MARKET MICROSTRUCTURE, TECHNICAL ANALYSIS, AND STOCK PRICE MOVEMENTS

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ABSTRACT

Market Microsructure, Technical Analysis, and Stock Price Movements

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This thesis uses quotation and trade-by-trade data from the Toronto Stock Exchange (TSE) to examine a number of issues associated with the efficiency of capital markets, asset pricing, and market microstructure. The thesis has important implications for the design of trading mechanisms, market making and price discovery.

The interactions between quotes and trades are examined for quote revisions, signed trading volumes, depth imbalances and number of trades. Unlike the literature, this VAR system uses both a broader subset of microstructure variables to measure market quotation and trading activities, and the returns on the actively traded market proxy, TSE 35 Index Participations (TIPs), to capture the co-movements of individual stock prices. Strong interactions are identified between quotes and trades for the individual stocks in the TSE 35 Index. The inferences from various existent theories on market microstructure relationships are tested, and many are supported empirically.

The short-run predictability of price changes and quote revisions, with(out) the use of three popular technical trading indicators, is examined using intraday data. The average level and quality of traders' information is captured by price and other microstructure variables (volume and number of trades, respectively). While historical trade information is useful in predicting current stock price movements and quote revisions, the incremental predictive power from adding technical trading rule signals (such as moving average crossings, trading range breaks and relative strength) is very limited. Thus, these technical techniques consistently and accurately reveal what has happened, and not what will happen.

The intraday behavior of three dimensions of quotes (bid-ask spreads, depths and quote levels) are examined cross-sectionally and endogenously in response to previous trading activities and to (non-)information events proxied by (thin) heavy trading intervals. Information (heavy trading) shocks are associated with higher information risk (higher quote level changes and larger spreads) and higher liquidity (thicker depth). The adverse selection component of the bid-ask spread is significant. Trading activity variables have different information contents for changes in each of the three quote dimensions. While trading volume is more informative for quote level changes, the number of trades and heavy (thin) trading indications are more informative for spread and depth changes, respectively. Using a VAR system, spread and depth are found to be endogenously and negatively related. While spread is associated more with information and risk aversion, depth is related more to the supply of market liquidity. Quote level changes are not endogenously related to both spreads and depths, but significantly related to asymmetric information.

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All remaining errors in the thesis are, of course, solely my responsibility.

BIOGRAPHICAL SKETCH

Feng Liu was born on 13 June 1963 in Hunan, China. After obtaining a Bachelor degree in Structural Engineering at Tianjin University in 1983, he joined the Fifth Construction Bureau of China as an assistant engineer. He was involved in technical and managerial activities for the extension of the Changsha beer factory. Feng returned to Tianjin in 1984 to start his graduate studies in Project Management. After receiving a Masters degree in Industrial Management in 1987, he became a lecturer in the School of Management at Tianjin University. During the period from 1987 to 1989, Feng was actively involved in both academic and consulting activities. He taught "Project Management" and "Engineering Economics" at Tianjin and other institutions, published several papers and co-authored a book dealing with management of large size industrial projects in China. One of his research projects was awarded the Second Prize of Science and Technology Progress by the State Education Committee, Government of China. He was a visiting researcher at HEC (Montreal) for three months in 1986. Feng selected Concordia University for his Ph.D. studies in Finance in 1989 after being awarded a CIDA scholarship. During his six years at Concordia, he learned much about modern financial theories and practices. Since 1991, Feng has lectured in corporate finance, and has been a consultant in Shenzhen International Holdings (Canada) Inc.. He has co-authored several papers in the area of international finance and market microstructure. Feng joins the Faculty of Business Administration at the University of Windsor as an Assistant Professor in August 1995.

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Chapter 1

Introduction

The market structure and trading behavior of market makers and traders (informed and uninformed) are important influences on stock price movements, especially over the short-run. The market structure of the Toronto Stock Exchange (TSE), which is described more fully in **Appendix 1**, is different from many other major stock exchanges in terms of its informational transparency and visibility. In turn, this may lead to improve market efficiency and lower trading costs. Compared to pure dealership markets such as NASDAQ or the International Stock Exchange (London) where public investors submit orders to and trade with multiple competitive market makers directly and immediately [Christie and Schultz (1994)], traders on the TSE can submit their limit orders to the Limit Order Trading System (LOTS) to compete with the Registered Trader (RT) quotations. Unlike the NYSE where only the specialist has monopolistic access to the limit order book [Lehmann and Modest (1994)], all market participants on the TSE have access to the limit orders on LOTS, RT market quotes and to transaction information on a real-time basis. The TSE is not a pure continuous auction market in the sense that the RTs still function like specialists on the NYSE, but with less monopoly power and more restrictions.[1] The continuous effort to establish an automated trading system by the TSE management has significantly reduced trading costs.[2] With a small trade spread, the electronic open limit order book is able to provide as much liquidity as can be expected in extreme adverse selection environments [Glosten (1994)]. Evidence from the Tokyo Stock Exchange also suggests that the presence of exchange-designed market makers is not a necessary condition for a well-functioning financial market [Lehmann and Modest (1994)]. Whether or not the price discovery process and market making behavior are more informationally efficient and liquid for the TSE where an electronic open limit order book and an designated market maker co-exist remains to be explored.

Thus, this thesis uses quotation and trade-by-trade data from the TSE to examine three primary issues associated with the efficiency of capital markets, asset pricing, and market microstructure. First, the intraday interactions and causal directions between trades and quote revisions are examined and tested using a four-equation Vector Autoregression (VAR) system in chapter two. Second, the predictive power of market statistics and technical trading rules for price changes and quote revisions is examined in chapter three. Third, the intraday competitive market-making behavior for three dimensional quote movements (bid-ask spreads, depths and quote

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[1] The Tokyo Stock exchange and many European exchanges (Paris, Madrid, Stockholm, and Milan) have developed continuous electronic auction systems based on the TSE's Computer Assisted Trading System (CATS), where market officers log limit orders and match them to incoming market orders but provide no market making services. The CATS is used by the TSE primarily for less actively traded stocks (for about 1/3 of all the stocks on the TSE).

[2] For example, the TSE members saved $6.5 million in trading costs in 1994 due to a gradual reduction in maximum trading fees, first from $1,750 to $1,000, and later from $1,000 to $100.

levels) in response to previous trading activities and to (non-) information events are examined in chapter four. The thesis has important implications for the design of trading mechanisms, market making and price discovery which are pursued further in chapter five.

The studied sample consists of all of the stocks in the TSE 35 index and the traded instrument called the TSE 35 Index Participations (TIPs) for the period 1 June 1990 to 30 June 1991.[3,4] The time-stamped trades (to the nearest second), trade size, and bid/ask quotes for each stock are drawn from the TSE transaction database. The data are then summarized into 13 30-minute intervals for each trading day from 9:30 AM to 4:00 PM (as in McInish and Wood (1992), and Lee, Mucklow and Ready (1993) for NYSE stocks). Three trade and four quote measures are formulated for each stock during each 30-minute time interval; namely, average transaction price of all trades over each interval, the total number of shares traded and the total number of trades during each interval, the last bid (ask) price and the quoted depth (size) of the last bid (ask) for each interval.

The interaction between trades and quote revisions on the TSE are examined in chapter 2. Unlike most of the existing literature which uses a two-equation VAR system for NYSE stocks [such as Hasbrouck (1988, 1991a, b) and Huang and Stoll

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[3] Among the 35 stocks, four of them (i.e., CAE, SCC, STM and TOC) are traded on CATS and the rest on the floor during the sample period. The estimation results for the CATS stocks are not reported separately in this study because they are not significantly different from the others.

[4] TIPs (the TSE 35 Index Participations) is a traded security on the Toronto Stock Exchange, where price is the weighted average of the market values of the stocks comprising the TSE 35 Index. The units (or shares) of TIPs can be converted proportionally into the shares of the 35 stocks under certain regulations. For a detailed description of TIPs, please see Appendix 2.

(1994)], a more general four-equation VAR system is used to include not only quote revisions and signed trading volume [as in Hasbrouck (1991a, b)], but also depth imbalance which provides additional information about the supply of liquidity by the market, and the number of trades which provides an additional dimension for tracking the trading behavior of informed traders.[5] This four-equation VAR system provides greater opportunity for capturing the endogenous relationships between quote and trades than the previously used two-equation systems. A number of hypotheses related to the microstructure theories dealing with adverse selection and inventory market making behavior are tested, and their results are compared to those for studies using NYSE stocks.[6] The impact of the trading mechanism change and of the weekend effect due to information gathering during this period of no trading on both quote and trade behavior are examined by adding dummy variables to the VAR models.[7] The pattern of co-movements between individual stocks and the market are examined by adding the price changes on TIPs to the VAR models. Granger causality tests are used to identify the causal direction between quote revision and trade.

Strong interactions are identified between quotes and trades. Quoted price levels and quoted depth are used simultaneously by market makers to protect themselves from trades with informed traders and to fulfil their mandate as liquidity

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[5] Barclay and Warner (1993) provide evidence that informed traders prefer to choose middle size orders to strategically minimize the price impact of their trades. This implies that the number of trades may be a better measure of the trading activities of informed traders.

[6] Two two-equation VAR systems of quote revision and trade innovation [similar to Hasbrouck (1991a, b)] are identified as being special cases of the four equation system.

[7] Like the NYSE, the TSE opens with a batch auction and switches to continuous trading for the remainder of the trading session.

providers in the market. While quoted price changes are related strongly to order flow which reflects an adverse selection process of quote revision, quoted depth changes are due mainly to the liquidity supply motivations. Trade innovation is related significantly to previous quote changes, which indicates that public investors obtain information by observing quote changes, and then adjust their trading activities accordingly. Trading frequency is significantly affected by a switch in the trading mechanism and weekend informational uncertainties. Specifically, the number of trades is significantly high during market opens and low during Monday market opens. The overall results imply that the price discovery process is affected by the historical trading and quotation activities for information asymmetry and liquidity supply reasons, although the automation and transparency of the trading process helps to make this process more efficient.

The intraday predictability of price changes and quote revisions are studied in chapter three by using publicly available information on quotation and trading history for individual stocks and technical trading rules on historical price movements. The predictive power of using market statistics and the incremental predictive power of using technical trading rules are investigated in two steps: First, two econometric prediction models based on publicly available market statistics for quote revision and transaction price changes are constructed to incorporate various microstructure theories. The information set of market statistics includes the most frequently used measures in the literature such as signed trading volumes, and other measures such as changes in the number of trades, effective bid/ask spread, depth imbalance, heavy and thin trading indicators, and the 30-minute returns on TIPs to capture the co-movement of individual stock prices. Second, the incremental usefulness of three popular technical trading rules (namely, the moving average, trading range break, and relative strength) is assessed by adding technical buy/sell indicators to the right-hand-side (RHS) of the basic prediction models estimated in the first step. A cross-sectional analysis of intraday changes in microstructure variables around technical buy or sell signals is conducted to examine market trade and quote behavior during signal periods in which technicians predict a turning point in price changes. A simulated program trading strategy based on technical trading rules is formulated and tested to make 1, 2, or 5 day "round-trip" trades, and their profitability is tracked.

Market statistics are found to be more useful in predicting quote revisions than transaction price changes. Quote revisions are affected significantly by previous trading activities and the trend in market co-movement, which implies an adverse selection effect. In contrast, transaction price changes are due mainly to the bid-ask bounce effect of previous trade and the information effect of previous quotes. Technical trading rules have limited incremental predictive powers over the very short term when benchmarked against other summary statistics of market momentum. Based on the cross-sectional analyses for buy and sell signal "events", technical analysis consistently and accurately reveals **what has happened** in the market, but has very limited power in predicting future short-run stock price movements. This supports the conjecture of Blume, Easley and O'Hara (1994) that technical analysis of only price statistics cannot reveal all the relevant information, and that other microstructure statistics such as trading volume improve information quality and may be helpful in explaining future stock price changes. The low level of incremental usefulness of technical trading rules based on historical price patterns for very short-term trading strategies implies that the price discovery process on the TSE may be more efficient due to greater transparency and immediacy of information on market statistics and low trading costs for professional traders.

How market makers use the three dimensions of market quotations simultaneously and strategically for market making and protecting themselves from trading with informed traders is investigated in chapter four. By examining the statistical properties of three dimensions (and not two) of market quotation to (non-) information events [proxied by heavy trading (thin or no trading) periods], the spreads are found to be significantly narrower around information events than non-information events, and the depths are found to be significantly thicker around information events than non-information events. This reflects a higher market liquidity during heavy trading periods than thin (or no) trading periods. The increased (decreased) spreads and decreased depths immediately after (non-)information events, and significantly increased quote levels immediately before the information events indicate an adverse selection effect of information on quote changes. Using a three-equation VAR system to capture the three dimensions of quote changes endogenously, trading activity variables are found to have different information contents for changes in each of the three dimensions of quotes. While trading volume is more informative for quote level changes, the number of trades and heavy (thin) trading indications are more informative for spread and depth changes, respectively. Spread and depth are endogenously and negatively related. Quote level changes are not endogenously related to both spreads and depths, but significantly related to asymmetric information. While spread is associated more with information and risk aversion, depth is related more to the supply of market liquidity. The evidence suggests that the three dimensions of market quote are collectively and strategically used by market makers to avoid exposure to informed traders and to fulfil their mandate to provide market liquidity.

The major findings of this research are summarized in chapter five, and their implications for the design of trading mechanisms, market making and price discovery are discussed. Some directions for future research are explored.

Chapter 2

Intraday Interactions Between Trades and Quote Revisions

2.1 Introduction

In a centralized continuous auction market such as the Toronto Stock Exchange (TSE), orders to buy and sell stocks from the investing public are "matched" for the best price currently available on the market.[8] This process is facilitated by the activities of market makers called Registered Traders (RTs) [or Designated Market Makers (DMMs)]. Each stock listed on the TSE is assigned to a RT, who has the responsibility to maintain an orderly and continuously liquid market at minimum spread in return for the privilege of trading for their own account. To maintain a reasonable quoted market for listed stocks, RTs post bid and ask quotations which are tradeable against their own accounts if an offsetting order comes into the market. The prices quoted must bear a reasonable relationship to the price of the last trade reported for the assigned stock. The RT's responsibility is to keep the actual spread reasonably close within the spread goal established by the Exchange.[9] The RTs also

[8] See Appendix 1 for a detailed description of the market structure on the TSE.

[9] TSE statistics show that, on average, about 30 per cent of the time the best bid or offer on stocks is posted by RTs. The RTs minimize price variations by trading for their own accounts. In 1985, almost 99% of all trades on the TSE were completed within 1/4 point ($0.25) of the price of the previous trade in

post the sizes for each quoted price on an ongoing basis to provide investors with an indication of market depth. Since the Limit Order Trading System (LOTS) allows brokers to enter limit orders electronically, the best market quotations are the result of competition of public limit orders of traders with RT quotations. Transactions result from matches between the best market quotes and the market orders from brokers or the Market Order System of Trading (MOST). Less actively traded stocks trade primarily on the Computer Assisted Trading System (CATS), which is a fully automated trading system for about 1/3 of all stocks on the TSE.

The trading procedure on the TSE is different from many other major stock exchanges in terms of its transparency, efficiency, visibility and low trading costs. Compared to pure dealership markets such as NASDAQ or the International Stock Exchange (London) where public investors submit orders to and trade with multiple competitive market makers directly and immediately, traders on the TSE can submit their limit orders to LOTS to compete with the RT quotations. Unlike the NYSE where only the specialist has monopolistic access to the limit order book, all market participants have access to the limit orders on LOTS, RT market quotes and to transaction information on a real-time basis on the TSE. The TSE is not a pure continuous auction market in the sense that the RTs still function like specialists on the NYSE, but with less monopoly power and more restrictions. The continuous effort to establish an automated trading system by the TSE management has significantly reduced trading costs on the TSE. Although the price discovery process

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a given stock.

and market making behavior on the TSE may be more informational efficient and more liquid than many of its counterparts, these aspects remain unexplored.

Thus, the purpose of this chapter is to examine the relationship between trades caused by information asymmetry and liquidity needs, and quote revisions based on adverse selection, inventory (or supply of liquidity), and order processing costs on the TSE. Unlike most of the existing literature which uses a two-equation VAR system for NYSE stocks [such as Hasbrouck (1988, 1991a, b) and Huang and Stoll (1994)], a more general four-equation VAR system is used herein to examine the interactions between quotes and trades. The VAR system includes not only quote revisions and signed trading volume as in Hasbrouck (1991a, b), but also depth imbalance and changes in the number of trades. The VAR system is estimated using transactional and quote data for the stocks in the TSE 35 Index, and for the traded instrument called TSE 35 Index Participations (TIPs).[10] This four-equation VAR system provides greater opportunity for capturing the endogenous relationships between quote and trades than the previously used two-equation systems. Furthermore, depth imbalance provides additional information about the supply of liquidity by the market, and the number of trades provides an additional dimension for tracking the trading behavior of informed traders. A number of hypotheses related to the microstructure theories dealing with adverse selection and inventory market making behavior are tested, and their results are compared to those for studies using NYSE stocks. Two two-equation VAR systems of quote revision and trade innovation [similar to Hasbrouck (1991a,

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[10] The 30-minute returns on TIPs are used herein to proxy market returns in order to capture the co-movements of individual stock prices.

b)] are identified as being special cases of the four equation system. This framework is used to investigate various specific issues such as the information content of a trade; and the impact on both transaction and quotation of previous effective bid-ask spread, trading volume, number of trades, heavy or thin trading, quote revision and quote depth imbalance.

Three additional issues not previously investigated in the literature are addressed. First, like the NYSE, the TSE opens with a batch auction and switches to continuous trading for the remainder of the trading session. The impact of this trading mechanism change and of the weekend effect due to information gathering during this period of no trading on both quote and trade behavior are examined by adding dummy variables to the VAR models. Second, the pattern of co-movements between individual stocks and the market are examined by adding the price changes on TIPs to the VAR models. Third, Granger causality tests are used to identify the causal direction between quote revision and trade.

