the trade process and the TSE's mechanisms for slowing down trade in the presence of order imbalances. Section II describes our data. In Section III, we present graphical and regression analyses of observable liquidity measures such as bid-ask spreads, intraday volatility, trading flow, and market depth. Finally, we summarize the results and draw some conclusions in Section IV.

I. Trading on the TSE: The Institutional Structure

The mechanism for trading equities on the TSE differs substantially from the mechanism for trading listed stocks in the United States. Trading on the New York Stock Exchange (NYSE) and the American Stock Exchange (AMEX) is managed by exchange-designated specialists. The specialists collect public limit orders (which are maintained in a *private* limit order book that cannot be readily viewed by the public³), match incoming buy and sell orders, and purchase and sell securities for their own account. They have an exchange-mandated obligation to maintain fair and orderly markets. In practice, this obligation is manifested through the maintenance of relatively narrow bid-ask quotes and the prevention of major price discontinuities that might result from the temporal fragmentation of investor buying and selling.⁴ Put some-

²The regional exchanges are Fukuoka, Hiroshima, Kyoto, Nagoya, Niigata, Osaka, and Sapporo.

³The book is often visible to the crowd in front of the specialist booth. However, there is no widespread public dissemination of the limit order book. In addition, floor brokers can leave orders with specialists with a request to fill them on a "best efforts" basis.

⁴For instance, New York Stock Exchange Floor Officials must approve all transactions that would be executed at a price of \$1 or more from the last transaction price for shares selling at less than \$20 and \$2 or more from the last transaction price for shares selling at \$20 or more. For an excellent and comprehensive discussion of NYSE trading procedures, see Hasbrouck, Sofianos, and Sosebee (1993).

what differently, the specialist on the NYSE and AMEX is the *liquidity-provider of last resort*. The specialists' reward for performing this function is their exclusive and near-monopolistic access to the limit order book, resulting in an informational advantage about net order flow.⁵ Specialists can exploit this advantage and apply their capital to benefit from temporary order imbalances subject to standard time and price priorities for public orders.⁶

The specialist system of the NYSE and AMEX—specifically the near-private access to the limit order book—potentially inhibits the provision of liquidity to the equity market by other participants who are at a handicap with regard to information about temporary order imbalances.⁷ In part as a response to this institutional structure, the last decade has witnessed rapid growth in off-exchange trading that is specifically organized to generate liquidity by advertising order flow. Examples include “fourth market” trading mechanisms such as Posit, the Arizona Stock Exchange, and two Reuter's trading venues: Instinet and the Crossing Network. Some of these mechanisms merely match buyers and sellers directly using exchange-generated prices or bid-ask quotes. These trading vehicles take advantage of the public good provided by the price discovery process on the exchange and provide lower transaction costs for their participants by eliminating intermediaries. Other fourth market trading mechanisms allow potential participants to view real-time limit order books—displaying the desired prices and quantities at which participants would like to trade—and have the potential to provide lower transaction costs for their customers by organizing liquidity.

Trading on the TSE is organized very differently from exchange trading in the United States and, in some aspects, is more similar to “fourth market” trading in the United States. There is no *liquidity-provider of last resort* in Tokyo. Instead, liquidity on the TSE is provided by the combination of a limit order book that is visible to TSE members and a mechanism for slowing down the trade process in the presence of order imbalances.⁸ The closest counterpart to the specialist on the TSE is the *saitori*. The *saitori*'s responsibilities, however, are limited to serving as repositories for public market information (i.e., limit orders) and to governing the trade process. In sharp contrast to

⁵Angel (1989) documents firm-specific factors influencing average bid-ask spreads (i.e., the significance of dummy variables for individual specialist firms) after accounting for differences in volume, volatility, and other liquidity descriptors. His results present some evidence that the efficiency of the market may, in part, depend on who has the monopoly franchise.

⁶According to the New York Stock Exchange (1993), specialists participated in 19.6 percent of the NYSE share volume in 1992. The American Stock Exchange (1993) reports that AMEX specialists participated in 10.9 percent of the AMEX share volume in 1992.

⁷The NYSE does not, in general, advertise order imbalances. However, it began a pilot program in April 1992 whereby the exchange announces order imbalances for *market on close* orders for a subset of NYSE stocks at 3:45 P.M. on the third Friday of every month. This program is a response to the large increase in *market on close* orders on these days, which is related to the expiration of index-related derivatives.

⁸Other useful English references on the institutional structure of the TSE include Amihud and Mendelson (1989), Tokyo Stock Exchange (1989), Lindsey and Schaede (1992), Hamao and Hasbrouck (1993) and Lehmann and Modest (1994).

specialists, they do not trade for their own account.⁹ They maintain the public limit order book,¹⁰ match market and limit orders, issue warning quotes when trade execution results in price changes that are larger than exchange-prescribed minimums, and halt trading when order execution would result in price changes that exceed exchange-mandated maximums.¹¹ The closest counterpart to the *saitori* in the United States is the order book official at the Chicago Board Options Exchange.

Stocks on the TSE are divided into two categories: First Section and Second Section stocks. The First Section consists of the 1,232 most actively traded firms; the remaining 429 firms trade on the Second Section. The 151 most heavily traded First Section stocks are traded on the trading floor.¹² The remaining First Section and all of the Second Section equities are traded electronically on the Computer-assisted Order Routing and Execution System (CORES).¹³ All orders for system-traded stocks are submitted electronically as are all orders for 3,000 shares or less of floor-traded stocks. Orders for more than 3,000 shares of floor-traded stocks must be brought to the exchange floor manually.

TSE trading takes place in two different trading sessions. The morning session begins at 9:00 A.M. and ends at 11:00 A.M., while the afternoon session begins at 12:30 P.M. and ends at 3:00 P.M. In our sample, the volume of trade was split almost evenly between the two sessions. Trade at the beginning of each session is initiated through a single-price auction called the *itayose*. However, stocks do not always open at the beginning of each trading session since five conditions must be met for trade to begin:¹⁴ (i) all market orders must be executed; (ii) all limit orders to sell at prices lower than the opening (*itayose*) price must be executed; (iii) all limit orders to buy at prices higher than the opening price must be executed; (iv) either *all* limit orders to buy or

⁹They are allowed to trade to correct trading mistakes and fulfill obligations to TSE members.

¹⁰Limit orders are valid for one day and then must be reentered. They can be placed beginning 25 minutes prior to the opening of each trading session. All limit orders received prior to the start of trading have equal time priority. Price, time, and size priority hold in this order for limit orders placed during the trading sessions.

¹¹The process that is used to slow down the trading process, the issuance of *chui and tokubetsu kehai* (warning and special quotes), is described more fully below.

¹²Newly listed First Section stocks are traded on the floor of the exchange for two days to meet the anticipated large and initial trading volume. After two days, they commence trading as system-traded stocks.

¹³The openness of the limit order book, the combination of floor and computerized trading, and the use of trading halts to slow down the trade process in less actively traded stocks make the TSE similar in several important dimensions to the Toronto Stock Exchange. The Toronto Stock Exchange, however, has a designated market maker with certain informational advantages similar to those accruing to specialists on the NYSE and AMEX. Many European exchanges have developed continuous electronic auction systems based on the Computer Assisted Trading System (CATS) system of Toronto. These include the exchanges in Paris, Madrid, Stockholm, and Milan.

¹⁴Tokyo Stock Exchange (1989) provides a more complete description of the opening conditions. Amihud and Mendelson (1989), Lindsey and Schaefer (1992), and Hamao and Hasbrouck (1993) provide examples of price setting at the *itayose*.

all limit orders to sell at the *itayose* price must be executed; and (v) at least one round lot of each limit order on the other side of the market must be executed at the opening price.¹⁵

Table I presents a breakdown by size decile of the average percentage trading volume that occurs under the *itayose* mechanism. Size-decile 1 contains the 10 percent of the firms with the lowest market capitalization of equity and size-decile 10 contains the 10 percent of the firms with the largest capitalization.¹⁶ On average, 26.10 percent of daily yen trading volume occurs at the open for stocks in the largest size decile (16.34 percent at the A.M. open and 8.78 percent at the P.M. open) and 32.67 percent of the daily yen trading volume for the smallest stocks (19.99 percent at the A.M. open and 14.58 percent at the P.M. open).¹⁷

The TSE also permits market-on-close orders to be executed in a single-price auction.¹⁸ As is evident from Table I, very little trade occurs using market-on-close orders. For stocks in all size groups, they account for less than 2.5 percent of average daily trading volume. Market-on-close orders are thus a much less important part of the trading process in Japan than in the United States. This difference partially reflects the stringency of simultaneously

Table I
Fraction of Trading Volume at Single Price Auctions (Itayose)

Stocks are assigned to size deciles based on the market value of their equity. Size decile 1 contains the 10 percent of the stocks with the smallest market capitalization, and size decile 10 contains the largest 10 percent of the firms. Table values are the cross-sectional averages of yen trading volume, as a percent of total trading volume, for stocks in each size decile.

	Size Decile									
	1	2	3	4	5	6	7	8	9	10
Market On Open										
A.M.	19.18	18.63	17.05	16.85	15.47	16.22	16.28	15.86	14.39	17.63
P.M.	13.49	11.90	10.45	9.07	9.45	9.04	8.92	8.52	7.54	8.47
Sub-total	32.67	30.53	27.50	25.92	24.92	25.26	25.20	24.38	21.93	26.10
Market On Close										
A.M.	0.23	0.30	0.38	0.38	0.39	0.44	0.43	0.48	0.42	0.44
P.M.	1.34	1.10	1.07	1.28	1.23	1.27	1.53	1.50	1.50	1.84
Sub-total	1.57	1.40	1.45	1.66	1.62	1.71	1.96	1.98	1.92	2.28
Total	34.24	31.93	28.95	27.58	26.54	26.97	27.16	26.36	23.85	28.38

¹⁵The last two conditions reflect, in part, the equal time priority given to all limit orders submitted prior to the opening of a trading session.

¹⁶Stocks are sorted into ten size portfolios based on the market value of their equity as of December 31, 1990, the day prior to the beginning of our sample. Stocks are not reclassified during the 26 months of our sample.