The empirical findings identify strong interactions between quotes and trades. For the four-equation VAR system, quoted price levels and quoted depth are used simultaneously by market makers to protect themselves from trades with informed traders and to fulfil their mandate as liquidity providers in the market. While quoted price changes are related strongly to order flow which reflects an adverse selection process of quote revision, quoted depth changes are due mainly to the liquidity supply motivations. Trade innovation is related significantly to previous quote changes, which indicates that public investors obtain information by observing quote changes, and then adjust their trading activities accordingly. Trading frequency is significantly affected by a switch in the trading mechanism and weekend informational uncertainties (specifically, the number of trades is significantly high during market opens and low during Monday market opens). The overall results imply that the price discovery process is affected by the historical trading and quotation activities for information asymmetry and liquidity supply reasons, although the automation and transparency of the trading process helps to make this process more efficient.

The remainder of this chapter is organized as follows: a brief review of the literature and the measures of market quotation and trade activities are presented in the next two sections. The sample, data and data manipulation are described in section four. The empirical models and hypotheses are discussed in section five. The empirical results are presented and analyzed in section six. The major findings and their implications are offered in section seven.

2.2 Review of The Literature

Trading generates price movements in three ways: first, the existence of traders with private information implies that rational market makers adjust their beliefs (and hence quotes) in response to order flow; second, inventory carrying costs create incentives for market makers to use prices to affect changes in their inventories; and third, transaction costs result in a "bid-ask bounce" as buy and sell orders arrive randomly. Most of the theoretical models for trading behavior focus on either the asymmetric-information or the inventory-control problem faced by market makers. Both types of models predict that prices move in the direction of the order flow, although for different reasons. Given nonnegativity constraints and carrying costs, the inventory-control models predict that the specialist sets quotes as an inventory-control mechanism, due to an imbalance of buy and sell orders, so as to maintain the inventory within some optimal neighborhood. These models focus on the problem that changes in the stocks and cash held by specialists follow a random walk, which, in turn, lead to large positive or negative inventory positions [e.g., Garman (1976), Stoll (1976), Amihud and Mendelson (1980, 1982), Ho and Stoll (1980, 1981, 1983), and O'Hara and Oldfield (1986)]. The asymmetric-information models address the problem of an uninformed market maker whose posted quotations become exposed to the actions of informed traders [e.g., Copeland and Galai (1983), Glosten and Milgrom (1985), Kyle (1985), Easley and O'Hara (1987), Glosten (1989), and Admati and Pfleiderer (1988)]. The market maker perceives each order as having some positive probability of being originated by an informed trader. Thus, orders convey information which may cause the market maker to update his quotes.

Hasbrouck (1988, 1991a, 1991b, 1993) presents an empirical framework which allows for the simultaneous existence of inventory-control and asymmetric-information effects. The primary implications of the model are that quote revisions are serially uncorrelated, and the impact of trades on quotes is persistent. He finds that negative autocorrelation in trades consistent with inventory-control behavior characterizes low-volume (and not high-volume) stocks, and that the evidence for inventory control for the impact of trades on quote revisions is inconclusive. The information content of trades is substantial, and large trades convey more information than small trades. Hasbrouck (1988) argues that the information and inventory control effects can be partially resolved based on the persistence of their impacts on security prices. Hasbrouck (1991a) states that inventory control effects and other non-information imperfections (such as price discreteness, price pressure, order fragmentation, and price smoothing) are inherently transient, and that the information inferred from a trade due to asymmetric information is impounded permanently into the stock price. Hasbrouck (1988) suggests that the private information inferred from a trade should only arive from the unanticipated trade component (i.e., trade innovation).

Based on a Bayesian model of intraday security price movements, Madhavan and Smidt (1991) find strong evidence of information asymmetry from the specialist's perspective, and a weak inventory effect. They also find that prices respond differently for large-block trades relative to small trades, and for buyer-initiated trades relative to seller-initiated trades.

Huang and Stoll (1994) develop a two-equation econometric model of quote revisions and transaction returns. They find that quote revisions react positively to the deviation of the trade price from the quote midpoint (i.e., one-half of the effective spread) in the prior period, z_{t-1}, which reflects the adjustment of quotes to private information contained in the prior trade. They find that five-minute transaction returns react negatively to z_{t-1}. This reflects an attenuated bid-ask bounce necessary to compensate market makers for the cost of processing orders. They also find that quoted depth conveys information in that quote and price returns tend to be negatively related to prior depth imbalance (i.e., ask depth minus bid depth). Huang and Stoll conclude that their model is successful in making out-of-sample predictions compared to naive alternatives, which is inconsistent with the efficient market hypothesis

(EMH). Not only may the predictive power of their model be due to the inclusion of past stock index future returns in their model, but most investors may not be able to economically exploit their predictions after allowing for transaction costs.

2.3 Measures of Market Quotation and Trade Activities

Market quotes are adjusted after a trade, and this process occurs in transaction and not (equally spaced) calendar time intervals.[11] However, the use of transaction time neglects the use of an important measure, time length between trades, which reflects information according to Easley and O'Hara (1992b). In contrast, the use of equally spaced calendar time intervals results in an aggregation problem no matter how small the chosen time interval is (for example, five, fifteen or thirty minutes). A 30-minute time interval is selected for this study after examining the trading and quotation frequencies, and the proportion of no trading periods for various calendar time interval lengths. The trading frequencies of even actively traded stocks on the TSE are not as smoothly continuous as is assumed in most of the theoretical models. If too many no trading periods exist in a time series, the real relationship among the variables can not be extracted. Although some empirical studies use very small time intervals,[12] they fail to reveal the percentage of no trading intervals in their samples.

For each interval, all transactions are aggregated as if they were one trade at a

[11] Transaction time intervals are not necessarily equal to each other, while calendar time intervals are equally spaced. For a detailed discussion of transaction and calendar time, see Hasbrouck (1991a).

[12] For example, Huang and Stoll (1994) use five minute intervals, Hasbrouck (1991a,b) uses transaction time intervals, and Lee, Mucklow and Ready (1993) and McInish and Wood (1992) uses 30-minute intervals for stocks on the NYSE.

transaction price (P_t) equal to the average price of all trades within the interval, and at a trade size (VOL_t) equal to the total trading volume of all trades within the interval. Trading frequency is measured by the number of trades in each interval (NT_t). The average price is statistically superior for reflecting price information for all trades than any single point price such as the closing price. Using the total volume as a proxy of trade size is superior to the use of average volume because total volume reflects the total number of shares traded in that interval, and the number of trades is used to measure trading frequency. Thus, the measures of three dimensions of trade activity (average price, total trading volume, and number of trades) reflect more information than the two dimensions commonly used in the literature (namely, average price and volume).

Similarly, the last rather than the average quotation is used to capture the most recent information about quote behavior, because quotes reflect information only from one side of the market (the market maker). B_t is the last bid price for interval t, A_t is the last ask price for interval t, DB_t is the quoted depth (size) of the last bid for interval t, and DA_t is the quoted depth (size) of the last ask for interval t. Since quoted orders become trades once crossed with market orders, information contained in the quotes within an interval are reflected in the trade measures. Thus, the last quote is the most updated quote immediately after the last trade within the interval.

A sequence of trades and quotes is characterized as follows: If the transaction at t occurs after the closing quotation at t-1 or the opening quotation at t, then the quotation at t is adjusted after the transaction at t. Therefore, a trade occurs ahead of a quote for the same subscript t. If no transaction occurs in the interval t, $VOL_t = NT_t$

$= 0$. Also, since $P_t = P_{t-1}$, the price change $\Delta P_t = P_t - P_{t-1} = 0$, based on the assumption that the absence of trading implies an unchanged price. If no new quotations occur in the interval t, $B_t = B_{t-1}$, $A_t = A_{t-1}$, $DB_t = DB_{t-1}$, $DA_t = DA_{t-1}$, and their respective changes are all equal to zero.

After opening with a batch auction, the TSE like the NYSE switches to continuous trading for the remainder of the trading session. French and Roll (1986) find that stock prices are more volatile when the market is open. Amihud and Mendelson (1987) find that opening returns exhibit greater dispersion, greater deviations from normality, and a more negative and significant autocorrelation pattern than closing returns. These results suggest that the no trading overnight period increases uncertainty or price volatility, while trading reduces price volatility. Three dummy variables TO_t, TC_t and QO_t are used to measure differential effects at the opening, and in closing trades and opening quotes, respectively. Two dummy variables (MTO_t and MQO_t) are used to measure differential effects on Monday opening trades and quotes, respectively.

2.4 The Sample, Data and Data Manipulation

The initial sample consists of all of the stocks in the TSE 35 index because they are actively traded in the market (see **Appendix 2** for a detailed description of this index). For each stock, time-stamped trades (to the nearest second), trade size, and bid/ask quotes are drawn from the TSE transaction database for the period 1 July 1990 to 30 June 1991. There are four stocks (i.e., CAE, SCC, STM and TOC) traded on CATS and the rest on the floor during the sample period. The data are summarized into 3276 intervals using 13 intervals of 30-minutes for each trading day (9:30 AM to 4:00 PM). Stock prices are adjusted for dividend distributions at the openings of the ex-dividend dates.[13]

Basic statistics about the trade variables are given in **Table 2-1**, where a time-series average is reported for each individual stock, and a cross-sectional average is reported for the sample for each measure. The cross-sectional average percentage of no trading intervals over the 3276 30-minute intervals is 14.7%, and ranges from 0.31% for B to 52.35% for SCC. The cross-sectional average transaction price and its standard deviation are C$22.36 and C$2.32, respectively. The average individual stock prices range from C$5.81 for CAE to C$101.59 for VO, with a standard deviation of C$17.43. The cross-sectional average trading volume and its standard deviation are 16,720 and 61,019 shares, respectively. The average trading volume for individual stocks ranges from 3,763 shares for STM to 60,198 shares for LDM.B, with a standard deviation of 12,173 shares. The cross-sectional average number of trades and its standard deviation are 10.22 and 10.40 trades, respectively. They range from 1.37 trades for SCC to 33.22 trades for BNS, with a standard deviation of 8.39 trades. The cross-sectional average transaction return and its standard deviation are -0.0004% and 0.53%, respectively. They range from -0.0292% for STE.A to 0.0084% for NTL, with a standard deviation of 0.0086%. The cross-sectional no trading periods average 483 out of the 3276 intervals, with a standard deviation of 462 periods. They range from 10 for B to 1715 for SCC (a CATS traded stock). By

[13] None of the 35 stocks split during the sample period.

examining the trading volume, the number of trades and the no trading periods, the four stocks traded on CATS are less actively traded compared to the others in the sample.

[Insert Table 2-1 About Here.]

The quotation statistics for the 35 stocks are summarized in **Table 2-2**. The cross-sectional average quote mid-point price and its standard deviation are C$22.37 and C$2.33, respectively. The average individual stock quote mid-point price ranges from C$5.81 for CAE to C$101.59 for VO, with a standard deviation of C$17.43. This is very close to the average of the transaction prices. The cross-sectional average depth and its standard deviation are 396.11 and 219.40 board lots (where one board lot equals 100 shares), respectively. The average depths for individual stocks range from 37.91 board lots for VO to 1402.38 board lots for NVA, with a standard deviation of 290.67 board lots. The cross-sectional average quoted bid-ask spread and its standard deviation are C$0.1546 and C$0.0510, respectively. The average spreads for individual stocks range from C$0.1118 for CAE to C$0.2682 for VO, with a standard deviation of 0.0295. The spread tends to be positively related to transaction price. The cross-sectional average quote mid-point return and its standard deviation are -0.0015% and 0.4302%, respectively. The average quote mid-point returns for individual stocks range from -0.0297% for STE.A to 0.0080% for NTL, with a standard deviation of 0.0083%. Both the cross-sectional average transaction return and its standard deviation are higher than the average quote mid-point return and its standard deviation.[14] If the average transaction price in interval t equals the prior quote mid-point, the trade for this interval cannot be classified as being buy or sell initiated. A cross-sectional average of 104 intervals have transaction prices equal to the prior mid-point quote, with a standard deviation of 51.71 periods. The number of such intervals ranges from 15 for BNS to 236 for ECO.

[Insert Table 2-2 About Here.]

The intraday patterns of price changes, quote revisions, depth imbalance, trading volume, number of trades, and signed trading volume are plotted in **Figure 2-1**. The plots are cross-sectional averages for the 35 stocks in the TSE 35 Index over the one-year sample period. Price changes and quote revisions have similar intraday patterns, with a significantly negative average return in the first 30-minute interval of each day and a positive average return in the last 30-minute interval of each day. Depth imbalances are negative in all 30-minute intervals of a day, and gradually increase during the day. This suggests that depth in bid dominates depth in ask on average, and that the differences decline over the day for the sample studied herein. Both trading volume and number of trades show a intraday U-shape, which indicates that trading is more active during the opening and the closing intervals (especially the opening). Average signed trading volume is positive for the opening interval, and negative for the closing interval. This suggests that, on average, buy-initiated trades

[14] The differences between quote and transaction returns are not statistically significant (t-value equals 0.5461). The minor differences for some individual stocks is probably due to various microstructure effects such as bid/ask bounce and asymmetrical trade direction. No reason exists to believe that this is due to the data aggregation procedure in which the transaction price is the average of all transactions within the 30-minute interval and the quote prices are based on the last bid and ask prices for each interval.

dominate at the open and sell-initiated trades dominate at the close.

[Insert Figure 2-1 About Here.]

2.5 Empirical Models and Hypotheses

2.5.1 A VAR System of Quote Revision and Trade Innovation

A Vector Autoregression (VAR) system of quote and trade specifications is proposed in this study based on the econometric models used by Hasbrouck (1991a, 1991b, and 1993), Madhavan and Smidt (1991), and Huang and Stoll (1994) to examine the interaction between trade and quote revision. The adjustment of quotes over time is based on the beliefs of market makers about true prices, which are conditional expectations based on the information sets used (such as the trading histories). According to Easley and O'Hara (1992b), the quote depends in a specific way on the outcomes for previous trading periods. The trading history should incorporate a broad information set, which includes trading volume, trade innovations, and the histories of quote revisions, price changes, order sizes, and bid-ask spreads.

A quote is specified by two variables: quote level revision, $r_{q,t}$, and depth imbalance, DI_t, which measure possible quote movement in the two dimensions of price and depth. The quote level revision is defined as the quote mid-point return, i.e., $r_{q,t} = ln[(A_t+B_t)/2] - ln[(B_{t-1}+A_{t-1})/2]$. In the literature, the mid-point normally is assumed to be the market consensus price because the quote price may be a better proxy of the efficient stock price than the transaction price due to transaction costs.

The depth imbalance, which equals the depth in ask minus the depth in bid (DI_t = DA_t - DB_t), is a market liquidity measure of the immediate market supply at the ask over the bid.

A trade is specified by four variables: signed square-root trading volume (SX_t), changes in number of trades (RNT_t), and relative heavy and thin trading indicators (RHT_t and RTT_t). Trade volume is a direct measure of trading activity which varies with competition and information arrival. Square-root trading volume is used instead of trading volume to smooth the impact of outliers. Trade direction (buy or sell initiated trade) is identified by comparing the current trade price to the mid-point of the prevailing bid/ask quote. A trade is a "buy" if the trade price is higher than the prevailing quote mid-point, and a "sell" if the price is lower, and "undetermined" if the price is the same [Blume, MacKinlay and Terker (1989)].[15] The signed square-root trading volume is measured as $Q_t\sqrt{VOL_t}$, where Q_t equals 1 if a trade is a "buy", -1 if a "sell", and 0 if an "undetermined" trade. Since public news about a stock's future dividends generates abnormal trading [Wang (1994)], relative heavy and thin trading interval indicators, RHT_t and RTT_t, are used to measure abnormal tradings, based on an assumed market memory of one month (260 periods for 20 trading days). RHT_t (RTT_t) $= 1$ if VOL_t is in the top (bottom) 10% of the trading volumes in the past month. $RTT_t = 1$ when $VOL_t = 0$ (no trading interval); and RHT_t

[15] Another method for identifying trade direction is the tick test, which compares the current-to-previous transaction prices. Lee and Ready (1991) provide details on the identification of trade direction and a comparison of different methods. Two methods are used in this study, and both produce highly correlated trade direction classifications (generally above 90%) herein. The method with less "undetermined" is used hereafter.

$= RTT_t = 0$, otherwise. The number of trades may measure a different information content than trading volume according to McInish and Wood (1991). For example, high volume may consist of one or several block trades, or many relatively smaller trades. According to microstructure theory, the most likely cause of the former and latter are liquidity and information tradings, respectively. McInish and Wood (1991) find that number of trades is the dominant component in relationship to the transaction returns. The change in number of trades, $RNT_t = NT_t - NT_{t-1}$, is used to reflect this aspect of information.

Combining the information revealed from past trading activities with the market mechanism results in the following quote level revision model:

$$r_{q,t} = a_0 + a_1 z_t + a_2 TRP_t + a_3 SX_t + a_4 RNT_t + a_5 RHT_t + a_6 RTT_t$$
$$+ a_7 r_{q,t-1} + a_8 DI_{t-1} + a_9 QO_t + a_{10} MQO_t + e_t. \quad (2.1)$$

where $z_t = lnP_t - ln[(B_{t-1} + A_{t-1})/2]$ is one-half of the effective bid-ask spread measure expressed as a proportion of the quote's midpoint [Huang and Stoll (1994)];[16] TRP_t is the 30-minute return on TIPs designed to capture the cross-stock (market) price co-movement; QO_t is a dummy variable to capture the open quote; MQO_t is a dummy variable for Monday opening in order to capture the weekly effect; e_t is the disturbance, which measures the innovation in the quote mid-point due to the arrival of new information not reflected in the trade and quote revision history; and all the other variables are as defined before.

When examining the impact of trades on quote level revisions, a significant

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[16] A positive (negative) z_t indicates a trade at or close to the ask A_{t-1} (bid B_{t-1}).

and positive z_t signifies that market makers revise quotes based on the private information revealed through trading, if the only source of the bid-ask spread is private information [Glosten and Milgrom (1985)]. If the market maker perceives this upwards shift as being demand-driven or information trading, he will revise the next quote at t upwards. The inventory holding cost theory of Ho and Stoll (1983) predicts that the quotes are adjusted in the same direction as the prior trade, since a market maker (the dealer) expects to buy by raising the quote after a sell-initiated trade (i.e., a prior trade which is above the quote midpoint). The TRP_t is expected to be positively related to $r_{q,t}$ if the individual stock price moves in the same direction as the market.

The coefficient of SX_t measures the information asymmetric effect of informed trading on price changes. The quote is revised positively to SX_t for a market maker who fears adverse information (asymmetric information argument), and wants to be compensated for inventory carrying costs (inventory cost argument). If trading volumes reflect information, buy- (sell-) initiated trading drives quote levels upwards (downwards). Sometimes, signed trading volumes cannot reflect fully the information conveyed in trading activities. For example, a zero (undetermined) is assigned to trading volume if the transaction price is equal to the last quote mid-point or the prior transaction price.

RNT_t, RHT_t and RTT_t are measures of trading activity that may measure different information contents than signed square-root volume SX_t. Positive (negative) RNT_t signify that the number of trades is increasing (decreasing). Quote levels should react significantly to RNT_t if market makers treat such changes in trading frequencies as information events. However, the direction of such quote level revisions is unknown since good or bad news can increase trade numbers. RNT_t is more informative than signed trading volume when the transaction price is at the mid-point of the previous quote, (i.e., when SX_t equals zero).

RHT_t and RTT_t are measures of abnormal trading volumes. Large trading volumes are generally equated with the block trades of institutional investors. While some observers argue that block trades reflect information, others argue that institutional investors are often liquidity traders, whose trades have no information effects on prices since they are crossed by specialists "upstairs" [Barclay and Warner (1993)]. RHT_t should be significantly related to $r_{q,t}$ if market makers treat heavy trading volumes as being caused by information events. Insignificance indicates no information content due to block trades (probably due to liquidity trading). Thin trading volumes often are related to the probabilities of information events [Easley and O'Hara (1992b)]. While the quote level should not change if no information enters the market, the bid-ask spread should narrow. RTT_t is insignificantly related to $r_{q,t}$ if thin trading implies no information arrival.

The lagged quote level revision, $r_{q,t-1}$, should provide useful information on the noninstantaneous quote revision processes due to market stabilization, limit orders and transaction costs. A positive effect of the lagged quote level revision on the subsequent one indicates a slow and gradual adjustment of quote levels. Alternatively, negative serial correlation in quote level revision captures inventory effects due to market makers adjusting their quote levels to induce inventory equilibrating trades [Huang and Stoll (1994)]. Depth imbalance measures the difference between the quote sizes for the ask and the bid. If negative, then demand exceeds supply. Since the following trade is driven by a "buy", the transaction price is most likely to be at or close to the ask. Depth imbalance should have a negative impact on price movements and quote revisions if limit orders reflect private information, or a positive impact if the specialist's inventory effect is significant [Huang and Stoll (1994)]. This inventory effect is based on the assumption that a specialist adjusts both quotes and depths to encourage transactions that equilibrate inventory. A specialist with a larger inventory at time *t-1* simultaneously lowers quotes and raises depth at the ask to attract buyers. Since price is low at *t-1*, the probability of a positive return is higher than that for a negative return over *t-1* to *t*. Therefore, a positive association between quote revision and depth imbalance should result.

Quote revisions include adjustments of the quote level, bid-ask spread, and bid and ask depths. The dependence of depth imbalance on the previous trade is examined herein using the following equation:

$$DI_t = b_0 + b_1 z_t + b_2 TRP_t + b_3 SX_t + b_4 RNT_t + b_5 RHT_t + b_6 RTT_t + b_7 r_{q,t-1} + b_8 DI_{t-1} + b_9 QO_t + b_{10} MQO_t + w_t. \tag{2.2}$$

where w_t is the residual depth imbalance used to capture the new and private information not reflected in the trading history, and all the other terms are as defined earlier. DI_t is positively related to z_t if the information conveyed by a transaction price higher than the prior quote mid-point induces more buy orders at ask prices, and the market maker has to increase depth in ask relative to in bid to fufil his mandate to provide market liquidity. Based on the adverse selection and inventory arguments, DI_t should be negatively related to z_t because a market maker should buy rather than sell more to increase the depth in bid in order to protect himself from trading with informed traders and to induce sell orders. DI_t should be negatively related to TRP_t if a positive market return reveals good news to the market. DI_t should be negatively related to SX_t and RNT_t due to the information content of trading volume and number of trades. If abnormal trading reflects the probability of information events, DI_t should respond significantly to RHT_t, and insignificantly to RTT_t. DI_t should be negatively related to $r_{q,t-1}$ and positively related to DI_{t-1} due to the information effect of previous quote revisions.

Since trades are assumed to be triggered by new information and the time dependence of trades is due to liquidity reasons, informed trading should not depend on previous quote revisions. Rational (liquidity) traders may reveal information in prior quotations and trades, if market makers are better informed or informed earlier than ordinary (uninformed) investors. The following trade innovation models are used to test the dependency of trade on trading history and quote revision:

$$SX_t = c_0 + c_1 z_{t-1} + c_2 TRP_{t-1} + c_3 SX_{t-1} + c_4 RNT_{t-1} + c_5 RHT_{t-1} + c_6 RTT_{t-1} + c_7 r_{q,t-1} + c_8 DI_{t-1} + c_9 TO_t + c_{10} TC_t + c_{11} MTO_t + u_t. \qquad (2.3)$$

$$RNT_t = d_0 + d_1 z_{t-1} + d_2 TRP_{t-1} + d_3 SX_{t-1} + d_4 RNT_{t-1} + d_5 RHT_{t-1} + d_6 RTT_{t-1} + d_7 r_{q,t-1} + d_8 DI_{t-1} + d_9 TO_t + d_{10} TC_t + d_{11} MTO_t + v_t. \qquad (2.4)$$

where u_t and v_t capture the unanticipated (innovative) component of trade relative to an expectation formed from a linear projection on the trade and quote revision history, respectively; and all the other terms are as defined earlier. Both SX_t and RNT_t are expected to be positively related to z_{t-1}, TRP_{t-1}, SX_{t-1}, RNT_{t-1} and RHT_{t-1}, and insignificantly related to RTT_{t-1} if the public believes previous trading history reveals information. Both SX_t and RNT_t should increase as the prior quote is revised upwards if the public believes that the market makers' quote revisions reflect information. If SX_t and RNT_t are negatively related to $r_{q,t-1}$, this implies that the crowd will sell or not trade while the quote is being lifted above their price expectation. This suggests no informational impact from quote revision to trade. SX_t is expected to be negatively related to DI_{t-1}, since the crowd will place more sell orders if they learn that the market maker increases the ask depth or decreases the bid depth. This implies an informational effect of depth on trade. RNT_t could respond to DI_{t-1} in either direction. Positive (negative) significance indicates that more (less) individuals trade if the market maker increases his liquidity supply in ask relative to in bid.

The impact of the trading mechanism (batch versus continuous auctions) is tested by the inclusion of the dummy variables QO_t, TO_t and TC_t for daily open quotes, open trades, and close trades, respectively, in (2.1) to (2.4). Seasonality is tested by including the dummy variable MQO_t (MTO_t) which is equal to 1 if the open quote (open trade) occurs on Monday, and to 0 otherwise. If information bunching occurs on weekends, the quote should be revised significantly on Monday opening. According to the information uncertainty argument, no trading on the weekend should increase the volatility of information events, which should negatively impact quote revisions. Signed square-root trading volumes should be positive (negative) on Monday opening for good (bad) news. The changes in number of trades should increase on Monday opening, if information bunching occurs. If no significance is found for SX_t and RNT_t to MTO_t, then no information accumulation occurs on the weekends.

The final VAR system, which consists of equations (2.1), (2.2), (2.3) and (2.4), can be estimated jointly or separately. The specification is restricted to one lag because experimentation indicates that more distant lags provide little additional explanatory power for quote level revision in (2.1) and signed square-root trading volume innovation in (2.2) [as in Huang and Stoll (1994)]. If the four equations are jointly estimated as a VAR system, a restriction must be imposed on the residuals (namely, covariance stationarity). Thus, e_t, w_t, u_t and v_t must not only be normally distributed, i.i.d. and serially uncorelated $[E(e_te_{t-1}) = E(w_tw_{t-1}) = E(u_tu_{t-1}) = E(v_tv_{t-1}) = 0]$, but also $E(e_tw_t) = E(e_tu_t) = E(e_tv_t) = E(w_tu_t) = E(w_tv_t) = E(u_tv_t) = 0$. In this VAR system, $r_{q,t}$, DI_t, SX_t and RNT_t are endogenous variables, and z_t, TRP_t, RHT_t, RTT_t, QO_t, MQO_t, TO_t, MTO_t and TC_t are exogenous variables.

The hypotheses and restrictions imposed on the VAR system by related microstructure theories are summarized as follows:

Adverse information: $a_1>0$, $a_3>0$, $a_4\neq 0$, $a_5\neq 0$, $a_6=0$, and $a_8<0$ in (2.1) for information effects of trade and quote history on quote level revisions; $b_1<0$, $b_3<0$, $b_4\neq 0$, $b_5\neq 0$, $b_6=0$, $b_7<0$ and $b_8>0$ in (2.2); $c_1>0$, $c_3>0$, $c_4\neq 0$, $c_5\neq 0$, $c_6=0$, $c_7>0$ and $c_8<0$ in (2.3); and $d_1>0$, $d_3>0$, $d_4\neq 0$, $d_5\neq 0$, $d_6=0$, $d_7>0$ and $d_8\neq 0$ in (2.4).

Inventory holding cost: $a_1>0$, $a_3>0$, $a_7<0$, $a_8>0$ in (2.1), $b_1<0$, $b_8<0$ in (2.2).

Liquidity supply: $b_1>0$, $b_3>0$ in (2.2).

Market efficiency: $a_2=0$, $b_2=0$, $c_2=0$ and $d_2=0$ in (2.1) - (2.4).

Block trading for liquidity reason: $a_5=0$, $b_2=0$, $c_2=0$ and $d_2=0$ in (2.1) - (2.4).

Trading Mechanism: $a_9\neq 0$, $b_9\neq 0$, $c_9\neq 0$ and $d_9\neq 0$ for market open in (2.1) - (2.4), and $d_{10} \neq 0$, $c_{10} \neq 0$ for market close in (2.3) and (2.4).

Weekend effect: $a_{10} \neq 0$, $b_{10} \neq 0$, $c_{11} \neq 0$ and $d_{11} \neq 0$ for Monday open in (2.1) - (2.4).

2.5.2 Two Special Cases of the VAR system

The four-equation VAR system may be very restrictive and its estimates may be biased due to the violation of the assumptions on the distributions and stationarity of the residuals. A potential solution is to reduce the number of equations and to increase the lag lengths. If the quote mid-point revision is the only measure of quote revision, and the signed square-root trading volume is the only measure of a trade, the four-equation system reduces to the following two-equation system:

$$r_{q,t} = \alpha_0 + \alpha_1 r_{q,t-1} + \alpha_2 r_{q,t-2} + \alpha_3 r_{q,t-3} + \alpha_4 r_{q,t-12} + \alpha_5 r_{q,t-13}$$
$$+ \beta_0 SX_t + \beta_1 SX_{t-1} + \beta_2 SX_{t-2} + \beta_3 SX_{t-12} + \beta_4 SX_{t-13}$$
$$+ \beta_5 QO_t + \beta_6 MQO_t + e1_t. \tag{2.5}$$

$$SX_t = \gamma_0 + \gamma_1 r_{q,t-1} + \gamma_2 r_{q,t-2} + \gamma_3 r_{q,t-3} + \gamma_4 r_{q,t-12} + \gamma_5 r_{q,t-13}$$
$$+ \delta_1 SX_{t-1} + \delta_2 SX_{t-2} + \delta_3 SX_{t-3} + \delta_4 SX_{t-12} + \delta_5 SX_{t-13}$$
$$+ \delta_6 TO_t + \delta_7 TC_t + \delta_8 MTO_t + u1_t. \tag{2.6}$$

where all the terms are as defined earlier. If the change in the number of trades RNT_t is used as the sole trade measure instead of SX_t, equations (2.5) and (2.6) can be rewritten as:

$$r_{q,t} = \alpha 1_0 + \alpha 1_1 r_{q,t-1} + \alpha 1_2 r_{q,t-2} + \alpha 1_3 r_{q,t-3} + \alpha 1_4 r_{q,t-12} + \alpha 1_5 r_{q,t-13}$$
$$+ \beta 1_0 RNT_t + \beta 1_1 RNT_{t-1} + \beta 1_2 RNT_{t-2} + \beta 1_3 RNT_{t-12} + \beta 1_4 RNT_{t-13}$$
$$+ \beta 1_5 QO_t + \beta 1_6 MQO_t + e2_t. \tag{2.7}$$

$$RNT_t = \gamma 1_0 + \gamma 1_1 r_{q,t-1} + \gamma 1_2 r_{q,t-2} + \gamma 1_3 r_{q,t-3} + \gamma 1_4 r_{q,t-12} + \gamma 1_5 r_{q,t-13}$$
$$+ \delta 1_1 RNT_{t-1} + \delta 1_2 RNT_{t-2} + \delta 1_3 RNT_{t-3} + \delta 1_4 RNT_{t-12} + \delta 1_5 RNT_{t-13}$$
$$+ \delta 1_6 TO_t + \delta 1_7 TC_t + \delta 1_8 MTO_t + v1_t. \tag{2.8}$$

Equations (2.5) and (2.6) constitute a two-equation VAR system similar to Hasbrouck (1988, 1991a, 1991b and 1993). According to Hasbrouck (1991a), the lagged effects of both quote and trade are probably caused by microstructure imperfections such as inventory control effects, lagged adjustment to information, exchange-mandated price smoothing, and threshold effects. Threshold effects are induced by price discreteness since a quote revision may not be optimal until a series of trades of the same direction occur. Since the lagged structure may be of infinite order, it is truncated at lag that is considered to be relatively important for empirical work. As in the four equation system, the disturbance $e1_t$ (or $e2_t$) should reflect public information, and $u1_t$ (or $v1_t$) should capture the unanticipated trade component (which, in turn, may reflect private information inferred from a trade).

If a quote revision has a trade impact, then the coefficients of SX_{t-i} $(i = 0, 1, 2, 12, 13)$ or RNT_{t-i} $(i = 0, 1, 2, 12, 13)$ should be significantly different from zero in equation (2.5) or (2.7), respectively. The lagged effects of quote revisions $r_{q,t-i}$ $(i = 1, 2, 3, 12, 13)$ in both (2.5) and (2.7) are assessed by the significance of their coefficients. If quote revisions affect trading, then the coefficients of $r_{q,t-i}$ should be significantly different from zero in equation (2.6) or (2.8).

2.5.3 Granger-Sims Causality Pattern between Quote and Trade

Since the data set of quotes and trades are arranged as a sequence along the time dimension, the structure of the time series VAR models in the previous two sub-sections permit causality from trades to quote revisions contemporaneously,and from lagged quote revisions to trades.[17]

The first hypothesis, that quotes are caused by previous trades, is tested using the following restricted forms:

$$r_{q,t} = a'_0 + a'_1 z_t + a'_2 TRP_t + a'_7 r_{q,t-1} + a'_8 DI_{t-1} + a'_9 QO_t + a'_{10} MQO_t + e'_t. \tag{2.9}$$

$$DI_t = b'_0 + b'_1 z_t + b'_2 TRP_t + b'_7 r_{q,t-1} + b'_8 DI_{t-1} + b'_9 QO_t + b'_{10} MQO_t + w'_t. \tag{2.10}$$

$$r_{q,t} = \alpha'_0 + \alpha'_1 r_{q,t-1} + \alpha'_2 r_{q,t-2} + \alpha'_3 r_{q,t-3} + \alpha'_4 r_{q,t-12} + \alpha'_5 r_{q,t-13} + \beta'_5 QO_t + \beta'_6 MQO_t + e1'_t. \tag{2.11}$$

where all the terms are as defined earlier. Equations (2.9) and (2.10) are the restricted forms of equations (2.1) and (2.2), respectively; and equation (2.11) is the restricted form for both equations (2.5) and (2.7). These restricted forms allow for a test of the null hypothesis that quote revisions are caused by previous trades represented by signed square-root trading volume, changes in number of trades, relative heavy and thin trading indicators jointly, or by signed square-root trading volume, or by changes in number of trades. The hypothesis that the depth imbalances are caused by prior trades represented by signed square-root trading volume, changes in number of trades, and relatively heavy and thin trading indicators jointly can be tested contemporaneously.

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[17] A time lag exists between a quote and a trade with the same subscript t.

The second hypothesis, that trades are caused by previous quotes, is tested by using the following restricted forms:

$$SX_t = c'_0 + c'_1 z_{t-1} + c'_2 TRP_{t-1} + c'_3 SX_{t-1} + c'_4 RNT_{t-1} + c'_5 RHT_{t-1} + c'_6 RTT_{t-1} + c'_9 TO_t + c'_{10} TC_t + c'_{11} MTO_t + u'_t. \quad (2.12)$$

$$RNT_t = d'_0 + d'_1 z_{t-1} + d'_2 TRP_{t-1} + d'_3 SX_{t-1} + d'_4 RNT_{t-1} + d'_5 RHT_{t-1} + d'_6 RTT_{t-1} + d'_9 TO_t + d'_{10} TC_t + d'_{11} MTO_t + v'_t. \quad (2.13)$$

$$SX_t = \gamma'_0 + \delta'_1 SX_{t-1} + \delta'_2 SX_{t-2} + \delta'_3 SX_{t-3} + \delta'_4 SX_{t-12} + \delta'_5 SX_{t-13} + \delta'_6 TO_t + \delta'_7 TC_t + \delta'_8 MTO_t + u1'_t. \quad (2.14)$$

$$RNT_t = \gamma 1'_0 + \delta 1'_1 RNT_{t-1} + \delta 1'_2 RNT_{t-2} + \delta 1'_3 RNT_{t-3} + \delta 1'_4 RNT_{t-12} + \delta 1'_5 RNT_{t-13} + \delta 1'_6 TO_t + \delta 1'_7 TC_t + \delta 1'_8 MTO_t + v1'_t. \quad (2.15)$$

where all the terms are as defined earlier. Equations (2.12), (2.13), (2.14) and (2.15) are the restricted forms of equations (2.3), (2.4), (2.6) and (2.8). This allows for a test of the null hypothesis that trades (represented by SX_t or RNT_t) are caused by previous quote revisions (represented by $r_{q,t-1}$ and DI_{t-1} jointly). The hypothesis that signed square-root volume (or changes in number of trades) are caused by previous quote level revisions can be tested simultaneously.