¹⁷Stoll and Whaley (1990) estimate that 10.59 percent of the U.S. trading volume occurs at the open.

¹⁸For the market to clear at the close, the first four (of the five) conditions listed above to open the market must be met. The fifth condition—that each member on the other side of the market must receive at least one round lot—need not be met.

meeting most of the opening *itayose* requirements as well as the maximum price variation limit on the difference between the last *zaraba* trade price and any prospective closing *itayose* price.¹⁹

The single-price auction at the beginning of each trading session is followed by the continuous market called the *zaraba*. Most of the trading volume on the TSE occurs under the *zaraba* mechanism, accounting for 65 to 70 percent of total trading volume for all firms regardless of their size decile. Virtually all trades occurring under the *zaraba* mechanism are the result of market orders hitting limit orders or limit orders crossing. Market orders almost never cross in Japan,²⁰ and consequently there are virtually no trades between the bid and ask prices.²¹

Following the opening *itayose*, the highest limit order to buy becomes the *best-bid* price and the lowest limit order to sell becomes the *best-ask* price. Suppose a market order to buy arrives at the exchange. If the *best-ask* price is a “regular” quote and if the order can be entirely filled at that quote (i.e., the depth at the quote is sufficient), the *saitori* will match the market order to the best limit order and execute the trade. The quote is considered regular if the price change from the last trade satisfies prescribed conditions set by the TSE. If the price change exceeds exchange-mandated maximums, the *saitori* temporarily halts trade. Thus, a market order in Japan may not be executed immediately.

Except for large orders, market orders arriving at an exchange in the United States are filled instantly at the best available price.²² The specialist is responsible for insuring that the price is “not too far” from the previous execution price and that the bid-ask spread is reasonable. The specialist can

¹⁹The more extensive use of *market on close* orders in the United States may also reflect the greater popularity of indexing in the United States and the plethora of index-related derivatives.

²⁰Crossing trades can occur only if the same member firm represents both sides of the trade. This typically only occurs when the same corporate entity “accidentally” acts as both buyer and seller. Since a majority of crossing trades occur at the end of the fiscal year, it appears that the crossing procedure is used to change the book value of an equity position on its balance sheet. Lindsey and Schaede (1992) also discuss private crossings, called *onna-hen no baikai*, in which transactions are matched by customers themselves and certified by an exchange member. Recent regulations strictly limit the difference between the price in *baikai* or crossing trades (even crossing trades consummated on a regional exchange) and the prior transaction on the TSE.

²¹This contrasts sharply with trading patterns on the NYSE. Shapiro (1993) reports that 20 to 30 percent of all trades on the NYSE occur between the best bid and offer. For stocks with spreads that exceed an eighth, he notes that approximately 60 percent of the trades occur between the best bid and offer.

²²A specialist can ask a NYSE Floor Official for permission to delay the opening of trading or to halt trading in the event of large order imbalances, pending news, or a substantial news announcement. NYSE trading halts, however, occur much less frequently than trading halts on the TSE. Bhattacharya and Spiegel (1993) examine all trading suspensions on the NYSE between January 1, 1974 and December 31, 1988 and identified 15,188 trading suspensions, which averages out four suspensions per day (total number of suspensions across all stocks). In our sample, there are approximately 300 trading halts a day across all system-traded stocks in the TSE First Section.

fill the order at the *best-bid* or *best-offer* on the limit order book;²³ the specialist can improve on the *best-bid* or *best-offer* and take the trade for his own account; or the specialist can stop the order, guaranteeing an execution price that is at least as good as the current *best-bid* or *best-offer*. In any event, the market participant is always guaranteed immediacy.

On the TSE, immediacy is sometimes sacrificed by a trading process designed to slow down trade in the face of potential order imbalances and to attract liquidity by advertising these imbalances to exchange members. The TSE uses the price limits shown in Table II to trigger indicative quote dissemination, to halt trade temporarily, and to allow continued price discovery through quote adjustment in some circumstances. While the limits are given in absolute yen, Table II also presents the numbers as a percent of the price-range midpoint. For a stock trading at ¥1,250, the minimum tick size is ¥10, the maximum price variation between trades without trade being halted is ¥20, and the daily price limit is ¥200.²⁴ At ¥1,250, this stock is trading at the midpoint of the ¥1,001 to ¥1,500 price range and the corresponding numbers, as a percent of the mid-point price, are 0.80 percent for the tick size,²⁵ 1.60 percent for the maximum price variation, and 16.00 percent for the daily price limit. The daily price limits for all stocks are quite large in percentage terms and, consequently, these limits are rarely hit. In contrast, the maximum price variation allowed between trades is on the order of 1.5

Table II
Minimum Tick Size and Limits on Prices Changes by
Stock Price

Percentage values in tables are as a fraction of the midpoint of the stock price range. Maximum price variation is the maximum price change that may occur between consecutive trades.

Price Range (in Yen)	Tick Size		Maximum Price Variation		Daily Price Limit	
	Yen	%	Yen	%	Yen	%
0 < 100	1	2.00	5	10.00	30	60.00
101-200	1	0.67	5	3.33	50	33.33
201-500	1	0.29	5	1.43	80	22.86
501-1000	1	0.13	10	1.33	100	13.33
1001-1500	10	0.80	20	1.60	200	16.00
1501-2000	10	0.57	30	1.71	300	17.14
2001-3000	10	0.40	40	1.60	400	16.00
3001-5000	10	0.25	50	1.25	500	12.50
5001-10000	10	0.13	100	1.33	1000	13.33
10001-30000	100	0.50	200	1.00	2000	10.00

²³An NYSE specialist may fill the order from the limit orders logged on the floor of the NYSE or route the trade to a better quote in another market through the Intermarket Trading System.

²⁴The daily price limit is based on the closing price of the previous day.

²⁵By contrast, the minimum tick size for a typical stock on the NYSE is on the order of 0.31 percent ($1/8$ divided by 40).

percent for most price ranges, and, thus, this barrier is hit much more frequently.²⁶

We now discuss in some detail the procedures used to slow down trade and attract liquidity: the *chui* and *tokubetsu kehai* mechanism (a more complete discussion is contained in Lehmann and Modest (1994)). Figure 1 describes these procedures by tracing the possible consequences of the arrival of a market order. In contrast with U.S. markets, a market order will only be executed immediately on the TSE if it satisfies certain exchange-prescribed "price" conditions. The main events in the figure are numbered as follows:

1. A market order is completely filled at the prevailing quote, and a regular trade occurs.
2. A market order walks up or down the limit order book (i.e., portions of the trade are executed at different prices), and the *saitori* issues warning quotes (*chui kehai*) as each new price is hit but no trading halt occurs.
3. The *saitori* only permits partial execution of a market order since the price change required to fill the entire order would exceed the maximum allowable price variation. In this situation, the *saitori* issues a warning quote (*chui kehai*) at the maximum price variation limit and halts trade.
4. The *saitori* prevents a market order from being fully executed, since the required price change would exceed the maximum price variation, and during the halt another market order arrives on the same side of the market from a different member firm. In this case, the *saitori* issues a special quote (*tokubetsu kehai*), continues the trading halt, and gradually revises the special quote in the absence of additional orders. This ultimately enables the trade to be fully executed, presuming the resulting price change would not exceed the daily price limit.²⁷

Figure 1 indicates that four possible events can occur following the arrival of a market order. Three of the four possible outcomes happen relatively infrequently. No part of the market order can be filled if no quote is available or if the difference between the quote and the base price (the previous trade price) exceeds either the maximum price variation or the daily price limits given in Table II. In these circumstances, the *saitori* issues a warning quote (*chui kehai*) and trade is halted.²⁸

²⁶As discussed in detail in Lehmann and Modest (1994), there were 722,217 warning and special quote events in our sample. This amounts to slightly less than 1.25 times per day per stock. Of these events, 19.7 percent resulted in trading halts because the maximum price variation was reached.

²⁷When a second order arrives on the same side of the market, the mechanism presumes that there may indeed be a new equilibrium price and the market is allowed to move to this new price in an orderly fashion. An order imbalance caused by a *single* order, as indicated by reaching the maximum price variation, is presumed to be temporary. *Tokubetsu kehai* events are discussed more fully below.

²⁸Since a market order cannot be executed when no quote is available, trade is effectively halted from the perspective of the trade initiator who placed the market order.