2.5.4 Test Methods and Procedures

The Box-Jenkins methodology and unit root tests are used to study the stationarity and the autocorrelation structure for the univariate time series of quote level revisions ($r_{q,t}$), depth imbalances (DI_t), signed square-root volumes (SX_t), and changes in number of trades ($\Delta NT_t = NT_t - NT_{t-1}$).[18] Quote midpoint returns exhibit significant and negative first-order autocorrelations and weak higher-order autocorrelations. Depth imbalance exhibits significant and positive first-order and unpredictable higher-order autocorrelations. Signed square-root trading volumes exhibit significant and positive first-order autocorrelations and weak higher-order autocorrelations. The changes in number of trades exhibit significant and negative higher-order autocorrelations. All four variables exhibit intraday patterns. No significant unit roots are found in these univariate time series, which suggests that they are stationary.

All of the above empirical models are estimated using OLS with standard error and variance adjustments for heteroscedasticity using the White (1980) methodology. Except for equation (2.4), the residuals are normally distributed, and appear to exhibit no significant autocorrelations. The estimation results for the four CATS traded stocks are not reported separately since they are not significantly different from the rest of the sample.

2.6 Empirical Results

The empirical results for the VAR system consisting of equations (2.1), (2.2), (2.3) and (2.4), which examines the interaction between quotes and trades, are summarized in Tables 2-3, 2-4, 2-5 and 2-6, respectively. The information effect of trades on quote revisions is strongly significant across all the stocks in the sample.

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[18] The univariate time series properties of trading volumes (VOL_t), signed trading volumes (X_t), and number of trades (NT_t) for proxing a trade are examined first. The results show that SX_t and RNT_t are more consistent and perform better than the above variables in terms of stationarity and autocorrelation structure.

Based on **Table 2-3**, the cross-sectional average adjusted R-square for equation (2.1) is 44.68% (ranges from 20% to 74% for individual firms). The quote level revision is significantly and positively related to the half effective spread measure z_t. The cross-sectional average coefficient of 0.485 reflects the adjustment of quote level to the private information contained in the prior trade [as in Huang and Stoll (1994)]. This result is also consistent with compensation for inventory holding costs [Ho and Stoll (1983)], since a market maker attempts to buy by raising the quote after a sell-initiated trade (i.e., after a prior trade above the quote midpoint). The quote level revision is positively and significantly related to the returns on TIPs, which rejects the hypothesis of quote revision efficiency. However, only 7.2% of quote revision is explained, on average, by this market return proxy.

[Insert Table 2-3 About Here.]

On average, market quote revisions are related significantly and positively to prior signed square-root volume SX_t, but not with the number of trade changes RNT_t and relatively high or low tradings. The positive relationship with signed square-root trading volume suggests an information effect based on real market demands for and supplies of the traded security. If trading volumes reflect information, buy- (sell-) initiated trading drives quotes upwards (downwards). The insignificant relationship between quote revision and RNT_t suggests that market makers do not perceive the changes in the number of trades as information events on average, although one-third of the stocks (13 out of 35) exhibit significantly positive relationships between quote revision and RNT_t.

Since quote revision is insignificantly related to relatively high trading levels, the hypothesis of an information impact of block tradings is not supported. The insignificant relationship between quote revision and relatively low trading levels supports the hypothesis that the probability of information arrival in no or thin trading periods are low [Easley and O'Hara (1992b)]. The coefficient of $r_{q,t-1}$ is negative for most of the stocks in the sample, but only significant for ten stocks. Thus, the inventory cost hypothesis is not supported on average. Lagged depth imbalance has a significant and negative relationship with quote revision for most stocks (33 out of 35). This is consistent with the asymmetric information hypothesis, but inconsistent with the inventory cost hypothesis.

From **Table 2-4**, the cross-sectional average adjusted R-square for equation (2.2) is 33.15% (ranges from 4% to 79% for individual firms). Depth imbalance is significantly and positively related to the half effective spread measure z_t. The cross-sectional average coefficient of 4952 reflects the adjustment of depths in the ask over those in the bid when the private information contained in prior trade induces more buy orders. This supports the hypothesis that market makers are liquidity providers. On average, depth imbalance is insignificantly related to the returns on TIPs, signed square-root volume SX_t, number of trade changes RNT_t, and relatively high or low trading levels. This implies that the prior trade has no information impact on current depth imbalances. The coefficient of $r_{q,t-1}$ is significantly negative to current depth imbalance on average and for most of the sample stocks. This reflects an information effect where depth in bid is increased if the prior quote level is lifted. Lagged depth imbalance has a significant and positive relationship with current depth imbalance for all the stocks. While this is consistent with the information effect, it is inconsistent with the inventory cost effect. Previous trade influences current depth by forcing the market maker to fufil his mandate as a liquidity supplier, and previous quote changes have an information effect on the current depth adjustment.

[Insert Table 2-4 About Here.]

Based on **Table 2-5**, the cross-sectional average adjusted R-square for equation (2.3) of 2.32% (ranges from 1.8% to 6.5% for individual firms) indicates a very low explanatory power. Past effective spreads z_{t-1} are significantly and positively related to current SX_t, which suggests an information effect of effective spreads on trade. Both $r_{q,t-1}$ and DI_{t-1} are significantly and negatively related to current SX_t. This suggests that the crowd infers information from prior quotations and trades by assuming that market makers are better informed (or informed earlier) than they are. SX_t is negatively related to the prior quote revision because the crowd sells (buys) if the quote is raised above (lowered below) their expected security price. SX_t is negatively related to DI_{t-1}, which indicates that the crowd places more sell orders if they learn that the market maker increases the ask depth or decreases the bid depth. This suggests that the crowd is willing to follow the quote. SX_t is insignificantly related to TRP_{t-1}, SX_{t-1}, RNT_{t-1}, RHT_{t-1}, and RTT_{t-1}, on average, which suggests that trade is efficiently innovated from the previous trade.

[Insert Table 2-5 About Here.]

From **Table 2-6**, the cross-sectional average adjusted R-square for equation (2.4) of 30.22% (ranges from 24.24% to 36.2% for individual firms) is much higher than that for equation (2.3). RNT_t is significantly and negatively related to RNT_{t-1} and RHT_t, and significantly and positively related to RTT_{t-1}. The negative serial correlation in RNT_{t-1} suggests a mean reverting behavior in the number of trades over time. Number of trades decreases if block trades occur in the previous period, and increases if trading volumes are low in the previous period. Unlike signed square-root trading volumes, RNT_t is insignificantly related to prior quote revision measures, $r_{q,t-1}$ and DI_{t-1}, and to z_{t-1}, TRP_{t-1}, and SX_{t-1}.

[Insert Table 2-6 About Here.]

With regard to the impact of the trading mechanism and the weekend effect, $r_{q,t}$ and DI_t for daily or Monday openings are not significantly different on average, and $r_{q,t}$ is significantly lower at daily openings for only 13 (out of 35) stocks. SX_t is not significantly different for daily and Monday opens and daily closes, while RNT_t (changes in number of trades) is significantly higher for daily opens and closes, and lower for Monday opens.

The Durbin-Watson tests do not reject the hypothesis of no autocorrelation in the residuals for equations (2.1) through (2.4). The univariate analyses suggest that the results for some variables may improve further if higher-order lags are included in the models. This is done by examining the two special cases of the four-equation VAR system discussed earlier. The results for the first two-equation VAR system consisting of equations (2.5) and (2.6) are summarized in **Tables 2-7** and **2-8**, respectively. In equation (2.5), quote revisions are based on previous quote revisions and signed square-root trading volumes. The cross-sectional average adjusted R-square for this equation is 28%. On average, $r_{q,t}$ is significantly and negatively related to its first-order lag, and significantly and positively related to SX_t and SX_{t-1}. The significantly negative serial correlation in $r_{q,t}$ suggests that quotes are either over-revised initially or the existence of an error induced by price discreteness [Harris (1989)]. In equation (2.6), innovations in signed square-root volumes are based on previous quote revisions and signed square-root trading volumes. The average adjusted R-square for this equation is only 1%. On average, SX_t is significantly and negatively related to $r_{q,t-1}$, and significantly and positively related to SX_{t-1}.

[Insert Tables 2-7 and 2-8 About Here.]

The results for the second two-equation VAR system consisting of equations (2.7) and (2.8) are summarized in **Tables 2-9** and **2-10**, respectively. In equation (2.7) quote revisions are based on previous quote revisions ($r_{q,t-1}$) and changes in number of trades (RNT_t). The cross-sectional average adjusted R-square for this equation is 3%. On average, $r_{q,t}$ is significantly and negatively related to its first-order lag, and insignificantly related to RNT_t and its higher-order lags. In equation (2.8), innovations in the changes in number of trades are based on previous quote revisions and changes in number of trades. The cross-sectional average adjusted R-square for this equation is 36%. RNT_t is insignificantly related to $r_{q,t-1}$ and its higher-order lags, but significantly and negatively related to RNT_{t-1} and its higher-order intraday lags.

[Insert Tables 2-9 and 2-10 About Here.]

Likelihood Ratio (LR) tests are used for the restricted and unrestricted functions to investigate the causality patterns between quotes and trades. Based on the results summarized in **Table 2-11** for the four equation VAR system, the hypothesis that quote level revisions are caused by previous trading activities (signed square-root trading volume, changes in number of trades, and relative high and thin trading level indicators jointly) can not be rejected (cross-sectional average LR of 148.18). The hypothesis that depth imbalances are caused by previous trades (signed square-root trading volume, changes in number of trades, and relative high and thin trading level indicators jointly) is rejected (cross-sectional average LR of 3.4). The hypothesis that signed square-root trading volumes are caused by previous quotes (quote level revision and depth imbalance jointly) is not rejected (cross-sectional average LR of 59.85). The hypothesis that changes in number of trades are caused by previous quotes (quote level revision and depth imbalance jointly) is rejected (cross-sectional average LR of 1.16). For the two-equation VAR system based on quote revision and signed square-root trading volumes, the hypothesis that quote level revisions are caused by previous signed square-root trading volumes cannot be rejected (cross-sectional average LR of 1051.04). The hypothesis that signed square-root trading volumes are caused by previous quote level revision is also not rejected (cross-sectional average LR of 26.19). For the two-equation VAR system based on quote revision and changes in number of trades, the hypothesis that quote level revisions are caused by previous changes in number of trades cannot be rejected (cross-sectional average LR of 23.73). In contrast, the hypothesis that changes in number of trades are caused by previous quote level revision is rejected (cross-sectional average LR of 5.47). Thus, only the postulated relationships for depth imbalances and for changes in number of trades are not supported empirically. This result implies that quote depth adjustment is most likely caused by liquidity supply motivations rather than by information associated with the previous trade, and that the trades of informed traders are caused by their private information rather than by previous quote changes.

[Insert Table 2-11 About Here.]

2.7 Concluding Remarks

Most of the empirical results obtained herein for the strong interactions between quotes and trades based on intraday data are consistent with the theories in the literature for market microstructure. The empirical results for the four-equation VAR system suggest that quote level revisions are affected significantly by previous trades in at least four major ways. First, the information content of trades for quote level revision is significant. The significant and positive relation between quote level revisions and prior signed square-root volumes implies an information effect of trade on quote revisions. The positive reaction of quote revision to the half effective spread measure z_t reflects the adjustment of quotes to the private information contained in the prior trade. Both of these results are also consistent with the inventory holding cost theory. Second, the strongly significant and negative impact of lagged depth imbalance on the current quote revision is consistent with the asymmetric information hypothesis, and inconsistent with the inventory holding cost theory. This suggests that market makers adjust quote levels and the relative supply of liquidity (measured by depth imbalances) simultaneously to protect themselves from trades with informed traders. Third, the insignificant impacts of relative high and thin trading level indicators on quote revisions suggest that block trades are most likely liquidity trades, and thin or no tradings convey no information, which is consistent with Easley and O'Hara (1992b). Fourth, the negative lag effect in quote revision implies that prior quotes tend to be consistently over-revised. This can be caused by an overreaction to information asymmetry or due to errors caused by price discreteness.

The information impact of previous trade on current depth imbalances is insignificant. The significantly positive relationship between current depth imbalances and prior effective spreads suggests that the market maker as a liquidity supplier has to fufil his mandate to provide liquidity to market orders even when he is knowingly in a disadvantageous position relative to informed traders. The significant relation between current depth imbalances and previous quote level revision and depth imbalance supports an information (and not inventory) effect of previous quotes on current depths. The results suggest that quoted price level revisions are most likely due to adverse selection of information to previous trades, while quoted depth changes are mainly due to liquidity supply motivations.

Based on the results for the trade innovation models, signed square-root trading volume is significantly affected by previous quote changes. The significant and negative relation between current signed square-root trading volume and lagged quote mid-point return (lagged depth imbalance) indicate that the crowd draws information from prior quotes and depths by assuming that market makers are better informed (or informed earlier) than the crowd. The significant and positive relation of the current signed square-root trading volume and the lagged effective spread indicates an information effect of effective spread to trade. Changes in the number of trades are not affected by quote changes, since the current directional indicator for number of trades is not significantly related to the previous half effective spread measure, the lagged quote mid-point return and the lagged depth imbalance. Large trading volumes and liquidity supply increases after thin trading periods appear to have no information content, since the current directional indicator for number of trades is significantly negatively and positively related to the relative heavy and thin trading indicators, respectively. This result implies that liquidity (uninformed) traders' trades are easily affected by previous quote changes, while informed traders trade only for their private information.

The empirical results for the two special cases of the four equation VAR system suggest that higher-order lags are not very helpful in explaining quote revisions and signed square-root trading volumes, but quite helpful in explaining the changes in the number of trades. The trading mechanism and weekend effect have non-significant impacts on both quote and trade changes. In contrast, changes in the number of trades exhibit higher trading frequencies at both the open and close, and lower trading frequencies at Monday opens.

The Granger causality test results suggest that quote revisions (and not depth imbalance) are caused by previous trading activities. This confirms previous findings that trading activities have an information impact on quote revisions. Although depth imbalance is not "caused" significantly by trading activities, it has a significant impact on the subsequent quote revision and trades. Signed square-root trading volume is caused by previous quote revision and/or depth imbalance, which implies that trading directions are sensitive to (or driven by) previous quotes for liquidity traders. The changes in number of trades are not caused by previous quote revision and/or depth imbalance, which implies informed traders are not affected by previous quote changes.

The interactions between quotes and trades is an evolving and information exchange process in which market makers and other market participants exhibit fast learning. The private information possessed by informed traders is revealed by their trading activities, and learned by market makers by examining trade directions and associated volumes, and changes in the number of trades. Since market makers make better assessments because they are closer to the market, uninformed investors act as if market makers are better informed and informed earlier. Following the quote and depth adjustments by market makers, traders modify their trading strategies and trade against the updated quotes or market orders. Market makers readjust their quotes and depths according to the new trading activities, and the cycle repeats itself. Thus, the transmission of information to the market occurs through a sequence of trades and quotes, rather than through a single trade and quote.

Since private information is not observable directly for most market participants, overreaction in both quote revision and trade innovation are possible. This may explain why the quote revision and the number of trades appear to be negatively serially correlated. The market maker attempts to protect himself against trading with informed traders by increasing quoted price levels, while supplying liquidity by adjusting depths in ask or bid to fulfil his mandate to maintain a continuous market. Liquidity (uninformed) traders are sensitive to previous quote changes and modify their trading activity accordingly, while informed traders are not affected by previous trade and quote changes and trade only when they possess private information.

Chapter 3

Predictive Power of Market Statistics and Technical Trading Rules for Intraday Stock Price Movements

3.1 Introduction

The study of market statistics based on trade history is found to be useful in predicting future price movements of stocks. For a rational expectations framework with aggregate supply uncertainty, Brown and Jennings (1989) and Grundy and McNichols (1989) show that traders can discover the private information held by others by using current and past prices, and Blume, Easley and O'Hara (1994) demonstrate that price and volume together reveal all the relevant information. Stickel and Verrecchia (1994) find evidence that large price changes on days with weak volume support tend to reverse, but not with strong volume support, which suggests that higher volume reflects a greater likelihood that the demand originated from informed rather than uninformed trade.[19] Although Huang and Stoll (1994) find that five-minute quote and transaction returns are more predictable when historical market microstructure statistics are used instead of naive alternatives, most investors could

[19] As they suggested, an interesting extention would be to examine whether intraday volume can predict subsequent intraday price change and yield profitable arbitrage opportunities.

not take advantage of this predictive power because of transaction costs. Neftci (1991) finds that the moving average method used by many technical analysts has some predictive value for forecasts of the Dow-Jones Industrial Index beyond its own lags. Brock, Lakonishok and LeBaron (1992) find strong support for technical strategies such as the moving average and trading range break for the Dow Jones Index for the period from 1897 to 1986. The results of these studies appear to be inconsistent with the efficient market hypothesis. By capturing the characteristics of the historical price path, various momentum indicators may play a significant role in the formulation of potentially profitable trading strategies. Discussions with professional traders suggest that any exploitable market momentum is generally dissipated by the end of a trading session.

Given the absence of published research on the intraday performance of technical analysis and the contradictory evidence on the predictability of intraday returns, this chapter examines the intraday predictability of price changes and quote revisions by using publicly available information on quotation and trading history for individual stocks, and technical trading rules on historical price movements. The studied sample consists of the 35 stocks that constitute the Toronto Stock Exchange 35 Index. Trade data summarized into 30-minute intervals over a one year period (1990.7 - 1991.6) are used to test the hypotheses. TSE-listed securities are used herein instead of NYSE stocks or indexes because the TSE trading process is more informationally transparent while simultaneously maintaining low trading costs for professional traders.[20] This study uses a more comprehensive information set of market microstructure statistics to capture the quotation and trading behaviors of market makers and public investors.

Intraday stock price behaviors are examined using market microstructure models based on publicly available market statistics. The predictive power of using market statistics and the incremental predictive power of using technical trading rules are investigated in two steps: First, two econometric prediction models of quote revision and transaction price changes are constructed to incorporate various microstructure theories. The information set of market statistics includes the most frequently used measures in the literature such as signed trading volumes, and other measures such as changes in the number of trades, effective bid/ask spread, depth imbalance, heavy and thin trading indicators, and the 30-minute returns on TIPs to capture the co-movement of individual stock prices. Second, the incremental usefulness of technical trading rules is assessed by adding technical buy/sell indicators to the right-hand-side (RHS) of the basic prediction models estimated in the first step. Three popular technical rules are examined; namely, the moving average, trading range break, and relative strength. The impact of a change in trading mechanism and of the weekend effect are examined by adding dummy variables to the prediction models.

Since technical analysis is often used to learn about the market momentum

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[20] NYSE stocks and/or indexes are used in most previous studies. For example, Huang and Stoll (1994) study 20 actively traded stocks drawn from the Major Market Index for all the trading days in 1988. Brock, Lakonishok and LeBaron (1992) study the Dow Jones Index from 1897 to 1986.

which directs the trading behavior of some investors, a cross-sectional analysis of intraday changes in microstructure variables around technical buy or sell signals is conducted to examine market trade and quote behavior during signal periods in which technicians predict turning points in price changes. If the studied technical rules lack predictive power, no significant changes in market momentum are expected in the pre- and post-signal periods. A simulated program trading strategy based on technical trading rules is formulated to make 1, 2, or 5 day "round-trip" trades. T- and sign-tests are used to examine the differences between the returns for the 1, 2 and 5 day holding periods and zero or market returns, respectively. The tests examine the validity of the popular market saying: "long-term fundamental, short-term technical".

The empirical results indicate that an examination of market statistics is more useful in predicting quote revisions than transaction price changes. Quote revisions are affected significantly by previous trading activities and the trend in market co-movement, which implies an adverse selection effect. In contrast, transaction price changes are due mainly to the bid-ask bounce effect of previous trades and the information effect of previous quotes. The impact of the trading mechanism switch and the weekend effect are not significant on average, although some stocks exhibit significantly negative quote revision and transaction price changes. The technical trading rules are found to have limited incremental predictive powers over the very short term when benchmarked against other summary statistics of market momentum. Based on the cross-sectional analyses for buy and sell signal "events", technical analysis consistently and accurately reveals **what has happened** in the market, but has very limited power in predicting future short-run stock price movements. This supports the conjecture of Blume, Easley and O'Hara (1994) that technical analysis of only price statistics cannot reveal all the relevant information, and that other microstructure statistics such as trading volume improve the information quality and may be helpful in explaining future stock price changes. Our empirical results are not consistent with the theoretical predictions of Brown and Jennings (1989) and Grundy and McNichols (1989), and with the empirical findings of Neftci (1991) and Brock et al (1992) about the usefulness of technically analyzing price patterns to predict future price movements. While our results may be due to the use of shorter time horizons (30-minute versus daily or monthly), they are probably due to the use of individual TSE stocks instead of NYSE indexes. As stated earlier, price discovery on the TSE may be more efficient due to greater transparency and immediacy of information on market statistics, and relatively low trading costs for professional traders.

The remainder of this chapter is organized as follows: In the next section, a brief review of the relevant literature is presented. In section 3.3, the sample and data are described. In section 3.4, the model is specified and the estimation methodology is discussed. In section 3.5, the empirical results are presented and analyzed. Section 3.6 concludes this chapter.

3.2 Brief Review of The Literature

The recent literature on market efficiency suggests that stock returns may not be explained fully by fundamentals [e.g., see the variance-bounds literature of Shiller (1979, 1981), and LeRoy and Porter (1981)]. Many empirical studies find that security returns are predictable using past returns. De Bondt and Thaler (1985), Fama and French (1986), and Poterba and Summers (1988) find significant negative serial correlation in the returns of individual stocks and portfolios over three- to ten-year periods. Jegadeesh (1990) finds negative serial correlation for lags of up to two months, and positive serial correlation for longer lags. Lo and MacKinlay (1990) identify positive (negative) serial correlation in weekly returns for indexes and portfolios (individual stocks). Lehmann (1990), and French and Roll (1986) find negative serial correlation for individual securities for weekly and daily returns. One potential explanation is market inefficiency in which prices deviate from their fundamental values [Poterba and Summers (1988), Summers (1986), and Shiller (1984)]. Another potential explanation is that markets are efficient, and the predictable variation is due to time-varying equilibrium returns [Fama (1991), Ferson and Harvey (1991)].

Technical analysis and market microstructure are related in four ways. First, many investment professionals are technicians. All the major brokerage firms publish technical commentary on the market and individual securities, and many newsletters are technically oriented [Brock, Lakonishok, and LeBaron, (1992)]. Second, market quotations are sensitive to irregular trading behaviors [Hasbrouck (1991a,b)]. Third, some stock price changes are caused by "internal" news, which occurs when the market does an imperfect job of revealing relevant information possessed by different investors, and when market developments cause more information revelation [Romer (1993)]. Fourth, some traders use technical analysis to update beliefs, especially for small, less-widely-followed stocks about which they are relatively less well informed.

Technicians study historical trading patterns because they believe that the current stock price does not immediately reflect all information shocks (unexpected events). Given that different investors react differently to news due to their different time horizons, a news event may not be absorbed by the market instantaneously. In such cases, prediction is possible for as long as the market takes time to absorb the event and its secondary effects. Kyle (1985) using an auction model and Glosten and Milgrom (1985) using a sequential model for a dealership market argue that, since long-lived information is gradually incorporated into prices, past prices or order flows are informative. Brown and Jennings (1989) and Grundy and McNichols (1989) use rational expectations models in which a single price does not reveal the underlying information but a price sequence does. Both papers show that traders can discover private information held by others by using current and past prices. Blume, Easley and O'Hara (1994) show that in a standard rational expectations framework with aggregate supply uncertainty, price and volume together reveal all relevant information. If price is not revealing, then volume may provide information not incorporated in price. This suggests that various momentum indicators may capture the characteristics of the historical price path, and therefore play a significant role in formulating potentially profitable trading strategies.

Madhavan and Smidt (1991) use a Bayesian model to test intraday security price movements on the NYSE. They find strong evidence for information asymmetry as perceived by the specialist, and that prices respond differently for large-block trades relative to smaller trades, and for buyer-initiated trades relative to seller-initiated trades. Huang and Stoll (1994) develop a two-equation econometric model of quote revisions and transaction returns to identify the relative importance of different microstructure theories, and to make predictions on the short-run behavior of stock returns. They find that five-minute transaction returns react negatively to trade price deviations from the quote midpoint in the prior period, which reflects an attenuated bid-ask bounce to compensate market makers for order processing costs. Quote revisions react positively to the same variable, which reflects the adjustment of quotes to the private information contained in the prior trade. Quote and price returns tend to be negatively related to prior depth imbalance (i.e., ask depth greater than bid depth). Huang and Stoll argue that since their model is successful in making out-of-sample predictions compared to naive alternatives, it is inconsistent with the efficient market hypothesis. However, the predictive power of their model may be due to the use of past stock index futures returns in their model. Furthermore, most investors would have difficultly exploiting this predictive power because of transaction costs.

Some empirical support also exists for the technical analysis of prices. Neftci (1991) finds that only a few of the methodologies frequently used by technical analysts are pure "Markov time" efficient, and that most signals cannot be fully determined from historical information. He finds that the moving average method has some predictive value for changes in the value of Dow-Jones industrials beyond its own lags. Brock et al (1992) find strong support for technical strategies such as the moving average and trading range break for the Dow Jones Index from 1897 to 1986. They obtain non-consistent results from these strategies with four popular null models: random walk, the AR(1), the GARCH-M, and the Exponential GARCH.

3.3 The Sample and Description of the Data

For each stock in the TSE 35 index, time-stamped trades (to the nearest second), trade size, and bid/ask quotes are drawn from the TSE transaction database for the period 1 June 1990 to 30 June 1991. Four of these stocks (i.e., CAE, SCC, STM and TOC) traded on the CATS, and the rest traded on the floor during the sample period. The data are summarized into 13 30-minute intervals for each trading day (9:30 AM to 4:00 PM). Stock prices are adjusted for dividend distributions at the openings of the ex-dividend dates. Since data for the first month are used to generate the technical signals, the sample for estimation and test is from 1990.7.1 to 1991.6.30 (a total of 3276 intervals).

The description of measures, data aggregation and basic statistics for trade and quote variables are given in section 2.3 and 2.4 of Chapter 2.

3.4 Model Specification and Empirical Procedure

The Toronto Stock Exchange (TSE) is a continuous auction market, where orders to buy and sell stocks from the investing public are "matched" for the best market quotes or with other concurrently arriving market orders. The best market quotations are the result of competition of public limit orders of traders (entered through the LOTS) with Registered Trader's quotations. Each stock listed on the TSE is assigned to a Registered Trader (RT), who has the responsibility to maintain an orderly and continuously liquid market at minimum spread in return for the privilege of trading for their own accounts. The RTs also post the sizes for each quoted price on an ongoing basis to provide investors with an indication of market depth. All these market statistics are publicly available to all market participants on a real-time basis. This kind of market structure is similar to a "free entry" market making dealership market [Madhavan (1992)].

3.4.1 The Empirical Models

The basic model is a simple conditional expectation model for returns, $\tilde{r}_t$, given by:

$$\tilde{r}_t = E(\tilde{r}_t \mid \Phi_{t-1}) + \tilde{\epsilon}_t, \tag{3.1}$$

where $E(\tilde{r}_t \mid \Phi_{t-1})$ is the expected return at t conditional on all available public information, Φ_{t-1}; and $\tilde{\epsilon}_t$ is the error term such that $\tilde{\epsilon}_t \sim N(0, \sigma^2)$. In the random walk model, market efficiency implies that the best forecast (or expectation) of the current return r_t is r_{t-1}; that is, $E(\tilde{r}_t \mid \Phi_{t-1}) = r_{t-1}$. Any information not included in Φ_{t-1} is redundant because r_{t-1} already reflects all the information available at $t-1$.

Versions of this model can be specified for various information sets of historical information. If the set is confined to historical transaction prices, then (3.1) becomes the autoregression (AR) model used by De Bondt and Thaler (1985), Fama and French (1986), Poterba and Summers (1988), Jegadeesh (1990), Lo and MacKinlay (1990), Lehmann (1990), French and Roll (1986), among others, to test the serial correlation in returns of individual stocks and portfolios over periods with daily, weekly, monthly, annually, and multi-year intervals. If Φ_{t-1} includes additional information about historical trading activities (such as trading volume, number of trades, bid/ask quotations and depths), then (3.1) can be specified as a multi-autoregression model. $E(\tilde{r}_t \mid \Phi_{t-1})$ is more accurate in predicting price changes, if such information is not perfectly correlated. Versions of this model can also consider the regularity of trading activity. Large stock price changes may be due to information events which can be proxied by unexpected trading volume, heavy or thin trading, switch of trading mechanism (e.g. from auction at market open to dealership thereafter), and market momentum.

The first variant of (3.1) is the following specification:

$$r_{q,t} = a_0 + a_1 r_{TIP,t} + a_2 z_t + a_3 SX_t + a_4 RNT_t + a_5 RHT_t + a_6 RTT_t + a_7 r_{q,t-1} + a_8 DI_{t-1} + a_9 QO_t + a_{10} MQO_t + u_t. \qquad (3.2)$$

where $r_{q,t}$ is the quote mid-point return (revision) given by $q_t - q_{t-1}$; q_t is the log quote mid-point given by $ln[(B_t+A_t)/2]$; $r_{TIP,t-1}$ is the 30-minute return on TIPs designed to capture cross-stock (market) price co-movement; z_t is one-half of the effective spread as given by $p_t - q_{t-1}$, where p_t is the log transaction price given by lnP_t [Huang and Stoll (1994)]; SX_t is the signed square-root trading volume at time t based on the transactions immediately before the quote revision at time t; RNT_t is the change in total number of trades in interval t; RHT_t (RTT_t) is the indicator of Relative Heavy (Thin) Trading, RHT_t $(RTT_t) = 1$ if VOL_t is among the top (bottom) 10% trading volumes over the past month (260 trading intervals of 30 minutes),[21] and RHT_t (RTT_t) $= 0$, otherwise; DI_t is the imbalance of depth (the immediate market supply at ask over bid) as measured by $DA_t - DB_t$; QO_t is a dummy variable for the open quote; MQO_t is a dummy variable for the open quote on Monday in order to capture the weekend effect; and u_t is the disturbance term which measures the public information

[21] RTT_t also equals 1 when $VOL_t = 0$ (a no trading interval).

unreflected in the trade and quote revision history.

The quote mid-point is normally taken as the market consensus price because of the impact of transaction costs on transaction price. The lagged returns on TIPs account for market co-movement to public information. One-half the effective spread captures the location of transaction price at t relative to the prior quote mid-point. Thus, a positive (negative) value of this measure indicates a trade closer to the ask (bid) than the bid (ask). According to Huang and Stoll (1994), the influence of z_{t-1} on quote revision reflects the impact of the preceding price deviation, which is the expected value of the private information revealed through trading [Glosten and Milgrom, (1985)]. RHT_t and RTT_t are used to measure the impacts of extreme trading activities on quote revision. The revision is upwards if heavy trading reflects private information, and insignificant otherwise. The specification is restricted to one lag because experimentation indicates that more distant lags provide little additional explanatory power [as in Huang and Stoll (1994)].

The second variant of (3.1) is based on the transaction price change prediction model:

$$p_t = q_{t-1} + z_t, \qquad r_{p,t} = r_{q,t-1} + z_t - z_{t-1}.$$

If z_t is serially dependent and $z_t = \rho\, z_{t-1} + e_t$ captures inventory effects, where e_t is the order arrival shock, then:

$$r_{p,t} = r_{q,t-1} + (\rho - 1)\, z_{t-1} + e_t. \tag{3.3}$$

Combining (3.2) and (3.3) yields:

$$r_{p,t} = a_0 + a_1\, r_{TIP,t-1} + (a_2 + \rho - 1)\, z_{t-1} + a_3\, SX_{t-1} + a_4\, RNT_{t-1} + a_5\, RHT_{t-1} + a_6\, RTT_{t-1} + a_7\, r_{q,t-2} + a_8\, DI_{t-2} + a_9\, QO_t + a_{10}\, MQO_t + e_t + u_{t}. \tag{3.4}$$

Adding the observable $r_{q,t-1}$ and DI_{t-1}, and market open (TO_t), close (TC_t) and Monday Open (MTO_t) indicators to the RHS of (3.4) gives:

$$r_{p,t} = b_0 + b_1 r_{TTP,t} + b_2 z_{t-1} + b_3 SX_{t-1} + b_4 RNT_{t-1} + b_5 RHT_{t-1} + b_6 RTT_{t-1}$$
$$+ b_7 r_{q,t-1} + b_8 DI_{t-1} + b_9 TO_t + b_{10} TC_t + b_{11} MTO_t + v_t. \qquad (3.5)$$

TO_t and TC_t allow for a test of the impact of market mechanisms on price changes; MTO_t is a dummy variable for the open transaction on Monday to capture the weekend effect; and v_t is the disturbance term to capture the public information unreflected in the trade and quote revision history.

Equations (3.2) and (3.5) cannot be jointly tested because there is a time lag between quote and trade variables. Microstructure theory predicts that $r_{q,t}$ is positively related to z_{t-1} because it captures the information effect associated with trade, that $r_{p,t}$ is negatively related to z_{t-1} due to the bid-ask bounce effect designed to compensate market makers for incurred trading costs; that $r_{q,t}$ and $r_{p,t}$ are positively related to the information effects of trading SX_t or SX_{t-1}, RNT_t or RNT_{t-1}, and RHT_t or RHT_{t-1}, and not significantly related to RTT_t and RTT_{t-1} due to the lack of information [Easley and O'Hara (1992a,b)]; and that $r_{q,t}$ or $r_{p,t}$ should be negatively related to DI_{t-1} to reflect an information effect from previous quote depth. An inventory effect predicts a positive impact of DI_{t-1} on $r_{q,t}$ or $r_{p,t}$, based on the assumption that both quote level and depth are adjusted to facilitate transactions that equilibrate inventory. The probability of a positive return from *t-1* to *t* increases if a market maker who has a large inventory at *t-1* simultaneously lowers quote level and raises depth at ask to attract buyers [Huang and Stoll (1994)].

3.4.2 The Technical Trading Rules

Three technical indicators of market sentiment, which can be mathematically formulated and give clear signals, are used herein. They are the moving average, trading range break, and relative strength index. Their ability to forecast future price movements can be tested by adding dummy variables which measure the signals to the RHS of the above models to test the explanatory power of market momentum on price discovery.

Buy and sell signals for the moving average method are generated by searching for crossings in two moving averages; one for a longer period (n), and one for a shorter period (m), where $n > m$. Let:

$$Z_t = \frac{1}{n}\sum_{s=0}^{n-1} P_{t-s} - \frac{1}{m}\sum_{s=0}^{m-1} P_{t-s}.$$

Then, signals: $\tau_i = inf\{t: t > \tau_{i-1}, Z_t Z_{t-1} < 0\}$, where $\tau_0 = 0$.