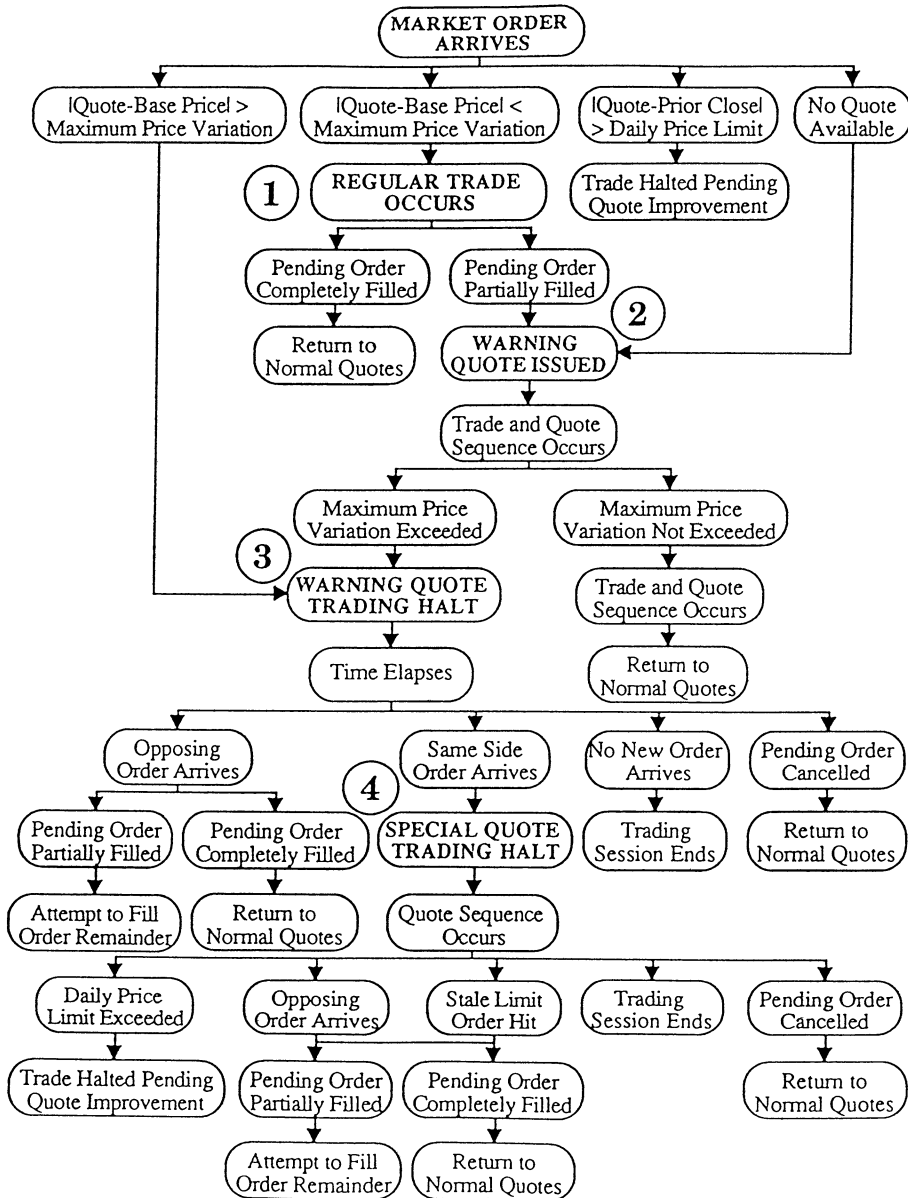


Figure 1. Possible events following the arrival of market order.

The more common occurrence is that the market order can be at least partially filled at a price such that the difference between the quote and the base price is less than the maximum price variation. The *saitori* fills the entire order if the depth at the prevailing quote is sufficient. If the market order can be executed at several different prices (i.e., if the order is suffi-

ciently large that continued execution requires walking up or down the limit order book) within the maximum price variation limit, warning quotes are usually issued as each new price is hit. If the order is so large that continued execution would be at prices that exceed the maximum allowable price variation, the order will be partially filled and the *saitori* will issue a final warning quote at the maximum price variation and halt trade, leaving the remainder of the order pending. This portion of the trade is effectively stopped pending the arrival of an opposing order (which enables execution within the allowable price range), the end of the trading session, the cancellation of the pending order, or the arrival of an order from another member firm on the same side of the market as the pending order.

This last possibility invokes one of the most interesting aspects of the TSE mechanism—the special quote (*tokubetsu kehai*) procedure for price discovery. If filling a single market order would require execution at a price that exceeds the maximum allowable price variation, the mechanism presumes that this order represents a transient order imbalance, and trade is halted until better quotes arrive in the market. However, the arrival of a second order on the same side of the market from another exchange member is taken to indicate a possible change in the equilibrium price, and the price discovery process is allowed to continue without waiting for opposing orders to arrive. In this situation, the *saitori* will issue a *tokubetsu kehai* (special quote), typically revising it every five minutes as it moves toward the current best quote. The *saitori* effectively advertises this change in the equilibrium price to the market through this slow revision of the special quote. When the special quote reaches the current best quote, the pending orders will be filled at the *best-bid* or *best-offer*.

In our sample, there were 876,799 events that resulted in warning or special quotes or were multiple-price-change events that appear to satisfy the conditions required for nonhalt warning quotes to be issued. Of these events, 0.33 percent were *tokubetsu kehai*, 66.14 percent were nonhalt *chui kehai* events, 15.89 percent were *chui kehai* events that resulted in trading halts, and 17.63 percent were multiple-price-change events where the *saitori* chose not to issue *chui kehai*. These numbers suggest that *chui kehai* trading halts are quite rare, occurring less than once every four days per stock. *Tokubetsu kehai* events are even more rare, occurring less than once every two months per stock. Thus, market participants clearly avoid exposing their orders to the *tokubetsu kehai* price discovery process.

II. Data

Our data consist of all completed transactions and available quotes for all TSE stocks during a 26-month period: January 1, 1991 through November 30, 1991 and February 1, 1992 through April 30, 1993.²⁹ The data were collected by the TSE, cleansed and checked by *Nihon Keizai Shimbun*, and provided to

²⁹The data for December 1991 and January 1992 are not available.

us by Nikko Securities. They include all transactions on the TSE and all quotes for system-traded stocks on the TSE. Various filters were run on the data in an attempt to eliminate data errors. For this study, we limit our attention to First Section stocks on the TSE, since Second Section stocks are much less actively traded and are likely to have very different trading and liquidity characteristics.

Our data on system-traded stocks are those that are widely available to market participants through brokers/dealers in broadcast form. Each record has six fields: a time stamp, bid price, bid code, ask price, ask code, and trading volume. Our data is time stamped to the nearest minute. The raw data is time stamped to the nearest second on the TSE's trading system, but the broadcast data have a coarser time stamp.³⁰ For completed transactions, the reported bid price is the same as the ask price, the bid and ask codes are recorded as 00,³¹ and trade volume is given in the fifth field.³² If both the bid and ask quotes are regular, a quote code of 80 appears in the third and fifth columns, and trading volume is recorded as zero. Unlike historical quote data on *best bids and offers* in the United States, indications of market depth are neither recorded nor widely disseminated in Japan. A quote code of 81 indicates either a nonhalt *chui kehai* or a *chui kehai* with a trading halt. The type of *chui kehai* event can be inferred from the transaction record.

Table III provides an example of a *chui kehai* (warning quote) sequence. At 9:48 A.M., the *best bid and offer* are regular quotes at ¥1,000 and ¥1,010,

Table III
Example of *Chui Kehai* (Warning Quote) Sequence

Bid and ask quote codes of 80 indicate regular quotes, and a quote code of 00 denotes a trade. The bid quote code of 81 at time 0952, indicating a warning quote, alerts the market that a buy order cannot be executed at the best-ask price of 1040, since it would violate exchange rules. This can be inferred from the trade sequence, because the maximum price variation between trades is 20 yen in this price range, and the previous trade occurred at 1010 yen.

Time Stamp	Bid		Ask		Share Volume
	Price	Code	Price	Code	
0948	1000	80	1010	80	0
0949	1010	00	1010	00	5,000
0949	1000	80	1040	80	0
0952	1000	81	1040	80	0
0952	1010	81	1040	80	0
0952	1020	81	1040	80	0
0952	1030	81	1040	80	0

³⁰This makes it difficult to detect any violations of time priority.

³¹A 00 code, along with a 0 in the volume field, is also used to indicate the absence of bid or ask quotes or quotes that are far from the market.

³²Trade volume is based on the size of the order that triggered the trade, usually the market order. If a market order for 5,000 shares is satisfied by limit orders of 2,000 and 3,000 shares, a 5,000-share transaction volume is reported.

respectively. The broadcast record provides no information on the depth of these quotes. A transaction for 5,000 shares is executed at 9:49 A.M. at the ask price of ¥1,010. In all likelihood, this transaction reflects a market order hitting the offer. The 5,000-share trade clears out the entire offer at ¥1,010, and the new best offer is a regular quote of ¥1,040. The depth of the ask quote was at most 5,000 shares, since the market order to buy 5,000 shares cleared out all offers to sell at ¥1,010. We can also infer that the order was not for more than 5,000 shares since the ¥1,040 quote appears as a regular quote.³³

Now suppose a market order to buy shares arrives at 9:52 A.M. The trade cannot be executed at the best offer price of ¥1,040 since the resulting price change would exceed the maximum price variation. This imbalance on the *ask* side of the market, which was generated by a market order to buy, is indicated by a *bid* quote code of 81. The *saitori* proceeds to move the quote up by the minimum tick size, issuing *chui kehai* at ¥1,020 and ¥1,030 if (opposing) trades do not arrive that satisfy the market order at the warning quotes. Since the quote at ¥1,030 is at the maximum price variation limit, this quote represents a *chui kehai* trading halt since the market is stopped and the pending order cannot be executed under the TSE rules. In this manner, one can infer from the 81 quote code and from the path of quotes in combination with the known maximum price variation that a *chui kehai* trading halt occurred. If another market order to buy arrived from a different broker, the quote code would change to 20, the designation of a *tokubetsu kehai*, and the *saitori* would execute the pending order at ¥1,040 after a 5-minute pause if no order hit the special quote. Other potential transaction and quote codes are 02 for the cancellation of a quote and 04 for an *itayose* price at the close.

III. Trading and Liquidity on the TSE: Empirical Evidence

In this section, we use the data to examine trading and liquidity characteristics of equities on the TSE. Due to the difficulty in effectively analyzing and presenting the data on an individual firm and record-by-record basis, our analysis is based on cross-sectional averages within size-decile groups and time-series averages within nine half-hour trading intervals during the *zaraba* and for the four *itayose*. For a subset of the variables analyzed, we also examine an eleventh group of equities, consisting of the floor-traded stocks.³⁴

³³ If the market order was for more than 5,000 shares, the trading process would behave as if a market buy order arrived after the offers at ¥1,010 were exhausted. As discussed in the text, the *saitori* would issue a warning quote and trade would be halted since the execution of additional shares at ¥1,040 would exceed the allowable maximum price variation.

³⁴ The size decile groups only include system-traded stocks. Stocks included in the floor-traded category are not included in any of the size groups.

A. Overview

Two types of evidence regarding trading patterns and liquidity are presented in this section. Three-dimensional graphs contain the first type of evidence. They plot the mean of the trade or liquidity characteristic on the Z-axis and the size-decile (or price) category and the time period on the X- and Y-axes. The graphs, which rely on quote information, contain data only for the nine half-hour time intervals that occur during the *zaraba*. The other graphs also include information from the four *itayose*.