Three pairs of moving average (MA) crossing buy (B) and sell (S) indicator variables are used herein. $Makj_t$ refers to a moving average crossing buy signal if $k = B$ and sell signal if $k = S$ based on a comparison of a daily (PAD_t) and a weekly (PAW_t) price average if $j = 1$, on a comparison of a daily (PAD_t) and a monthly (PAM_t) price average if $j = 2$, and on a comparison of a 30-minute (P_t) and a monthly (PAM_t) price average if $j = 3$. The daily, weekly and monthly moving averages are based on 13, 65 and 260 half-hours, respectively. The dummy variables for the moving average crossing buy indicators are set as follows:[22]

$$
\begin{aligned}
MAB1_t &= 1 \quad \text{when } PAD_t > PAW_t \text{ and } PAD_{t-1} < PAW_{t-1}\,, \\
&= 0 \quad \text{otherwise}\,;
\end{aligned}
$$

$$
\begin{aligned}
MAB2_t &= 1 \quad \text{when } PAD_t > PAM_t \text{ and } PAD_{t-1} < PAM_{t-1}\,, \\
&= 0 \quad \text{otherwise}\,;
\end{aligned}
$$

$$
\begin{aligned}
MAB3_t &= 1 \quad \text{when } P_t > PAM_t \text{ and } P_{t-1} < PAM_{t-1}\,, \\
&= 0 \quad \text{otherwise}\,.
\end{aligned}
$$

The buy and sell signals for the two pairs of trading Range Break indicators are generated as stock prices hit local highs or lows. $TRBB1_t$ and $TRBS1_t$ are trading range break indicators generated by comparing the current 30-minute price to the maximum ($PMAW_{t-1}$) and minimum ($PMIW_{t-1}$) prices for the previous 65 half-hours (one week), respectively; $TRBB2_t$ and $TRBS2_t$ are trading range break buy and sell indicators generated by comparing the current 30-minute price to the maximum ($PMAM_{t-1}$) and minimum ($PMIM_{t-1}$) prices for the previous 260 half-hours (one month), respectively. The dummy variables for these buy (sell) indicators are set as:

$$
\begin{aligned}
TRBB1_t\ (TRBS1_t) &= 1 \quad \text{if } P_t > PMAW_{t-1}\ (P_t < PMIW_{t-1}), \\
&= 0 \quad \text{otherwise}\,;
\end{aligned}
$$

$$
\begin{aligned}
TRBB2_t\ (TRBS2_t) &= 1 \quad \text{if } P_t > PMAM_{t-1}\ (P_t < PMIM_{t-1}), \\
&= 0 \quad \text{otherwise}\,.
\end{aligned}
$$

The relative strength indicator (RSI) measures the relationship between the sum of the daily price increases during a given period and the sum of the daily price decreases during the same period. This momentum measure examines the relative strength of positive over negative price changes rather than providing clear-cut buy or

---

[22] The corresponding dummy variables for the moving average **sell** signals are set to 1 by reversing the direction of the above inequalities.

sell signals. By definition, $-100 \leq RSI_t \leq 100$. The two intraday measures used herein are:

$$RSI1_t = 100 - 200 / [1 + SPCD_t / \mid SNCD_t \mid]$$

$$RSI2_t = 100 - 200 / [1 + SPCW_t / \mid SNCW_t \mid]$$

where $SPCD_t$ is the sum of the positive price changes over the 13 half-hours in one day, or $\{\Sigma\Delta P_{t-s} \mid \Delta P_{t-s} = P_{t-s} - P_{t-s-1} > 0,\ s = 0, \ldots, 12.\}$; $SNCD_t$ is the sum of negative price changes over the 13 half-hours in one trading day, or $\{\Sigma\Delta P_{t-s} \mid \Delta P_{t-s} = P_{t-s} - P_{t-s-1} < 0,\ s = 0, \ldots, 12.\}$; $SPCW_t$ is the sum of the positive price changes over 65 half-hours in one week, or $\{\Sigma\Delta P_{t-s} \mid \Delta P_{t-s} = P_{t-s} - P_{t-s-1} > 0,\ s = 0, \ldots, 64.\}$; and $SNCW_t$ is the sum of negative price changes over 65 half-hours in one week, or $\{\Sigma\Delta P_{t-s} \mid \Delta P_{t-s} = P_{t-s} - P_{t-s-1} < 0,\ s = 0, \ldots, 64.\}$.

If $SNCD_t = SNCW_t = 0$, $RSI1_t$ and $RSI2_t$ are set to be equal to 100, $RSI1_t = RSI2_t = -100$ if $SPCD_t = SPCW_t = 0$, and $RSI1_t = RSI2_t = 0$ if $SPCD_t = SNCD_t \neq 0$ or $SPCW_t = SNCW_t \neq 0$. Therefore, $-100 \leq RSI1_t$ (or $RSI2_t$) ≤ 100. No relative strength of positive over negative price changes occurs over the past specified period if the indicator equals 0. Positive (negative) RSI should be followed by positive (negative) price changes.

The technical indicators are added to the RHS of equations (3.2) and (3.5) to test the predictive quality of the information captured by these signals. If buy (sell) signals reveal good (bad) news, then quote revisions and price changes should react positively (negatively). The buy and sell indicators generated by each of the three trading rules for several past (lagged) periods $t-j$ ($j = 1, 2, 7, 13, 26$) are added to the RHS of equations (3.2) and (3.5) to test the usefulness of each trading rule to predict quote revisions and price changes. For example, $MAB1_{t-j}$, and $MAS1_{t-j}$ are added to the RHS of equations (3.2) and (3.5) separately. Both $r_{q,t}$ and $r_{p,t}$ should be positive and negative with $MAB1_{t-j}$ and $MAS1_{t-j}$, respectively.

3.4.3 Cross Sectional Analysis of the Technical Signals

By treating the technical buy and sell signals as events, event study methods can be used to investigate the significance of such technical signals on subsequent stock price movements and six microstructure variables: VOL_t, NT_t, $r_{p,t}$, $r_{q,t}$, RS_t and DI_t. The means and standard deviations of each variable in the pre- and post- signal panes of the two days (26 half-hour intervals) are compared and tested using t- and sign-tests (the total window length is 53 half-hour intervals).[23] Trading volumes and numbers of trades are expected to increase after both buy and sell signals are triggered, if traders believe that such signals reveal information. Price changes and quote revisions are expected to be higher (lower) after buy (sell) signals are triggered, if traders and market makers believe that such signals reveal good (bad) news. The relative spread is expected to be smaller (larger) after buy (sell) signals are triggered, if market makers believe that such information is now public. Depth imbalances are expected to decrease (increase) if market makers believe such buy (sell) signals reveal good (bad) news based on an adverse selection motive. Depth imbalances are expected to increase (decrease) if market makers believe such buy (sell) signals result in more buy- (sell-) initiated trading based on liquidity needs.

[23] The t-test requires a normal distribution, while the nonparametric sign-test is distribution free assuming median is zero.

A program trading strategy based on technical trading rules is formulated and tested using the same data set. Suppose a buy signal triggers a stock purchase for both limit and market orders. An investor, who places a limit order triggered at the closing price of that period, purchases one unit of that stock, and then sells it at the prevailing bid price 1, 2, or 5 days thereafter, respectively. An investor, who places a market order crossed at the outstanding ask price of that period, purchases one unit of that stock, and then sells it at the prevailing bid price 1, 2, or 5 days thereafter, respectively. If technical analysis is useful, the one-, two-, or five-day returns will be positive. Tests are conducted to determine if these active returns are significantly greater than zero and significantly greater than market returns.[24] Using similar logic for a sell signal, the one-, two-, or five-day active returns are expected to be negative.

3.5 Empirical Results

Based on unreported univariate analyses of price changes and quote revisions, the current price appears to be relatively efficient, since past price changes contribute little to current price changes (i.e., price changes are negatively but not significantly autocorrelated). Quote revisions are negatively and significantly first-order autocorrelated. Signed square-root trading volume and depth imbalance are positively and significantly first-order autocorrelated. Changes in number of trades are strongly negatively autocorrelated over about 13 periods (one day). The estimation results for

[24] The market returns is proxied by using the return on TIPs for the same period as the stock tested after a technical signal is triggered.

the four CATS traded stocks are not reported separately since they are not significantly different from the rest of the sample.

Equations (3.2) and (3.5) are estimated using OLS with White (1980) heteroscedasti -consistent standard errors and variance, and using the General Methods of Moments (GMM) approach of Hansen (1982) to test for robustness. GMM captures non-linear relations if the residuals are conditionally heteroscedastic, permits a simple procedure to account for the presence of serially correlated errors, and imposes no specific distributional assumption on the residuals. Since both estimation methods yield similar results, only the OLS estimation results are reported below.

Estimation results for the quote revision model (3.2) and the price prediction model (3.5) are reported in **Tables 3-1** and **3-2**, respectively. Their average adjusted R squares are 44.68% and 27.43%, respectively. The past returns on TIPs are significantly and positively related to both current quote revisions and price changes. On average, 7% of quote revisions and 3.5% of price changes are explained by the previous returns on TIPs. This indicates that quote revisions are more related to market co-movements than transaction prices (probably due to transaction costs).

[Insert Tables 3-1 and 3-2 About Here]

The past effective spread measure z_t (or z_{t-1}) is significantly and **positively** related to current quote revision $r_{q,t}$, and significantly and **negatively** related to the current transaction price change $r_{p,t}$ [as in Huang and Stoll (1994)]. On average, 48.41% of the deviation of a transaction price from the quote mid-point is reflected in a change in the quote mid-point in the next interval. This suggests an information effect of prior transaction price to the next quote revision. The average coefficient of -0.7114 indicates that 71.14% of the price deviation from the mid-point quote in this interval is reversed in the next interval. This reflects an attenuated bid-ask bounce effect (a coefficient of -1 reflects a full reflection of the bid-ask bounce).

The information effect of prior trade is much stronger on current quote revisions than on current price changes. Past signed square-root trading volume is significantly and positively related to current quote revision $r_{q,t}$, and insignificantly related to current price change $r_{p,t}$, on average. Past changes in number of trades are insignificantly related to both current quote revision and price change, on average. Of the 35 stocks, 13 exhibit a significantly positive relationship in the quote revision models. This implies that trading volumes are more dominant in affecting quote revisions than number of trade changes. Past relatively heavy (thin) trading indicators are not significantly related to both current quote revisions and price changes, on average. This suggests that irregular trading activities have very limited information content for both quote revision and price changes. Ten out of the 35 stocks have a significantly positive relationship between RTT_t and $r_{q,t}$, and 10 have a significantly negative relationship between RTT_{t-1} and $r_{p,t}$. This implies that quote levels tend to be raised and transaction price tends to increase if no or thin trading occur in the previous period.

Past quote revisions are insignificant and significantly negatively related to current $r_{q,t}$ (for ten stocks), and significantly and positively related to current $r_{p,t}$, on average. The former indicates a reverting behavior for quote revisions so that market makers cap recoup their inventory and trading costs. The latter indicates a strong impact of quote revision direction on the next transaction. This implies strong predictive power for prior quote revisions in tracking stock price movements (about 72.5% of price changes are explained by past quote revisions, on average). Previous depth imbalances are significantly and negatively related to both current $r_{q,t}$ and $r_{p,t}$. This is consistent with the information effect and not the inventory effect hypothesis. If depth at the ask exceeds depth at the bid, declared sellers exceed declared buyers. This drives quote and price returns to be negative over the next interval (i.e., selling pressure pushes prices down).

With regard to the impact of the trading mechanism and the weekend effect, both quote revision $r_{q,t}$ and price changes $r_{p,t}$ are not significantly different on average for daily openings or closings or Monday openings. Nevertheless, 13 and 8 stocks for $r_{q,t}$ and $r_{p,t}$, respectively, have significantly lower returns at daily openings, and 13 stocks for $r_{p,t}$ have significantly higher returns at daily closings. These results suggest that both trading mechanism and weekend effects are weak on average for both $r_{q,t}$ and $r_{p,t}$.

The quote revision model (3.2) and price prediction model (3.5) are used to test the usefulness of technical trading signals for predicting stock price movements in terms of quote revisions and price changes.[25] For the same signal type, the indicators generated at 30 minutes, one hour, one and half hours, three hours, one day and two days prior to the current quote and trade are added to the RHS of equations (3.2) and

[25] The tests are joint tests since they also test the other historical microstructure variables already considered in the prediction models, such as past returns on TIPs, effective spread, signed square-root trading volume, changes in number of trades, relatively heavy (thin) trading indicators, quote mid-point returns, depth imbalance, and market open and close indicators.

(3.5) to test their significance in predicting quote or trade returns beyond the trading history variables already considered. Based on the results reported in **Tables 3-3** and **3-4**, the technical trading indicators generally are **not** significant in predicting quote revisions and price changes beyond the variables already considered. Exceptions include four first lagged trading range break indicators for predicting quote revisions (see Panels D and E of Table 3-3). A significant and positive (negative) relationship exists between $TRBB1_t$ or $TRBB2_t$ ($TRBS1_t$ or $TRBS2_t$) and current quote revisions. This implies that only trading range break signals capture information not reflected in other past trading activity measures for price movement. In addition, the first lagged relative strength indicators based on weekly sums of positive or negative price changes are significantly and positively related to current quote revisions for 16 out of the 35 stocks. This suggests that technical trading indicators based on historical price series have no short-term predictive power for quote revisions and price changes beyond that already provided by the microstructure variables. The sole exceptions are the trading range break signals for predicting quote revisions.

[Insert Tables 3-3 and 3-4 About Here]

This does not mean that technical analysis is not useful for tracking stock price movements. The reason is that the time series analyses of technical signals conducted herein are based on quote revision and price prediction models which already account for microstructure variables based on historical trading activities. These variables may already reflect the information that technical analysis tries to reveal.

Table 3-5 presents a cross sectional analysis of the behavior of six microstructure variables around technical signals.[26] The signals are generated for the 35 stocks over the one year time period. The 26-interval (two trading day) mean transaction price returns and mean quote returns (revisions) post-buy (sell) signals are significantly **lower** (**higher**) than the 26-interval mean price returns and quote returns pre-buy (sell) signals for all indicators but MAB3 for price and quote returns, and for MAS3 for quote returns. The 26-interval accumulated transaction price returns and quote returns pre- and post-signal exhibit a similar pattern. This suggests that the technical signals give contrarian recommendations. Lower average (or total) two-day returns occur post-buy signal than pre-buy signal if stocks recommended by the buy signals are purchased; and higher average (total) two-day returns occur post-sell signal than pre-sell signal if stocks recommended by the sell signals are not sold.

Panel A in **Figures 3-1** and **3-2** plots the intraday distributions of mean price changes and quote mid-point returns around buy and sell signals, respectively. Significant breaks occur for both price changes and quote returns in the intervals in which the buy or sell signals are generated. The mean transaction price change and quote return increase (decrease) dramatically pre-buy (sell) signal. This occurs within 6-7 hours for MAB1 and MAB2, within 3-4 hours for TRBB1 and TRBB2, and in the signal interval for MAB3. All peak (bottom) in the signal intervals. They drop (or bounce) significantly to a level close to zero immediately after the signal period, and remain at that level hereafter. The plots confirm the results of the previous statistical

[26] The tests are conducted only for those technical analysis methods which generate clear-cut buy or sell signals (i.e., moving average crossings and trading range breaks in this study). The relative strength index, which is scaled from -100 to 100, measures relative market momentum, and does not give clear-cut buy or sell signals.

tests, since higher (lower) returns for both trades and quotes appear **before** the buy (sell) signals rather than after the signals. This is as expected since technical analysis is just a study of historical patterns of price movements. While its underlying premise is that recent historical abnormal price changes reveal information, and that the future direction of such changes is expected to be unchanged, this does not hold in an efficient stock market.

[Insert Table 3-5, and Figures 3-1 and 3-2 About Here]

The volatilities of price and quote returns in the post-signal periods are significantly higher than in the pre-signal periods for all buy and sell signals, with the exception of MAB1 and MAS2 for price changes, and MAS2 for quote returns. Furthermore, post-MAB2 standard deviations of returns for trades and quotes are significantly lower than pre-signal. In Panel B of Figures 3-1 and 3-2, the mean standard deviations of price and quote returns around buy and sell signals, respectively, are plotted. Significant changes occur in volatility around the signal intervals. The volatility for quote revisions is higher than for price changes, probably due to the aggregation of transaction information. The 26-interval means and standard deviations of trading volumes and number of trades post-signal are significantly higher than those pre-signal for most buy and sell signals (see Table 3-5).[27] The heavy trading volume and number of trades happen most frequently around the signal intervals (see Panels A and B in **Figure 3-3**). This is consistent with the information

[27] Means and standard deviations of trading volume post-signal are not significantly different from those pre-signal for MAS1, MAS2 and TRBS1. Means and standard deviations of number of trades post-signal are not significantly different from those pre-signal for MAS1 and MAS2 (standard deviation only for TRBS2).

hypothesis in which the market reacts to the information that triggers the technical signals.

[Insert Figure 3-3 About Here]

The quote variables react differently to buy and sell signals. The 26-interval means of relative quoted spreads post-signal tend to be significantly narrower (wider) than pre-signal for most buy (sell) signals.[28] The volatilities of relative spreads post-signal are significantly lower (higher) than those pre-signal for only trading range break buy (sell) signals TRBB1, TRBS1 and TRBS2. This suggests that market makers react to good and bad news revealed by technical analysis differently. Since good news is less risky, they increase the spread after a sell to protect themselves from trading against the public, and decrease the spread after a buy signal to stimulate trading. This is shown by the distribution plots in Panel A of **Figure 3-4**.

[Insert Figure 3-4 About Here]

The mean and standard deviation of depth imbalance are not significantly different in the post- and pre-signal periods for most indicators (see Table 3-5).[29] Based on Panel B in **Figure 3-4**, the mean depth imbalances are negative (positive) for most periods except around signals where they change sign. This weakly supports the liquidity hypothesis that market makers increase depth in ask (bid) relative to depth in bid (ask) after the buy (sell) signals to ease the buy (sell) pressure from the

---

[28] The difference for MAB3 and MAS3 is not significant.