We also present the results from dummy variable regressions of the general form:

$$y_{pt}^k = \alpha + \sum_{l=1}^{10} \beta_l dmkt_{lt} + \sum_{j=1}^9 \gamma_j dtime_{jt} \\ + \delta dflr_t + (1 - \delta) dsys_t + \sum_{m=1}^5 \theta_m dwk_{mt} + \varepsilon_{pt}$$

where y_{pt}^k denotes the cross-sectional mean of characteristic k for stocks belonging to group p ³⁵ during time interval t , ε_{pt} denotes the regression residual, and the greek symbols are coefficients to be estimated. The dummy variables are denoted by $dmkt$, $dtime$, $dflr$, $dsys$, and dwk . They equal 1 if the observation of the dependent variable belongs to the relevant category, and 0 otherwise. To avoid linear dependency among the explanatory variables, we impose the constraint that all within-group dummy variable coefficients—that is, those on the size ($dmkt$), time-of-day ($dtime$), and day-of-the-week (dwk) dummies, respectively—sum to zero.³⁶ As the equation indicates, we also impose the restriction that the coefficients on the floor ($dflr$) plus system ($dsys$) dummies sum to zero. We estimate the parameters by stacking all of the observations and using an ordinary least squares procedure. We report t -statistics based on Hansen-White heteroskedastic-consistent standard errors that account for contemporaneous correlation among the residuals.

B. Liquidity and Bid-Ask Spreads

Proponents of the specialist system often argue that immediacy of execution is a critical prerequisite for a well-functioning capital market and that a designated market maker is necessary for maintaining sufficient liquidity over the entire trading day to guarantee continuous immediacy of execution at a reasonable cost. One of the most frequently examined measures of liquidity of a stock is its quoted bid-ask spread,³⁷ since the difference between

³⁵ Either one of the ten size-decile groups or the category containing the floor-traded stocks.

³⁶ We are grateful to Richard Lindsey for suggesting this approach.

³⁷ Actually, there is not a single bid-ask spread, but a schedule of spreads that depend on the size of the trade and the immediacy required. In this article, we follow the tradition of the literature and examine the quoted spread for immediate execution of small-medium orders.

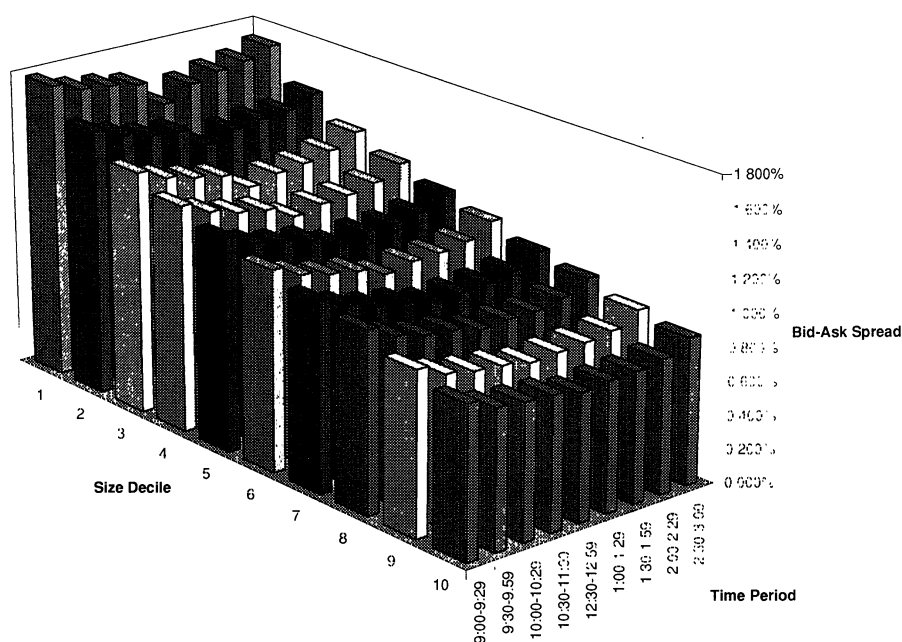


Figure 2. Bid-ask spreads for Japanese equities sorted by size deciles.

the quotes represents the round-trip cost of immediately reversing a trade position.³⁸ There is no *liquidity provider of last resort* on the TSE whose designated role is to maintain relatively narrow bid-ask spreads. Hence, it is of particular interest to examine the cross-sectional and time-series variation in bid-ask spreads in Japan and compare their behavior to similar spreads in the United States.

Figure 2 presents a three-dimensional graph of the average percentage bid-ask spread for stocks in ten different size-decile groups over the nine half-hour trading intervals.³⁹ Several broad regularities emerge from this picture: the bid-ask spread is a monotonic function of firm size with the bid-ask spread largest for the smallest firms; the spread is U-shaped over the course of the trading day for firms in all size-decile categories; the largest spreads of the day occur during the first half-hour of trading in the morning session; and the lowest bid-ask spreads occur during the first half-hour of the afternoon trading session, after the afternoon *itayose*. The U-shaped pattern

³⁸ Excluding commissions and presuming the bid-ask spread remains constant between consecutive trades. Another important aspect of trading costs is market impact. Angel (1993) attempts, largely unsuccessfully, to estimate the market impact on the TSE using a relatively small dataset.

³⁹ The percentage bid-ask spread is defined as the difference between the ask and bid prices divided by the average of the quote prices. There are no bid-ask quotes available for the four time periods corresponding to the *itayose* since the *itayose* is a single-price auction.

of bid-ask spreads has been documented in virtually all market microstructure studies, regardless of the underlying instrument or country in which the market exists.⁴⁰

The first two columns of results in Table IV contain the coefficients and *t*-statistics from the dummy variable regression in which the percentage bid-ask spread is the dependent variable. The explanatory variables are dummy variables for size-decile classification, half-hour time period, and day of the week. The average bid-ask spread across all system-traded stocks, all time intervals, and all days is 1.154 percent. The bid-ask spread averages range from 0.817 percent for the largest size-decile firms to 1.662 percent for the smallest size-decile firms. As previously noted, the bid-ask spread is U-shaped over the trading day. It is the highest during the first half-hour of trading—averaging 1.314 percent across all stocks—in the period immediately after the opening *itayose* in the morning. The average spread diminishes over the course of the morning session, reaching a low of 1.062 percent during the first half-hour of trading of the afternoon session. It tends to increase over the rest of the afternoon session, reaching 1.201 percent during the last half-hour of trading. Finally, the regression results suggest that the average bid-ask spread across all firms tends to be highest on Mondays when it equals 1.193 percent.

Figure 3 presents a three-dimensional graph of the average percentage bid-ask spread for stocks in eight different price categories over the nine half-hour trading intervals. The price categories are chosen to correspond to the break points in tick size. All stocks with prices less than ¥1,000 have a tick size of ¥1, stocks in the ¥1,001 to ¥10,000 price range have a minimum tick size of ¥10, and stocks between ¥10,001 and ¥30,000 have a tick size of ¥100. In general, as would be expected, stocks with higher prices tend to have lower percentage bid-ask spreads. The relation, however, is not quite monotonic since stocks in the ¥1,001 to ¥1,500 price range (minimum tick size of ¥10, which is 0.80 percent of the price range mid-point) have higher percentage bid-ask spreads than stocks in the ¥501 to ¥1,000 price range (minimum tick size of ¥1 which is 0.13 percent of the price range midpoint). It is interesting that the dispersion in bid-ask spreads between the largest size-decile firms and the smallest size-decile firms exceeds the dispersion between firms in the highest and lowest price categories. As observed in Figure 2 using the size sort, the spread is U-shaped over the trading day for firms in all price-level categories. The largest spreads of the day occur during the first

⁴⁰ Other evidence of U-shaped bid-ask spread patterns includes Bollerslev and Domowitz (1990), Hsieh and Kleidon (1992), and Ferguson, Mann, and Schneck (1993) in the foreign exchange market; and Brock and Kleidon (1992), McNish and Wood (1992a), and Foster and Viswanathan (1993) in U.S. equity markets. Not all studies find a U-shaped pattern, although we are unaware of a study that does not find the spreads largest at the morning open. Chan, Christie, and Schultz (1993) and Affleck-Graves, Hegde, and Miller (1992) find that NASDAQ spreads are at their highest at the open and narrow over the trading day. Similar results have been detected in the Chicago Board Options Exchange options market by Mayhew (1993).

Table IV
Bid-Ask Spread, Squared Returns, and Order Imbalance Dummy Variable
Regression Results

The bid-ask spread is the percentage bid-ask spread on the quote midpoint. The quote midpoint squared returns are computed using half-hour returns based on the quote midpoint of the latest bid and ask prices. The transaction returns use the last transaction price of the interval. If there is no trade in an interval, the transaction return is missing. The reported coefficients in the squared return regressions are the actual numbers multiplied by 10,000. Order imbalance (in millions of yen) is the average absolute half-hour signed trading volume.

Variable	Bid-Ask Spread		Quote Midpoint Returns		Transaction Returns		Order Imbalance	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	1.154%	1,155.26	0.7170	162.95	0.8310	184.26	9.813	154.99
Size 1	0.508%	113.90	0.2630	18.52	0.2550	24.52	-8.961	-123.78
Size 2	0.315%	88.70	0.1580	13.86	0.1550	16.72	-8.323	-114.88
Size 3	0.158%	48.89	0.0907	8.10	0.0883	10.09	-7.207	-96.53
Size 4	0.068%	22.96	0.0824	5.68	0.0808	5.90	-5.692	-69.63
Size 5	-0.006%	-2.24	0.0396	3.30	0.0364	2.64	-4.555	-54.59
Size 6	-0.079%	-27.53	-0.0122	-0.95	0.0015	0.15	-2.591	-25.65
Size 7	-0.147%	-56.76	-0.1000	-7.75	-0.0051	-0.47	-0.287	-2.64
Size 8	-0.199%	-86.15	-0.1300	-11.40	-0.1000	-11.70	2.549	18.15
Size 9	-0.281%	-130.09	-0.1700	-11.04	-0.1900	-24.90	11.867	52.27
Size 10	-0.337%	-151.80	-0.2200	-14.10	-0.3100	-43.06	23.200	47.60

Table IV—Continued

Variable	Bid-Ask Spread		Quote Midpoint Returns		Transaction Returns		Order Imbalance	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
9:00–9:29	0.126%	45.69	1.1500	37.70	0.0880	8.15	0.152	1.03
9:30–9:59	0.051%	18.93	-0.1400	-20.74	0.0022	0.25	-0.502	-4.34
10:00–10:29	0.011%	4.04	-0.1700	-25.22	-0.0649	-7.85	-0.279	-1.89
10:30–11:00	-0.013%	-4.68	-0.1400	-18.94	0.0301	3.11	0.224	1.52
12:30–12:59	-0.092%	-33.70	0.0336	3.05	-0.1600	-17.52	-2.292	17.10
1:00–1:29	-0.060%	-20.62	-0.2400	-32.92	-0.1200	-11.76	-1.632	-14.03
1:30–1:59	-0.047%	-16.21	-0.2600	-38.52	-0.1500	-18.07	-1.568	-13.18
2:00–2:29	-0.024%	-8.22	-0.2200	-31.12	-0.0695	-8.39	-0.445	-3.30
2:30–3:00	0.047%	16.00	-0.0104	-1.27	0.4480	33.68	6.342	16.62
Monday	0.039%	18.39	0.0251	2.77	-0.0314	-4.52	-1.517	-11.43
Tuesday	-0.002%	-1.15	-0.0474	-7.61	-0.0331	-5.26	-0.403	-3.04
Wednesday	-0.015%	-7.69	-0.0171	-2.47	-0.0020	-0.29	0.506	4.03
Thursday	-0.007%	-3.72	0.0651	5.13	0.0530	7.18	0.941	7.29
Friday	-0.015%	-7.65	-0.0259	-3.38	0.0136	1.96	0.472	4.21
Floor					0.0033	0.74		
System					-0.0033	-0.74		

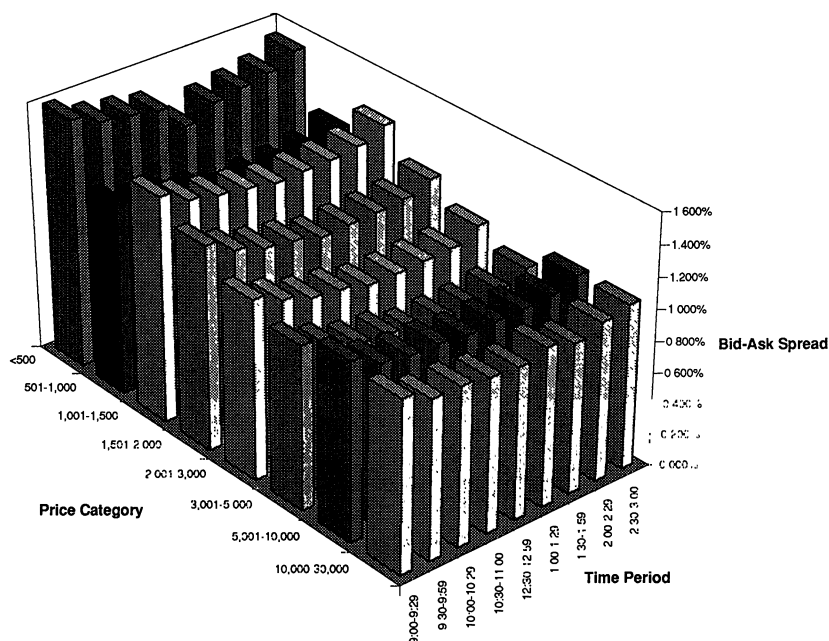


Figure 3. Bid-ask spreads for Japanese equities sorted by stock price level.

half-hour of trading in the morning session and the lowest bid-ask spreads occur during the first half-hour of the afternoon trading session.

C. Trading Volume, Size, and Frequency

Figure 4 plots the average trading volume (in millions of yen) of stocks in ten different size-decile groups for thirteen time periods, including the four daily *itayose*. The following trading regularities emerge from an examination of this graph. The largest amount of trading volume occurs during the opening *itayose* in the morning session. For the firms in the largest size-decile group, the average trading volume at the morning open is ¥124 million, which equals 17.63 percent of daily trading in those stocks. The comparable numbers for the smallest size-decile stocks are ¥3.7 million or 19.18 percent of daily volume. Trading is also intensive during the afternoon opening *itayose* and the last half-hour of the trading day. The average volumes for the largest market capitalization stocks are ¥59 and ¥104 million, respectively, in these two time periods. Thus for these stocks, an average of 8.47 percent of daily trading volume occurs at the afternoon opening *itayose* and 14.8 percent during the last half-hour of trading. For these time periods, the corresponding figures for the smallest size stocks are ¥2.6 and ¥2.1 million, which comprise 13.49 and 9.23 percent of daily trading volume. Thus for stocks in both the large-firm and small-firm deciles, slightly

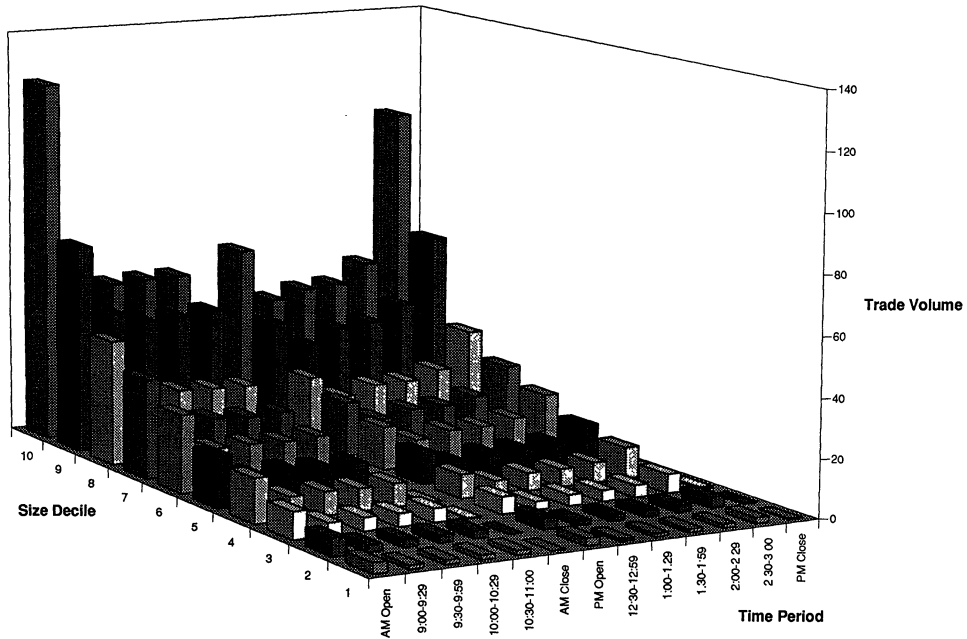


Figure 4. Trading volume for Japanese equities sorted by size deciles. Averages are for half-hour time periods and are measured in millions of yen.

over 40 percent of daily yen trading volume occurs at the two opening *itayose* and during the last half-hour of trading.

Apart from the volume at the afternoon opening *itayose*,⁴¹ Figure 4 shows volume to be U-shaped over the trading day. This intraday temporal pattern in volume manifests itself in almost all financial markets.⁴² Despite this broad-based finding, it has been much harder to reach consensus on the underlying theoretical justification for this trading behavior, presuming optimal behavior by agents. Admati and Pfleiderer (1988) present a model where it is possible to generate concentrations of trading at an arbitrary time of the day (not necessarily the open). In their model, informed traders cluster their trades when there are more liquidity traders in the market, hoping to hide their trading intentions. The liquidity traders in the model also concentrate their trade, taking advantage of the lower cost of trading when there is competition among the informed agents. Their model predicts that volume

⁴¹Also ignoring the *itayose* at the close of the morning session.

⁴²Among the studies which find a U-shaped pattern in intra-day trading volume are Jain and Joh (1988), McInish and Wood (1989), McInish and Wood (1990), McInish and Wood (1991), Gerety and Mulherin (1992), Kleidon and Werner (1992), Foster and Viswanathan (1993) and Roomans (1993).

should be highest when trading costs are the lowest. However, we have already identified the high-volume trading periods as high-cost periods.⁴³

Subrahmanyam (1991) introduces risk-averse informed traders into the Admati-Pfleiderer model, which can explain increased trading when the cost of trading is high. His model, however, requires more informed participants at the beginning and end of the trading day. Another explanation has been put forward by Brock and Kleidon (1992), who suggest that, due to periodic market closure, there is greater liquidity demand at the open and close for hedging purposes despite the higher trading costs. Under the assumption that liquidity supply is fixed, their model provides an explanation of the clustering of demand at the opens and closes. In equilibrium, however, it is unclear why the supply of liquidity must be held constant over the day, especially for relatively open-access computerized markets such as the TSE or the foreign exchange market.

The results from the dummy-variable regression with volume as the dependent variable are contained in the left pair of columns in Table V.⁴⁴ The regressions results indicate that system-traded stocks have ¥4.92 million lower trading volume per half-hour, on average, than floor-traded stocks. This number corresponds to approximately 22 percent of the trading volume of the largest system-traded stocks, the stocks that would seem to be the most similar to the floor-traded stocks a priori. The results also show that volume is substantially lower on Mondays, approximately ¥4.82 million lower per half-hour, than the average on the other four days of the week. To give this figure some perspective, ¥4.82 million is 21.5 percent of the unconditional average trading volume per time period.⁴⁵ It is noteworthy that volume is the lowest on Mondays, after the market has been closed for two days and trading demand would be expected to be higher.⁴⁶ This perhaps reflects both reduced demand to trade from liquidity traders who may face increased information asymmetry due to the weekend close, and the higher trading costs on Mondays since this is the day of the week when bid-ask spreads are substantially higher. In general, however, there is no simple relation between trading volume and the size of the bid-ask spread since volume tends to be

⁴³The bid-ask spread need not be an accurate measure of trading cost for both sides of the market. In principle, if the equilibrium price is not at the quote mid-point, it may be relatively cheap for one side of the market to trade even if the total spread is large. Handa and Nabar (1992) present some recent evidence that the equilibrium price isn't always at the quote mid-point and that dealers may make it cheaper to trade on one side of the market. This would be consistent with numerous inventory-based theoretical microstructure models. The empirical evidence in favor of inventory effects, however, is quite weak. See, for instance, Hasbrouck (1988).