[29] The exceptions are MAB1 and MAS1, where the mean depth imbalances are significantly higher and lower post-signal than pre-signal. Only t-test values show that the mean depth imbalances are significantly higher post-signal than pre-signal for MAB1, MAB3 and TRBB1. The standard deviation of depth imbalance tends to be lower post-signal than pre-signal for all buy and sell indicators, but only is significant for TRBB1 and TRBS1.

public.

The simulated program trading strategy results based on the technical buy and sell recommendations are reported in **Table 3-6**. They are consistent with those reported in Table 3-5. One-, two- and five-day returns and abnormal returns for both limit- and market orders after buy signals MAB1, MAB2 and MAB3 are significantly lower than zero.[30] Most one-, two- and five-day returns and abnormal returns after buy signals TRBB1 and TRBB2, and after all sell signals MAS1, MAS2, MAS3, TRBS1 and TRBS2 are significantly higher than zero. Since all of these returns are not economically significant (all less than 1%), technical indicators are not helpful in predicting short-term future stock price movements of one, two and five days durations.

[Insert Table 3-6 About Here]

The means and standard deviations of the six microstructure variables are plotted in **Figures 3-5** and **3-6** for the range of levels (-100, +100) taken by technical indicators RSI1 and RSI2, respectively. The mean price changes and quote revisions become less negative as the indicators become less, and become more positive as the indicators become higher positive values (see Panel A of Figure 3-5). No significant changes in the volatilities of price changes and quote revisions occur as indicator values move from -100 to +100 (see Panel B of Figure 3-5). Trading volumes and number of trades are slightly U shape as indicator values increase from -100 to +100

---

[30] The one- (or two- or five-) day return for each stock is the real return for that stock, while the abnormal return is the real return net of the market return as proxied by the return on TIPs for the same period. The results reported in Table 8 are average returns and abnormal returns for the 35 stocks during the one year period from 1990.7.1 to 1991.6.30.

(see Panels A and B of Figure 3-6). The relative spread is flat and slightly reversed-U shape as the values of RSI1 and RSI2, respectively, increase from -100 to +100 (see Panel C of Figure 3-6). Negative (positive) depth imbalances occur more frequently as the value of RSI1 (and not for RSI2) increases from -100 to +100 (see Panel D of Figure 3-6).

[Insert Figures 3-5 and 3-6 About Here]

While technical analysis extracts information from historical trading price changes, the public traders and market makers react quickly to reflect that information. Since the market is very efficient in response to whatever information is generated and technical analysis only reveals what has happened, profits are not earned by exploiting technical buy and sell signals. The reason is that technical analysis reveals information about **what has happened and not what will happen.** In fact, technical trading signals are not true information events, since they are triggered by price changes caused by information or liquidity trading. Since technical trading signals are generated only when the prices break certain limits, real information events precede **(not follow)** technical trading signals.

3.6 Conclusion

Information about historical trading (especially volume and number of trades) is relatively <u>less</u> useful in predicting current stock price movements than market quote revisions. While price impounds information about the average level of traders' private information, other microstructure variables capture important information about the quality of traders' information signals. Quote revisions are more predictable than transaction price changes, and are more related to market co-movement as proxied by TIPs.

Current quote revisions are significantly and positively related to past effective spread and signed square-root trading volume, which is consistent with both the information and inventory hypotheses. Current quote revisions are significantly and negatively related to previous depth imbalance, which is consistent with the information (not inventory) hypothesis. Transaction price changes are mainly due to the bid-ask bounce effect of previous trade, and the information effect of prior quote revision and depth imbalance. Current price changes are significantly and negatively related to past depth imbalance and effective spread (an attenuated bid-ask bounce effect), and significantly and positively related to past quote revisions. Price changes and quote revisions are not influenced by the changes in number of trades and abnormal heavy or thin trading behaviors on average, although some stocks exhibit significant relationships. Quote revisions and price changes are not significantly different on average for daily market opens or closes or Monday opens.

While technical analysis reveals the causes of significant changes in stock prices, most technical trading rules examined herein have limited incremental predictive power when considered against the predictive power of various microstructure measures of historical trading activities, such as trading volume, number of trades, effective spread, depth imbalance in ask over bid, and market returns. The major exception is the trading range break indicator, which significantly predicts one period forward quote revisions for 30-minute-to-weekly and 30-minute-to-monthly local maximum or minimum prices. Thus, technical trading rules such as moving average crossings, trading range breaks and relative strength reveal no additional information to that revealed by various market microstructure statistics about the short-term direction of future stock price movements. Based on the cross-sectional analyses, technical analysis can consistently and accurately reveal **what has happened** in the market, but has very limited power in predicting future short-term stock price movements.

These results imply that the current stock price is efficient in reflecting the information gleanable from the historical transaction price series. While relying only on historical price patterns is not very helpful, the study of the historical patterns of other market statistics is somewhat more useful in tracking future price movements. Our evidence supports the theoretical work of Blume, Easley and O'Hara (1994) that technical analysis of only price statistics cannot reveal all relevant information, and that other microstructure statistics (such as trading volume) can improve information quality and be helpful in explaining future stock price changes. Our results are not consistent with the theoretical works of Brown and Jennings (1989) and Grundy and McNichols (1989) and the empirical findings of Neftci (1991) and Brock et al (1992) that technical analyses on only price patterns are useful in predicting future price movements. while this may be due to the use of different time horizons (30-minute returns versus daily or monthly returns) and/or different samples (TSE stocks versus NYSE stocks or indexes), it may be due to more efficient price discovery on the TSE caused by greater transparency and immediacy in the supply of market statistics and low trading costs for professional traders.

Chapter 4

Adverse Selection, Liquidity Supply, and Competitive Market-Making Behavior

4.1 Introduction

Due to the organization of its competitive market making, the Toronto Stock Exchange (TSE) differs from most other major stock exchanges in terms of its informational transparency and visibility.[31] Each stock listed on the TSE is assigned to a market maker called a Registered Trader (RT), who is responsible for making a continuously liquid market at minimum spread in return for the privilege of trading for their own accounts. The RTs post bid/ask prices and sizes (depths) which are tradeable against their own accounts, and which compete with the limit orders from the Limit Order Trading System (LOTS). The best market quotations are the result of competition between the public limit orders of traders and the RT quotations. Transactions result from matches between the best market quotes and the market

[31] The TSE is a continuous auction market with "free entry" market making by any market participant, where the market makers function like the specialists on the NYSE with less monoply power and more restrictions. Public investors in a pure dealership market like NASDAQ or the International Stock Exchange (London) submit orders to and trade with multiple competitive market makers [Christie and Schultz (1994)]. On the NYSE, only the specialist has monopolistic access to the limit order book as partial compensation for his market-making obligation [Lehmann and Modest (1994)].

orders from brokers or the Market Order System of Trading (MOST).[32] The quoted prices must bear a reasonable relationship to the price of the last trade and the actual spread must be kept reasonably close within the spread goal established by the Exchange. The market quote can be adjusted strategically along three dimensions after each trade: quote level (measured by the mid-point of bid and ask prices), bid-ask spread, and quoted depths at bid and ask. Only the second and/or third of these dimensions is considered in the existing literature.[33]

A market maker's market-making behavior may be contradictory due to his dual role. By providing liquidity, he takes a position opposite to that of public traders [specifically, he has to buy (sell) when the public wishes to sell (buy)]. To trade for his own account, he moves with the market to maximize expected profit by buying (selling) more on good (bad) news. In addition, the market stipulates a minimum variation of \$1/8 between bid and ask prices for stocks valued above \$5, and stipulates a minimum liquidity supply of one board lot for each side of depth. These regulations suggest that no single dimension of a market quote sufficiently measures quote behavior by itself. The three dimensions are used collectively and strategically by the market maker to trade against informed traders, to compensate for trading costs (including the risk premium for inventory) and to fulfil his mandate as liquidity provider.

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[32] Less actively traded stocks trade primarily on the Computer Assisted Trading System (CATS), which is a fully automated trading system for about 1/3 of all stocks on the TSE.

[33] Studies focusing on the estimation of the bid-ask spread and its components include Roll (1984), Glosten and Harris (1988), Stoll (1989), and George, Kaul and Nimalendran (1991). Others studies examine spread and depth separately [e.g., Kyle (1985) and Rock (1989)], or jointly [e.g., Lee, Mucklow and Ready (1993)].

Given the very competitive nature of market-making behavior on the TSE, this study uses quotation and trade-by-trade data for stocks in the TSE 35 Index to show how market makers use the three dimensions of market quotation simultaneously and strategically. By examining the statistical properties of three dimensions (and not two) of market quotation to (non-)information events [proxied by heavy trading (thin or no trading) periods], the spreads are found to be significantly narrower around information events than non-information events, and the depths are found to be significantly thicker around information events than non-information events. This reflects a higher market liquidity during heavy trading periods than thin (or no trading) periods. The increased (decreased) spreads and decreased depths immediately after (non-)information events, and significantly increased quote levels immediately before the information events indicate an adverse selection effect of information on quote changes. Using a three-equation VAR system to capture the three dimensions of quote changes endogenously, trading activity variables are found to have different information contents for changes in each of the three dimensions of quotes. While trading volume is more informative for quote level changes, the number of trades and heavy (thin) trading indications are more informative for spread and depth changes, respectively. Spread and depth are endogenously and negatively related. Quote level changes are not endogenously related to both spreads and depths, but significantly related to asymmetric information. While spread is associated more with information and risk aversion, depth is related more to the supply of market liquidity. The empirical results herein suggest that the three dimensions of market quote are collectively and strategically used by market makers to avoid exposure to informed traders and to fulfil their mandate to provide market liquidity.

The remainder of this chapter is organized as follows. The related literature is briefly reviewed in the next section. Section three describes the trade and quote measures, the data and the sample. The statistical properties of the quote variables and their relationships to information events are presented in section four. Sections five and six investigate the adverse selection component of the bid-ask spread and the three dimensions of quote revision to previous trading activities, respectively. The empirical findings for the VAR model of conditional three-dimensional quote behavior are presented and analyzed in section seven. Section eight concludes this chapter.

4.2 A Brief Review of The Literature

Two of the three dimensions of market quotes are generally treated separately in most theoretical models. Early models focus on the estimation of the bid-ask spread and its components. In Blume and Stambaugh (1983), Roll (1984) and French and Roll (1986), the entire bid-ask spread is assumed to be due to factors such as specialist rents, inventory carrying costs, and/or transaction costs. These factors explain the transitory spread component, which causes price changes to be negatively serially correlated.

Subsequent models argue that spreads are caused by the market maker revising his expectations based on asymmetric information. This suggests that the spread is positively related to order size [Kyle (1985), Easley and O'Hara (1987), and Glosten (1987)]. Glosten (1987) shows that the adverse selection component leads to fluctuations in true price, and that the other component (mainly transaction costs) leads to specialist gross profit, measurement biases in the means and variances of return, and negative serial covariance. Glosten and Harris (1988) estimate the two spread components using transaction data, and cannot reject the significance of spread due to asymmetric information. Their findings lead to a testable hypothesis that the first component is a positive function of both trading volume and number of trades in the previous period.

Stoll (1989) investigates the time series behavior of spreads, and the relation between quoted and realized spreads. He finds that the adverse information, inventory (holding) cost and ordering cost components represent 43%, 10% and 47% of spreads, respectively. The new measure of George, Kaul and Nimalendran (1991) adjusts for time-varying expected returns. Their evidence indicates that order processing costs are the predominant component of quoted spreads.

The asymmetric information models, developed by Copeland and Galai (1983), Glosten and Milgrom (1985) and Easley and O'Hara (1992a), ignore depth by assuming a unit size for all trades. Other auction models presented by Kyle (1985) and Rock (1989) capture the depth implicitly by having the specialist quote complete pricing functions rather than individual bid and ask prices. This results in an inextricable association between the price dimension (spread) and quantity dimension (depth) of market liquidity. According to Lee, Mucklow and Ready (1993), very little work focuses on how these dimensions interact, particularly in response to changes in information. They argue that, if the specialist is averse to quoting extremes in either dimension, he is likely to use both spreads and depths in managing liquidity risk.

Easley and O'Hara (1992b) argue that traders learn from both trades and the lack thereof, because each is correlated with different aspects of information (direction and existence, respectively). Bid-ask spreads decrease as the time between trades increases, and the absence of trades is correlated with volume. Their model predicts a testable relation between spreads and normal (expected) and unexpected volume, and how volume affects the speed of price adjustment. The prediction is that the specialist sets the initial spread based on the ex ante probability of informed traders, and widens the spread in response to an unusually high number of trades. Thus, depth should decrease with higher volume. Therefore, their model suggests a negative relation between volume and market liquidity in a time-series context. In contrast, Harris and Raviv (1993) argue that if volume shocks reflect mainly a lack of consensus among market participants, the periods of higher volume may correspond to the arrival of public limit orders on both sides of the bid-ask spread. Therefore, higher volumes should be associated with tighter spreads and increased depths.

Lee, Mucklow and Ready (1993) argue that quoted liquidity provided by dealer(s) should be measured by both spreads and depths. They show that wide spreads are accompanied by low depths, and that spreads widen and depths fall in response to higher volume. Their results suggest that liquidity providers are sensitive to changes in information asymmetry, and use both spreads and depths to actively manage this risk. Unlike effective spreads, quoted depths follow an reversed U-shape pattern. This suggests a negative relation between depths and spreads (or volume).

Recent empirical evidence finds intraday quoted spreads and volume to be U-shaped [Brock and Kleidon (1992), and McInish and Wood (1992)], which suggests that spreads and trading volume have a positive relation. Based on cross-sectional differences in volume and spreads, firms with tighter spreads generally have higher volumes and more trades. However, the time-series relation between volume and quoted liquidity has remained largely unexplored.

4.3 The Trade and Quote Measures, the Data and the Sample

Three dimensions of quotation activities are measured by quote level revisions, relative bid-ask spread and quote depth, respectively. Quote level revision is defined as quote mid-point returns, i.e., $r_{q,t} = ln[(A_t+B_t)/2] - ln[(A_{t-1}+B_{t-1})/2]$. Relative bid-ask spread is defined as the percentage of spread relative to mid-point price, i.e., $RS_t = (A_t-B_t)/[(A_{t-1}+B_{t-1})/2]$. Relative spread is used instead of dollar spread because the price level is a statistically significant determinant of spread, even after controlling for variables such as market value, volatility, trading volume, and trade frequency (Harris, 1994). Quote depth is defined as the sum of depth in ask and in bid, i.e., $D_t = DA_t+DB_t$. The last rather than the average quotation is used herein to capture the most recent information about quote behavior, because quotes reflect information only from one side of the market (the market maker and limit orders). B_t (A_t) is the last bid (ask) price for interval t, DB_t (DA_t) is the quoted depth (size) of the last bid (ask) for interval t. Since quoted orders become trades once crossed with market orders, information contained in the quotes within an interval are reflected in the trade measures. Thus, the last quote is the most updated quote immediately after the last trade within the interval. Market quotes are adjusted immediately after each trade (i.e., in transaction rather than calendar time).[34]

The description of other related measures, data aggregation and basic statistics for trade and quote variables are given in section 2.3 and 2.4 of Chapter 2.

4.4 Statistical Properties of Quotes and Their Reactions to Information Events

4.4.1 Cross-sectional Relationships and Intraday Patterns

Market makers and limit order placers protect themselves against informed traders and decrease inventory and trading costs by moving in all three quote dimensions. Cross-sectional relations among these three quote dimensions can be tested by examining their correlation structures. Quote spread is expected to be negatively correlated to depth due to the substitution effect between the two, and quote level revision is expected to be positively related to spread and negatively related to depth based on the adverse selection hypothesis.

The correlation structure for quote return, relative spread, and quoted depth for the TSE 35 stocks over the one year period are reported in **Table 4-1**. The highest average correlation is between relative spread and quoted depth (0.1278). The other pairs have very low correlations, which indicates that the quote variables are relatively independent from each other cross-sectionally. Among the trade variables, signed square-root trading volume (*SX*) is not significantly correlated with changes in number of trades (*RNT*), relative heavy trading indicator (*RHT*), and relative thin

[34] Transaction time intervals are not necessarily equal in length, unlike calendar time intervals which are equally spaced. For a detailed discussion of transaction and calendar time, see Hasbrouck (1991a).

trading indicator (*RTT*). While *RNT* is positively related to *RHT* (0.2574), *RTT* is negatively related to *RNT* (-0.2124) and *RHT* (-0.1594).

[Insert Table 4-1 about Here]

The intraday patterns of quote level revisions, relative spread, quote depth and depth imbalance are plotted in **Figure 4-1**. The intraday patterns of related trading activity variables, such as price changes, trading volume, number of trades, and signed trading volume are plotted in **Figure 4-2**. The plots are averages for the 35 stocks in the TSE 35 Index over a one-year period (1990.7.1 to 1991.6.30, for a total of 3276 30-minute intervals). Quote level revisions and price changes have the same intraday pattern, with a significantly negative average return in the first 30-minute interval of each day and a positive average return in the last 30-minute interval of each day. Relative spread exhibits an intraday U-shape, where the spread is relatively wider during the opening and closing intervals than during the rest of the day (especially the opening). Quote depth exhibits an intraday reversed U-shape, i.e., depths in opens and closes are generally lower than during the middle of the day. Depth imbalances are negative in all 30-minute daily intervals, and gradually increase during the day. This suggests that depth in bid dominates depth in ask on average, and that the differences decline over the day (at least for the sample studied herein). The intraday distribution of effective spreads (transaction price minus previous quote mid-point) shows that all trades occur, on average, at prices below the previous quote-mid-point or close to bid prices, especially during the opens. Both trading volume and number of trades display an intraday U-shape, which indicates that tradings are more active during the opening and closing intervals (especially openings). The intraday patterns of depth imbalance and effective spreads are consistent, which suggests that tradings happen most frequently at or close to bid prices, and that orders in bid are thicker (deeper) than those in ask on average. Average signed trading volume is positive for the opening interval, and negative during the closing interval. This suggests that, on average, buy-initiated trades dominate at the open, and sell-initiated trades dominate at the close. A similar U-shape intraday pattern for spreads, volumes and numbers of trades are consistent with the asymmetric information hypothesis of bid-ask spreads in which the spread is increased if market makers realize that they have an information disadvantage [also see Brock and Kleidon (1992), and McInish and Wood (1992)].[35]

[Insert Figures 4-1 and 4-2 About Here.]