⁴⁴All of the volume regressions use only observations for the nine half-hour trading intervals and exclude the single-price auctions. This is in contrast to the graph, which includes trade from the *itayose*. The graph, however, only contains data for the system-traded stocks.

⁴⁵The reader is again reminded that the regression results do not include trades from the *itayose*.

⁴⁶Especially in light of the Brock and Kleidon (1992) model.

lowest during the 12:30 to 1:00 P.M. time interval when bid-ask spreads are the lowest.

The middle two columns of Table V contain the regression results for trade size, and the last two columns of results in Table V contain the regression output for trade frequency.⁴⁷ The average stock trades 2.927 times per half-hour and the average trade size is ¥5.834 million. As expected, the average trade size and trade frequency are monotonically increasing in firm size. There is no consistent pattern in trade size and frequency over the

Table V
Volume, Size, and Frequency of Trade Dummy Variable
Regression Results

Trade volume and size are cross-sectional averages per half-hour of trading and are measured in millions of yen. Trade frequency is also per half-hour of trading. The data underlying these regressions do not include trade from the *itayose*.

Variable	Trade Volume		Trade Size		Trade Frequency	
	Coefficient	<i>t</i> -Statistic	Coefficient	<i>t</i> -Statistic	Coefficient	<i>t</i> -Statistic
Constant	22.384	185.51	2.927	371.98	5.834	295.95
Size 1	-16.000	-122.66	-2.828	-138.60	-2.290	-111.27
Size 2	-15.000	-115.34	-2.312	-105.72	-1.997	-96.54
Size 3	-13.000	-97.60	-1.843	-84.20	-1.418	-66.23
Size 4	-12.000	-80.72	-1.072	-42.77	-1.125	-32.00
Size 5	-12.000	-68.65	-0.274	-11.44	-1.215	-27.58
Size 6	-9.293	-41.92	-0.279	-15.25	-0.996	-24.38
Size 7	-0.130	-0.44	0.455	19.40	0.936	17.70
Size 8	5.555	20.45	1.151	46.94	1.321	28.45
Size 9	24.001	59.24	2.471	72.79	2.463	48.60
Size 10	47.559	88.50	4.531	81.91	4.322	71.62
9:00-9:29	2.533	7.59	0.306	8.21	0.044	0.94
9:30-9:59	0.472	1.62	-0.014	-0.58	0.040	0.87
10:00-10:29	0.175	0.54	-0.241	-11.26	0.213	4.13
10:30-11:00	0.623	1.83	-0.137	-6.30	-0.079	-1.70
12:30-12:59	-6.774	-24.50	0.084	3.34	-1.573	-36.13
1:00-1:29	-4.331	-16.94	-0.054	-2.36	-0.852	-20.35
1:30-1:59	-4.374	-16.73	-0.145	-6.39	-0.801	-19.99
2:00-2:29	-1.600	-6.05	-0.179	-8.49	-0.091	-2.20
2:30-3:00	13.277	30.52	0.379	7.04	3.099	52.54
Monday	-4.822	-23.39	-0.217	-10.55	-0.745	-24.04
Tuesday	-1.016	-4.51	-0.019	-0.94	-0.233	-7.38
Wednesday	1.269	5.60	0.119	5.24	0.119	3.62
Thursday	2.446	11.10	0.086	3.80	0.496	14.27
Friday	2.122	9.25	0.030	1.61	0.363	10.66
Floor	4.921	35.16	-1.139	-87.36	2.561	122.44
System	-4.921	-35.16	1.139	86.36	-2.561	-122.44

⁴⁷A number of researchers have found evidence that trade frequency, i.e., the number of trades, is at least as important as the volume of trade in affecting prices. These articles include Algert and Marsh (1990) and Jones, Kaul, and Lipson (1991).

trading day,⁴⁸ except that trade size tends to be the largest during the first and last half-hours of trading. Trade frequency appears to be relatively flat during the morning session, reaches its low during the first half-hour of the afternoon session when bid-ask spreads are their lowest, and increases monotonically until the close. The typical stock trades almost 9 times during the last half-hour of trading compared to the overall mean of 5.834. During this time interval, the average trade size is 12.95 percent higher than the mean for all periods (¥3.306 million as compared to ¥2.927 million). In general, trade size and trade frequency tend to be positively correlated. This can be inferred from the fact that the average trade volume (¥22.384 million) exceeds the product of the average trade size times the average trade frequency ($¥2.927 \times 5.834 = ¥17.076$ million).

One very surprising result is that the average trade size of system-traded stocks exceeds that of floor-traded stocks by ¥2.278 million (¥4.066 vs. ¥1.788 million) despite the fact that floor-traded stocks are larger and more actively traded stocks. On average, floor-traded stocks have an extra 5.122 trades per half-hour. The larger number of trades for floor-traded stocks outweighs the smaller size per trade, resulting in a larger total yen trading volume for these stocks. The larger number of smaller trades for floor-traded stocks may reflect lower liquidity for these stocks *ceteris paribus* and, hence, it may be that market participants break up larger trades in these stocks more frequently.⁴⁹

The results indicate there is very little variation in the size of trades across different days of the week, although the average trade size is about 7.4 percent smaller on Mondays. Finally, there are an average of 0.745 fewer trades per half-hour on Mondays and only small differences in trade frequency among the other four days. Overall, there does seem to be less liquidity and trade activity on Mondays as bid-ask spreads are the highest and volume, trade size, and trade frequency are at their lowest of the week.

D. Volatility and Order Imbalance Evidence

Figure 5 is a graph of the squared quote midpoint returns (multiplied by 10,000) for stocks in ten different size-decile categories during nine time intervals.⁵⁰ The squared return is a measure of asset return volatility. To

⁴⁸Since trade at the *itayose* auctions is recorded as a single trade, evidence from these time intervals is not reported.

⁴⁹Chan and Lakonishok (1993a, 1993b) and Keim and Madhavan (1993) present evidence on the strategies used by institutional investors in the United States to breakup sizable trades. Chan and Lakonishok, for instance, estimate that one-half of the dollar volume of trade undertaken by the institutions in their sample take four or more days to execute.

⁵⁰To calculate the quote midpoint return, we first compute the quote-based "price" as the average of the last bid and ask quotes in effect during the time interval. The return is the natural logarithm of the ratio of the quote midpoint-based price during the current periods to the quote midpoint-based price in the previous interval. The quote midpoint return for 9:00 to 9:29 A.M. uses the quote midpoint from 2:30 to 3:00 P.M. of the previous day and hence includes the overnight return. The quote midpoint return for 12:30 to 12:59 P.M. uses the quote midpoint from 10:30 to 11:00 A.M. of the morning session.

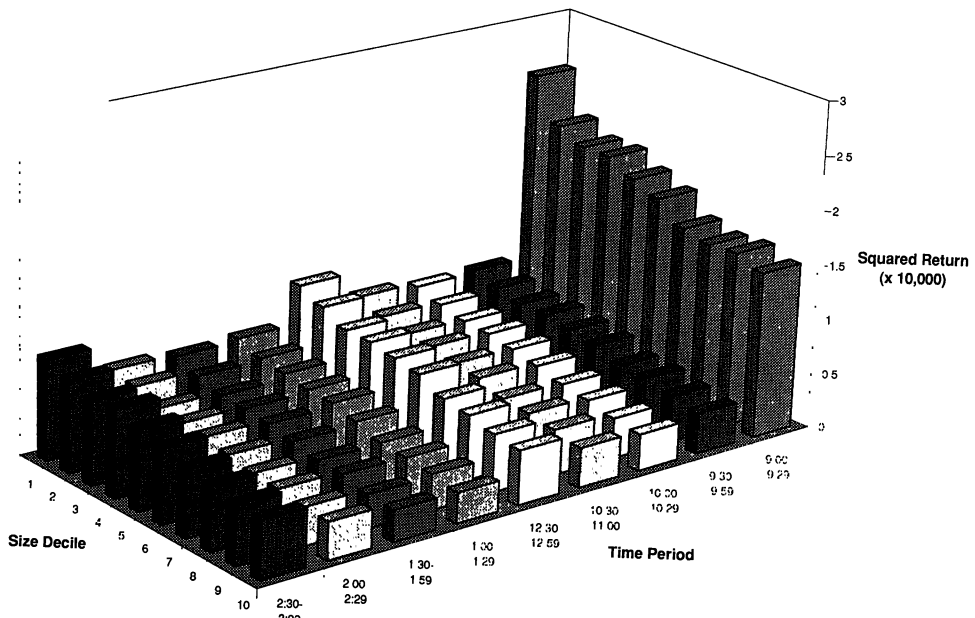


Figure 5. Squared quote midpoint returns for Japanese equities sorted by size deciles. Actual squared returns are multiplied by 10,000.

ease viewing, the time axis is reversed relative to the other graphs. The regression results for both quote midpoint and transaction squared returns are contained in the middle set of columns in Table IV. There is an important difference in the construction of quote midpoint and transaction returns in the periods following the opening *itayose* that must be kept in mind in interpreting these results. An illustration best explains the difference. The quote midpoint return for the 9:00 to 9:29 A.M. interval, for example, is based on the difference between the quote midpoint price in effect at the end of the 9:00 to 9:29 A.M. interval and the quote midpoint price in effect at the end of the 2:30 to 3:00 P.M. interval of the previous day. On the other hand, the transaction return is based on the difference between the last transaction price of the 9:00 to 9:29 A.M. interval and the *itayose*, which occurred at 9:00 A.M. (if the market opens immediately). Thus, the difference in coefficients on the 9:00 to 9:29 A.M. and 12:30 to 12:59 P.M. dummies between the quote midpoint return and transaction return regressions provides information on the returns when the market is closed.⁵¹

⁵¹Unfortunately, this inference is clouded by a selection bias in the transaction returns. This bias arises because transaction returns only have nonmissing values in periods when trades occur. This induces an upward bias in average squared transaction returns since trades are more likely when prices are volatile.

The figure and regression results that use the quote midpoint returns show that the highest volatility occurs overnight between the last half-hour of trading on one day and the first half-hour of trading on subsequent next day. Graphically, the average squared quote midpoint return during the first half-hour of trading (which includes the overnight return) dwarfs the squared returns of all other periods. As can be seen from Table IV, the average squared quote midpoint return during the first half-hour of trading is over three times the corresponding squared return during the next half-hour interval (1.867 vs. 0.577). A comparison of the coefficients on the 9:00 to 9:29 A.M. dummy between the quote midpoint return regression (1.1500) and the transaction return regression (0.0880) clearly indicates that most of the volatility can be attributed to the overnight period when the market is closed. There is a similar difference in the coefficients on the 12:30 to 12:59 P.M. dummy variables. The coefficient is 0.0336 in the quote midpoint regression and -0.1600 in the transaction return regression. This implies that the second most volatile period of the trading day is the period during which the market is closed for lunch. However, the period right after the afternoon open is the most tranquil.

There appears to be a fairly stable relation between volatility and the magnitude of bid-ask spreads. Both variables are high at the beginning and end of the day. Similarly, both volatility and bid-ask spreads are at their lowest levels during the first half-hour of the afternoon trading session. Ignoring the *itayose* time periods, volatility appears to be relatively U-shaped over the trading day. It reaches its lowest point of the day in the first half-hour of trading in the afternoon session (when bid-ask spreads and trading volume are at their lowest values) and increases monotonically until the close.⁵²

The remaining regularities concern day-of-the-week, firm size, and floor/system effects. Volatility differences across days of the week appear to be neither substantial nor systematic. For instance, the regression results using quote midpoint returns suggest volatility is 3.5 percent higher on Mondays than the unconditional mean, while the results using transaction returns indicate volatility is 3.7 percent lower on Mondays. As expected there is a monotonic relation between firm size and volatility. The average squared quote midpoint return of the smallest firms is 0.9800, and the average for the largest stocks is 0.497. We do not find any substantial difference between the squared returns of system- and floor-traded stocks.

Table IV also contains results from a regression of order imbalance on the size, time-of-day, day-of-week, and system/floor dummies. As a measure of order imbalance, we use average absolute signed trading volume per half-hour. Specifically, each half-hour we compute signed trading volume for each stock

⁵² The U-shaped pattern in volatility has been well-documented in other markets, especially the U.S. equity markets. Among the articles that have documented this effect are Wood, McInish and Ord (1985), Harris (1986), Hsieh and Kleidon (1992), Kleidon and Werner (1992), McInish and Wood (1992a), and Foster and Viswanathan (1993a, 1993b).

where buyer-initiated trades (trades at the ask price) count as positive volume and seller-initiated trades (trades at the bid price) count as negative volume. Cross-sectional and time-series means are computed of the *absolute* values of the signed trading volume figures. We compute means of the absolute values rather than the raw values, since the time series means of the raw values will tend to equal zero as order imbalances must eventually average out.

The results suggest an average order imbalance of ¥9.813 million per half-hour. By far, the largest order imbalances occur during the last half-hour of trading. The order imbalance during this period is, on average, ¥6.342 million higher than other periods during the day. Interestingly, the smallest order imbalance occurs in the first half-hour of the afternoon session. This is also the period of the day when volatility and bid-ask spreads are at their lowest.

E. Return Evidence

Table VI contains results from regressions where transaction returns and quote-midpoint returns are the dependent variables. All of the regressions only use observations for the nine half-hour trading intervals. During this sample period, the average half-hour transaction return is -0.0260 percent for system-traded stocks. This compares to an average half-hour return of -0.0110 percent for the same stocks based on quote midpoint returns. As mentioned above, this difference may partially be explained by the selection bias involved in computing transaction returns. In particular, transaction returns only take on nonmissing values when there is a trade during the half-hour interval. Thus, we are more likely to have a transaction observation when there is a large movement in stock prices. Since the overall movement in this sample was downward, we might expect the average of transaction returns to be biased downward relative to the quote midpoint return average.

Over this period, large market capitalization stocks substantially outperformed small stocks; the largest size-decile stocks had a mean quote midpoint return of -0.0040 percent, and the smallest firms had an average return of -0.0290 percent. While there is a monotonic relation between average return and firm size, there is a large jump between the means of size deciles 1 and 2, especially for the transaction returns. This may, in part, reflect the selection bias already discussed. The smallest size-decile stocks had a mean transaction return of -0.0690 percent and the second smallest size-decile stocks had a substantially higher mean of -0.0410 percent. The corresponding numbers using quote midpoint returns are -0.0290 and -0.0192 .

The results in Table VI suggest there are substantial day-of-week effects that depend, in part, on the method used to construct returns. Both sets of returns suggest a very significant Monday effect, with returns substantially lower on Monday than any other day of the week.⁵³ Average half-hour quote

⁵³ Numerous researchers have found a negative Monday effect in U.S. equity returns using daily return data.

Table VI
Mean Return and Frequency of One-Sided vs. Two-Sided Quote Revision
Dummy Variable Regression Results

Both return measures are cross-sectional averages of half-hour returns. Transactions returns are only computed if there is a transaction in consecutive half-hour trading intervals. Otherwise, the transaction return is counted as missing. The quote-based return is computed from the average of the bid and ask prices and, hence, can only be calculated for system-based stocks. Transaction returns are computed for both system- and floor-traded stocks. The quote revision frequencies are computed based on the first minute after a trade. Only regular quotes are used in constructing these variables. The frequencies are as a percent of regular quote revisions.

Variable	Quote-Based Return		Transaction Return		Frequency of One-Sided Quote Revisions		Frequency of Two-Sided Quote Revisions	
	Coefficient (%)	t-Statistic	Coefficient (%)	t-Statistic	Coefficient (%)	t-Statistic	Coefficient (%)	t-Statistic
Constant	-0.0110	-6.75	-0.0260	-12.04	73.221	1,208.26	26.780	441.91
Size 1	-0.0180	-3.60	-0.0430	-8.78	7.043	32.34	-7.043	-32.34
Size 2	-0.0082	-1.69	-0.0150	-3.17	6.118	31.26	-6.118	-31.26
Size 3	-0.0011	-0.23	-0.0059	-1.27	4.519	26.21	-4.519	-26.21
Size 4	0.0021	0.41	-0.0007	-0.10	2.299	13.39	-2.299	-13.39
Size 5	0.0045	0.90	0.0151	2.25	0.918	5.80	-0.918	-5.80
Size 6	0.0013	0.27	0.0042	0.88	2.057	13.45	-2.057	-13.44
Size 7	0.0026	0.54	0.0050	1.05	0.000	0.00	0.000	0.00
Size 8	0.0037	0.80	0.0139	3.24	-3.203	-18.93	3.203	18.93
Size 9	0.0060	1.28	0.0123	2.99	-9.848	-54.99	9.848	54.99
Size 10	0.0070	1.38	0.0135	3.33	-9.904	-44.45	9.904	44.45

Table VI—Continued

Variable	Quote-Based Return		Transaction Return		Frequency of One-Sided Quote Revisions		Frequency of Two-Sided Quote Revisions	
	Coefficient (%)	<i>t</i> -Statistic	Coefficient (%)	<i>t</i> -Statistic	Coefficient (%)	<i>t</i> -Statistic	Coefficient (%)	<i>t</i> -Statistic
9:00–9:29	0.0126	1.44	–0.0300	–5.71	–17.851	–98.03	17.851	98.03
9:30–9:59	–0.0450	–12.71	–0.0320	–6.78	2.307	14.09	–2.307	–14.09
10:00–10:29	0.0013	0.35	0.0246	5.43	4.255	25.88	–4.255	–25.88
10:30–11:00	0.0255	6.71	0.0402	8.31	4.978	31.23	–4.978	–31.23
12:30–12:59	–0.0400	–8.02	–0.0300	–6.41	–19.262	–88.64	19.262	88.64
1:00–1:29	–0.0095	–2.61	0.0002	0.05	2.041	10.55	–2.041	–10.55
1:30–1:59	0.0042	1.30	0.0106	2.54	5.248	30.49	–5.248	–30.49
2:00–2:29	0.0067	2.05	0.0082	1.89	7.570	49.57	–7.570	–49.57
2:30–3:00	0.0447	11.26	0.0081	1.41	10.714	90.80	–10.714	–90.80
Monday	–0.0470	–13.66	–0.0550	–16.52	0.183	1.41	–0.183	–1.41
Tuesday	–0.0150	–5.00	–0.0014	–0.43	0.014	0.11	–0.014	–0.11
Wednesday	–0.0074	–2.31	0.0012	0.35	–0.364	–3.10	0.364	3.10
Thursday	0.0500	14.08	0.0468	13.30	–0.042	–0.36	0.042	0.36
Friday	0.0187	6.05	0.0084	2.45	0.210	1.78	–0.210	–1.78
Floor			–0.0069	–3.18				
System			0.0069	3.18				

midpoint returns are -0.0580 percent on Mondays compared to the overall average of -0.0110 percent. The corresponding figures using transaction returns are -0.0810 percent for Mondays and -0.0260 percent for the overall average. The other substantial day-of-the-week effect during this sample period is that returns on Thursdays tend to be substantially above the grand mean; the Thursday means are 0.0500 percent using quote midpoint returns and 0.0468 percent using transaction returns. Since it is difficult to put forth a simple economic or institutional argument to justify this pattern in returns, it is possible that these apparently significant differences may be spurious.

The time-of-day effects are more difficult to categorize. Using both sets of returns, the average returns seem to be substantially lower during the second half-hour of trading and during the first half-hour of the afternoon session. Quote midpoint returns tend to be substantially higher during the last half-hour of trading, although this does not show up in the transaction returns. In sum, there appears to be quite a substantial variation in mean returns across days of the week and across the trading day.⁵⁴

F. *Kehai and Regular Quote Adjustments*

A unique characteristic of the trading mechanism of the TSE is its use of nonhalt *chui kehai* to advertise potential order imbalances for price changes within the maximum price variation, and the use of *chui kehai* trading halts to stop the trading process when price changes would exceed these maximums, advertise the imbalance, and allow the market time to generate liquidity. In this section, we study market depth and liquidity by examining the adjustment of quotes to trades and the utilization of the *chui kehai* trading mechanism.

Table VII contains regression results examining the frequency of quote revisions within one minute of trades. The results indicate that after 55.820 percent of the trades there are no quote revisions. Changes in the bid or ask price, resulting in "regular" quotes for both the bid and the ask, occur after 42.774 percent of the trades. As expected, there is substantially less liquidity in the smaller stocks. For the smallest stocks, there are no quote revisions after 45.498 percent of the trades, which is substantially less than the figure of 67.458 percent for the largest stocks.

The occurrence of *chui kehai* events is quite rare. Quote revisions that result in nonhalt warning quotes for either the *best-bid* or *best-offer* occur after only 1.072 percent of the trades, and quote changes that result in *chui kehai* trading halt quotes follow a minimal 0.334 percent of the trades. While

⁵⁴ Miller (1989), for instance, attributes the intraday pattern of returns in the United States to the specialist's job of maintaining price continuity. If this explanation is accurate, it is indeed not surprising that we fail to find similar effects in Japan. Terry (1986), Foerster, Keim, and Porter (1990), and Porter (1992) provide evidence that the U-shaped pattern to returns in the United States may be an artifact of the greater probability of a trade at the ask price during the beginning and end of the day.

there is evidence of less liquidity in the smaller stocks, there is not much greater use of the *chui kehai* and *tokubetsu kehai* mechanisms to slow down trading in these stocks. For the smallest stocks, 1.056 percent of the trades result in quote changes where either the bid or ask quote is a nonhalt *chui kehai* and 0.659 percent of the trades trigger *chui kehai* trading halts. The numbers for the largest stocks are of a similar magnitude; 0.832 percent of the trades generate nonhalt *chui kehai* events, and 0.125 percent of the executions result in *chui kehai* outcomes with trading halts.

The reliance on these trading mechanisms to slow down trading tends to be U-shaped, as are bid-ask spreads, trading volume, and volatility. The two highest periods of utilization are the first half-hour and last half-hour of trading. During these two periods, 1.41 and 1.623 percent of the trades trigger nonhalt *chui kehai* quotes and 0.396 and 0.382 percent of the trades generate *chui kehai* trading halts. These mechanisms are least employed during the first half-hour of trading in the afternoon, the period when bid-ask spreads are at their lowest. Whereas 1.072 percent of the overall trades result in nonhalt *chui kehai* events, only 0.805 percent of the trades in this period generate this outcome. Similarly, only 0.209 percent of the trades during the 12:30 to 12:59 P.M. interval result in *chui kehai* events with trading halts, compared to an overall average of 0.334 percent. While there appear to be interesting differences in the utilization of these mechanisms across the trading day, there appear to be few significant differences across the days of the week. This observation contrasts with the interesting differences in several of our trading descriptors across the different trading days.

Table VI contains some additional information on the liquidity of equities on the TSE. Two sets of columns in that table present regression results on the frequency of regular quote revisions that are one sided and two sided. Most simple models of an electronic limit order book would suggest that quote changes should be two sided. Nevertheless, a substantial portion of the quote revisions are only one sided. On average, 73.221 percent of regular quote revisions are one sided and 26.780 percent are two sided.⁵⁵ The proportion of one-sided quote revisions for the smallest stocks (80.264 percent) substantially exceeds this average, and the proportion of one-sided quote revisions for the largest stocks (63.317 percent) falls substantially short of the average. It is thus much more likely that trade in a large stock results in a two-sided quote revision. This occurs after 36.684 percent of the trades in the largest size stocks. In part, this may simply reflect the increased trading activity in larger stocks.

There also seems to be significant variations in the supply and demand for liquidity over the trading day. In particular, it is much less likely for a quote revision to be one sided after the market has been closed, either overnight or for the lunch break. Overall, 73.221 percent of the regular quote revisions are

⁵⁵A quote change is considered to be two sided if both the bid and the ask price change within one minute of a trade, although the change need not occur simultaneously. If only one quote changes within one minute, the change is classified as one sided.

Table VII
Frequency and Type of Quote Revisions After Trade Dummy Variable
Regression Results

Trades are categorized based on the first minute after the trade. If there is no quote revision within one minute of trade, the trade is categorized as occurring without a quote revision. If either the bid or ask price changes, the quote is considered to be revised. If either quote becomes a *kehai* quote, the revision is counted as a “*kehai*” revision. Any other revision is counted as a regular quote revision.

Variable	Frequency of Trades without Quote Revisions		Frequency of Regular Quote Revisions		Frequency of Nonhalt <i>Kehai</i> Revisions		Frequency of <i>Kehai</i> Halt Revisions	
	Coefficient (%)	<i>t</i> -Statistic	Coefficient (%)	<i>t</i> -Statistic	Coefficient (%)	<i>t</i> -Statistic	Coefficient (%)	<i>t</i> -Statistic
Constant	55.820	1,686.39	42.774	1,336.69	1.072	236.17	0.334	95.16
Size 1	-10.322	-89.99	10.012	88.37	-0.016	-1.05	0.325	18.59
Size 2	-8.666	-82.45	8.504	81.85	-0.035	-2.48	0.196	13.45
Size 3	-5.366	-55.61	5.236	55.82	0.037	2.74	0.093	8.07
Size 4	-2.760	-28.05	2.577	27.21	0.137	10.00	0.046	4.57
Size 5	-1.169	-12.28	1.160	12.60	0.042	3.25	-0.033	-3.67
Size 6	0.723	7.70	-0.871	-9.75	0.175	12.25	-0.027	-3.03
Size 7	2.363	26.05	-2.398	-27.85	0.112	8.40	-0.076	-9.83
Size 8	4.530	49.51	-4.357	-49.40	-0.044	-3.41	-0.129	-18.19
Size 9	9.029	95.24	-8.674	-95.53	-0.168	-13.77	-0.187	-29.82
Size 10	11.638	108.77	-11.189	-109.37	-0.240	-17.52	-0.209	-30.42

Table VII—Continued

Variable	Frequency of Trades without Quote Revisions		Frequency of Regular Quote Revisions		Frequency of Nonhalt <i>Kehai</i> Revisions		Frequency of <i>Kehai</i> Halt Revisions	
	Coefficient (%)	<i>t</i> -Statistic	Coefficient (%)	<i>t</i> -Statistic	Coefficient (%)	<i>t</i> -Statistic	Coefficient (%)	<i>t</i> -Statistic
9:00–9:29	–1.783	–18.27	1.383	14.62	0.338	21.82	0.062	5.45
9:30–9:59	–0.808	–9.05	0.708	8.18	0.036	2.88	0.064	5.80
10:00–10:29	0.530	5.90	–0.476	–5.50	–0.073	–6.08	0.019	1.86
10:30–11:00	0.226	2.47	0.036	0.40	–0.220	–20.95	–0.041	–4.60
12:30–12:59	1.139	10.87	–0.747	–7.27	–0.267	–21.36	–0.125	–13.68
1:00–1:29	1.350	13.76	–1.105	–11.64	–0.212	–17.38	–0.033	–3.32
1:30–1:59	1.278	13.54	–1.101	–12.13	–0.142	–11.27	–0.036	–3.89
2:00–2:29	0.447	4.84	–0.478	–5.38	–0.011	–0.85	0.043	4.17
2:30–3:00	–2.379	–28.87	1.780	22.68	0.551	38.54	0.048	5.23
Monday	–0.086	–1.24	0.100	1.50	–0.044	–4.60	0.030	3.82
Tuesday	0.074	1.13	–0.004	–0.06	–0.064	–7.43	–0.006	–0.89
Wednesday	0.229	3.56	–0.207	–3.30	0.000	0.00	–0.023	–3.48
Thursday	–0.163	–2.50	0.097	1.54	0.064	7.02	0.002	0.26
Friday	–0.054	–0.82	0.012	0.19	0.045	4.77	–0.002	–0.34

one sided. This number drops to 55.37 percent for the first half-hour of the morning session (when volume is high) and 53.959 percent for the first half-hour of the afternoon session (when volume is low). In contrast, it is much more likely for a quote revision to be one sided during the last half-hour of the trading of the day (when volume is high). During this time interval, 83.935 percent of the regular quote revisions are one sided. It is apparent that there is no simple relation between the proportion of one-sided and two-sided trades and the amount of trading activity.

The absence of a direct link between trade activity and the proportion of one-sided and two-sided quote revisions suggests that information factors may have a role in explaining intertemporal variations in stock market liquidity. For instance, the greater proportion of two-sided quote revisions after market closures may reflect, in part, the potential for increased information asymmetry after the market has been closed and the consequent need of market makers to manage aggressively both sides of their limit order book. An information-based story may also be useful in explaining the greater proportion of one-sided quote revisions during the last half-hour of trading (when volume is high). This is also the period of the day when order imbalances are at their maximum and hence a predominance of orders may be expected on one side of the market. This diminishes the need for market makers to manage both the bid and the ask with equal fervor.

IV. Summary and Conclusions

This article has attempted to provide a comprehensive overview of the trading mechanism of the TSE and to contrast it with the specialist-system for trading stocks on the NYSE and AMEX in the United States. The primary differences between the two systems are the absence of a designated market maker in Tokyo and the TSE's elaborate system for advertising order imbalances, generating liquidity from its member firms, and slowing down the trading process when deemed necessary. We analyzed all completed transactions and available quotes for all TSE listed stocks during a 26-month period: January 1, 1991 through November 30, 1991 and February 1, 1992 through April 30, 1993. We examined the intertemporal and cross-sectional behavior of bid-ask spreads, trading volume, trade size and frequency, returns, volatility, order imbalance, and the utilization of the TSE's *keihai* warning mechanism. It should come as no surprise that the evidence suggests that the presence of exchange-designated market makers is not a necessary condition for a well-functioning financial market. Either the TSE has evolved into a marketplace that fulfills the needs of its customers or the customers have adapted successfully to its trading mechanism.

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