4.4.2 Quote Behavior Around (Non-)Information Events

In most of the microstructure literature, trade size (trading volume and number of trades) is used as a proxy for information asymmetry based on the assumption that informed traders trade on their superior information since such information is normally short-lived [see Kyle (1985), and Admati and Pfleiderer (1988)]. This suggests that spreads should be increasing in trade size, i.e., market makers widen the spread after the arrival of a large trade as it aggravates the adverse selection problem faced by them. Barclay and Warner (1993) argue that informed traders choose middle size orders to strategically minimize the price impact of their trades due to the "up"

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[35] The probability of trades by informed traders is assumed to be higher if trade size is larger and the number of trades is higher in one period compared to the others.

and "down" stairs trading arrangements on most stock exchanges.[36] Most market or limit orders are submitted to "downstairs" or floor markets for trading, and are absorbed by floor traders or market makers after matching with the limit order books. In contrast, unusually large size orders are negotiated in the upstairs market. The negotiation process removes the anonymity of trades that characterize downstairs trading. Therefore, informed traders are not likely to trade in the upstairs market since camouflaging trades with those from uninformed traders is an important requirement for preventing discovery. Upstairs trading is probably used more often for liquidity reasons where information uncertainty is lower. Therefore, the use of high trading volume as the only proxy for an information event may induce considerable error.

Quote level revisions, bid-ask spreads and quote depths are expected to be higher, wider and smaller, respectively, when information is believed to have arrived in the market, and to be lower or unchanged, narrower and deeper, respectively, when no information arrival is expected based on the asymmetric information hypothesis. An (non-)information event is identified if (1) VOL_t in an interval is among the top (bottom) 10% of the total trading volume in the sample period, and (2) NT_t exceeds (falls below) the average number of trades for the sample period. While the former criterion identifies the heavy (thin or no) trading intervals, the latter criterion ensures that the heavy trading volume does not occur from one or a few

[36] On the TSE, an order from one client for a class of security with a value of $100,000 or more is viewed by the Exchange as an institutional-size order.

block trades (i.e., institutional orders crossed among members "upstairs").[37]

The averages of the relative spread, quote level revision, quote depth and depth imbalance immediately after the (non-)information events are compared to each other and those for the rest of the intervals. The results of statistical tests are reported in **Table 4-2**. The relative spreads immediately after the information events are significantly larger than those for the other intervals. The relative spreads immediately after non-information events are significantly larger than those for the other intervals, and for those immediately after information events. The mean frequencies one day (13 intervals) before and after (non-)information event intervals for relative spread, quote level revision, and quote depth are plotted in **Figure 4-3**. Based on this figure, the overall level of spreads around non-information events are significantly higher than those around information events. For example, the average spread immediately after non-information events is 0.0104, compared to the spread of 0.0097 for the period immediately after information events. There is a significant upwards (downwards) shift of spreads immediately after (non-) information events. The relatively large spread for information events is consistent with the information hypothesis that market makers increase the spread to protect themselves against trades with informed traders. The immediate spread shift after (non-)information events suggests an information effect on spread changes. This result is also consistent with the hypothesis for no trading periods; namely, that the spread decreases during non-information periods

[37] Another way to proxy information events is to use the top 10% intervals with the largest number of trades in the sample period, based on the assumption that changes in the number of trades reflect more information about trading activities of informed traders, and that the problems identified by Barclay and Warner (1993) can be avoided. Similar results are obtained in this study from this method.

[Easley and O'Hara, (1992a)]. The relatively low (high) level of spreads around (non-)information events suggests high (low) market liquidity during (non-) information periods.

Quote level revisions are not significantly different immediately after (non-) information events compared to other periods. Based on Figure 4-3, quote level revisions always are negative around non-information events, and significantly positive for three periods before (but not after) information events. When many trades come to the market (high trading volume), quote levels already are higher. This suggests that the upward movement in quote levels may induce heavy trading. In turn, this implies that the (quote) price is more efficient than trading volumes.

Quoted depths immediately after (non-)information events are significantly thicker (thinner) than those in other periods (including non-information periods). The overall level of depth around information events is significantly higher than that around non-information events (see Figure 4-3). This suggests that high (low) market liquidity is associated with (non-)information events, and implies that quoted depth is posted for liquidity and not for informational reasons. The significant downward shift in depth immediately after the information events indicates an information effect on quoted depth. This phenomenon is not significant for non-information events.

Depth imbalances always are negative (i.e., depth in bid dominates depth in ask). The deficiency between depths in ask and in bid are significantly smaller immediately after information events compared to other periods and immediately after non-information events, which suggests higher liquidity in information event periods. The deficiencies between depths in ask and in bid immediately after information events are significantly larger than for other periods, which suggests lower liquidity for non-information events.

The overall results suggest information (heavy trading) shocks are associated with higher information risk (larger spread) and higher market liquidity (thicker depth), and that non-information (thin or no trading) periods are associated with a lower supply of market liquidity (larger spread and thinner depth).[38]

[Insert Table 4-2 and Figure 4-3 about Here]

The differences in the pre- and post-event averages for each variable are compared using t- and sign-tests. Based on **Table 4-3**, the differences in means and standard deviations of relative spread are significantly different for only non information events (higher mean and standard deviation pre-event). This is consistent with Easley and O'Hara (1992b) who conjecture that spread should narrow and volatility should decrease during no trading periods due to the arrival of no information. The mean and standard deviation of quote level revisions and quoted depths pre-(non-)information events are significantly higher (lower) than those post event.[39] The mean and standard deviation of depth imbalances pre-(non-)information events are not significantly different from those post event.

[Insert Table 4-3 about Here]

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[38] While the former is consistent with Easley and O'Hara (1992b) and Lee, Mucklow and Ready (1993), the latter is not. These studies conjecture that lower market liquidity is associated with volume shocks.

[39] The results for quoted depth are found for only the t-test.

4.5 Adverse Selection Component of Bid-Ask Spread

As in Glosten and Harris (1988), the "true" price process can be written as

$$m_t = m_{t-1} + e_t + Q_t Z_t. \tag{4.1}$$

where m_t is the efficient price which reflects all publicly available information immediately following a transaction at t (i.e., the expected stock value conditional on the public information); e_t is the unobservable innovation in "true" prices between transactions t and quotation t due to the arrival of public information (assumed to be normally i.i.d.); Q_t is the unobservable indicator for the initiation (direction) of a transaction;[40] and Z_t is one-half of the adverse selection component of quoted spread at the end of period t. If C_t is one-half of the component of quoted spread that compensates market makers for trading costs, then the two components are distributed symmetrically around the quote mid-point. It follows that:

$$B_t = m_t - Z_t - C_t, \qquad A_t = m_t + Z_t + C_t.$$

Therefore, $A_t - B_t = 2Z_t + 2C_t$ is the quoted spread, and $A_t + B_t = 2m_t$. Thus, the efficient price can be treated as the quote mid-point, which is consistent with the literature [see Hasbrouck (1991a, 1991b), and Huang and Stoll (1994)]. Equation (4.1) can be rewritten as

$$Q_t Z_t + e_t = m_t - m_{t-1} = (1/2)(A_t+B_t) - (1/2)(A_{t-1}+B_{t-1}) = r_{q,t}. \tag{4.2}$$

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[40] Trading direction (buy or sell initiated trade) is determined by comparing the current trade price to the mid-point of the prevailing bid/ask quote. A trade is a "buy" if the trade price is higher than the prevailing quote mid-point, and a "sell" if the price is lower, and "undetermined" if the price is equal to [Blume, MacKinlay and Terker (1989)]. Another method for identifying trade direction is the tick test, which compares the current-to-previous transaction prices. Lee and Ready (1991) provide details on the identification of trade direction and a comparison of the different methods. Both methods are used herein. They produce highly correlated trade direction classifications (generally above 90%). The method with less "undetermined" is used hereafter.

In (4.1), the quote level revision is due to adverse selection (private information) and public information arrival. If the adverse selection component of the spread Z_t is related to the private information of informed traders,[41] Z_t should be related positively to the square-root trading volume $SVOL_t$ in the previous period; namely:

$$Z_t = a + b*SVOL_t + v_t. \quad (4.3)$$

Substituting (3) into (2), gives $r_{q,t} = a*Q_t + b*Q_t*VOL_t + Q_t*v_t + e_t$. Then:

$$r_{q,t} = a0 + a1*Q_t + a2*SX_t + \epsilon_t. \quad (4.4)$$

where SX_t is signed square-root trading volume; ϵ_t is the error term; and all other terms are as defined earlier. An estimated coefficient $a2$, which is significant and greater than 0, supports a significant adverse selection component in the spread. If ϵ_t is autocorrelated, it can be fitted with the following AR(1) process:

$$\epsilon_t = \rho\, \epsilon_{t-1} + \varepsilon_t. \quad (4.5)$$

where ρ is the AR(1) parameter; and ε_t is i.i.d normal with zero mean and constant variance.

The estimation and test results for equations (4.4) and (4.5) are reported in **Table 4-4.**[42] On average, the coefficient of $a2$ of 1.67×10^6 is significantly greater than zero (t-value of 18.23). This implies a significant adverse selection component in the bid-ask spread, which is consistent with the information effect hypothesis of Glosten (1987) and Glosten and Harris (1988).

[Insert Table 4-4 about Here]

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[41] It is assumed that informed traders must trade if they possess superior information since its value is short-lived.

[42] Models such as (4.4) and (4.5) are estimated and tested herein by using OLS with White (1980) heteroscedastic-consistent standard errors and variances.

4.6 Three-Dimensional Quote Reaction to Previous Trading Activities

Variations of models (4.4) and (4.5) can also be applied to spread and depth as dependent variables, and with signed square-root trading volume, changes in number of trades and abnormal trading indicators as proxies of trading activities. Specifically:

$$Q_t = b0 + b1 \times SX_t + b2 \times RNT_t + b3 \times RHT_t + b4 \times RTT_t + w_t. \quad (4.6)$$

$$w_t = \rho\, w_{t-1} + u_t. \quad (4.7)$$

where Q_t represents the quote variable which equals RS_t, $r_{q,t}$ and D_t, separately; SX_t is signed square-root trading volume in interval t (i.e., direct measure of trading activity which probably varies with competition and information arrival); RNT_t is the change in the number of trades [a different information content measure than trading volume as in McInish and Wood (1991)]; RHT_t (RTT_t) is a relatively heavy (thin) trading indicator (measures abnormal tradings based on an assumed market memory of one month or 260 periods); RHT_t $(RTT_t) = 1$ if VOL_t is in the top (bottom) 10% of the trading volume in the past month;[43] w_t is the residual term which follows an AR(1) as in (4.7); ρ is the AR(1) parameter; and u_t is i.i.d. normal with zero mean and constant variance.

The estimation and test results for equations (4.6) and (4.7) are reported in **Table 4-5**. Quote returns are significantly and positively related to previous signed square-root trading volumes, which suggests an information effect of previous trade on current quote level revision. Significantly negative serial correlations exist in the quote return series. Relative spreads are significantly and positively related to

[43] $RTT_t = 1$ when $VOL_t = 0$ (no trading interval); and $RHT_t = RTT_t = 0$, otherwise.

previous changes in the number of trades and relatively heavy trading indicators, and are significantly and negatively related to previous relatively thin trading indicators. These results are consistent with the information effect hypothesis of bid-ask spreads proposed by Glosten (1987) and Easley and O'Hara (1992b). Quoted depths are significantly and negatively related to previous changes in the number of trades and relatively heavy trading indicators, and insignificantly related to previous relatively thin trading indicators. This is also consistent with the hypothesis of an information effect of a previous trade on quoted depths. Since the previous signed square-root trading volume is not significantly related to both the relative spread and quoted depth, changes in the number of trades appear to be more informative for updating spreads and depths than signed trading volume. Both relative spread and quoted depth have significantly positive ρ, which indicates significantly positive serial correlations in the series of relative spreads and quoted depths.

[Insert Table 4-5 about Here]

4.7 A VAR Model of Three-dimensional Quote Behavior

If a market maker believes that the probability that some traders possess superior information has increased, he responds by increasing spreads, quoting less depth, and/or increasing quote levels (the mid-point of bid and ask prices). The observed market quote is assumed to be the best one at that moment, no matter who posts it.[44] Each quote is assumed to be updated immediately after each trade. In this setting, bid-ask spreads, quote level revisions and quoted depths are all time varying, and conditional on the previous trade and quote. As in the literature, spreads have adverse selection and order processing cost components. Since the time-varying properties of these components are not observable in the market, they have to be inferred from observable information. Unlike Roll (1984), Stoll (1989), and George, Kaul and Nimalendran (1991) who assume a constant spread, and Glosten and Harris (1988) who learn the components only from transaction information, the model developed and tested in this section is based on the time series of trade and quote innovations.

The three-equation VAR system used to examine the endogenous relationship among the three dimensional behaviors of quotes is:

$$\boldsymbol{Q}_t = \boldsymbol{c} + \boldsymbol{\alpha} \times \boldsymbol{Q}_{t-1} + \boldsymbol{\beta} \times \boldsymbol{T}_t + \boldsymbol{\gamma} \times \boldsymbol{M}_t + \epsilon_t. \tag{4.8}$$

where $\boldsymbol{Q}_t = (RS_t,\ r_{q,t},\ D_t\ )'$ is the quote vector; $\boldsymbol{T}_t = (SX_t,\ RNT_t,\ RHT_t,\ RTT_t,\ LP_t,\ RPSQ_t)'$ represents the trade vector; $\boldsymbol{M}_t = (QO_t,\ MQO_t\ )'$ is the vector to capture trading mechanism switch and weekend effects; $\boldsymbol{c}$, $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ are 1×3, 3×3, 4×4, and 2×2 coefficient matrices; ϵ_t is the error vector which is assumed to be distributed as $N(0,\ \Sigma^2)$; LP_t is equal to the log of the average transaction price in interval t as a control variable; $RPSQ_t$ is the transaction return volatility in interval t, and all the

[44] The observed market quote (including spread, depth and level) is not the quote provided by any one individual market maker, but a competing result between RT quotes and public limit orders. Given a "free entry" continuous market system, the dynamic interactions of market makers should nonetheless cause market quotes to behave as if there were one dealer quoting competitive prices (Stoll, 1989). Also, see the empirical evidence in Laux (1993) and Hamilton (1976, 1979).

other variables are as defined before.[45]

Spread is expected to be positively autocorrelated and correlated to lagged quote level revision, and negatively related to the depth if quote changes are not efficient and do not gradually reveal information. Spread should be positively related to square-root trading volume, changes in the number of trades, relatively heavy trading indicators and volatility, and negatively related to relatively thin trading indicators. This is based on the asymmetric information models that show that spreads will **increase** given substantial information changes in the market. Spreads should decline over time given no trades [Easley and O'Hara (1992b)]. Spreads should increase with volatility because dealers are risk averse and volatility is probably correlated with information asymmetry (market makers must recover from uninformed traders what they lose to informed traders).

Spreads should decrease with competition because competition eliminates monopoly power. The transaction cost argument predicts that greater trading activity should lead to **lower** spreads due to economies of scale in trading costs [Schwartz (1988), Copeland and Galai (1983)]. This suggests a negative relationship between current spread and $SVOL_t$, RNT_t and RHT_t, and a positive relationship with RTT_t.

The inventory control models predict that spreads will **increase** if greater trading activity moves market makers away from their desired inventory positions. Uncertainty in the arrival of buy and sell orders forces dealers away from their optimal inventory positions [Garman (1976), Ho and Stoll (1980, 1981, 1983)]. The

[45] The volatility measure at t is proxied by the square of the average transaction return in interval t herein.

spread is reduced as the market maker approaches his desired inventory position. This implies that the spread should be positively related to $SVOL_t$, RNT_t and RHT_t, and negatively related to RTT_t.

The empirical results for the VAR model (4.8) are reported in **Table 4-6**. Quote returns are significantly and negatively related to previous quote returns and past return volatility, and positively related to past signed square-root trading volume, on average.[46] The significantly negative autocorrelation of quote returns (for 31 out of 35 stocks) suggests a reverting behavior of quote levels over time. The significantly positive association between quote returns and prior trade size (for all stocks in the sample) indicates a strong information effect of previous trade on quote level changes.

Relative spreads exhibit significantly positive serial correlation (for all stocks), and are significantly and positively related to prior changes in the number of trades (for 24 stocks) and relatively heavy trading indicators (for 28 stocks), on average. This suggests an information effect of prior trading activity on spreads which is consistent with the predictions of inventory control models, but inconsistent with transaction cost arguments. The relative spreads are significantly and negatively related to prior relatively thin trading indicators (for 34 stocks) on average, which suggests no information spread narrowing as in Easley and O'Hara (1992b). The relative spread is significantly and negatively related to previous quoted depths (for all stocks) on average, which indicates a strongly endogenous and negative cross-impact

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[46] The significant and negative relationship between quote level revisions and previous transaction return volatility exists for the mean but not for the median. Actually, only eight out of 35 stocks exhibit significant and negative relationships. Thus, this average significance is biased.

between spreads and depths. The relative spread is significantly and negatively related to prior log transaction price (for 34 stocks) on average, which implies smaller relative spreads with higher priced stocks. Spread is not significantly related to previous quote returns, signed square-root trading volume and transaction return volatility. Quoted depths exhibit significantly positive serial correlation (for all stocks), and are significantly and negatively related to prior changes in the number of trades (for 29 stocks) and relatively heavy trading indicators (for 20 stocks), on average. This suggests an information effect of prior trading activity on depths, in which trading activities for stocks with high information risk cause a decrease in market liquidity.[47] Quoted depths are significantly and negatively related to previous relative spreads (for all stocks) on average, which again indicates a strongly endogenous and negative cross-impact between spreads and depths. Quoted depths are significantly and negatively related to prior log transaction price (for 30 stocks) on average, which suggests thinner quoted depth for high priced stocks. Quoted depths are not significantly related to previous quote returns, signed square-root trading volume, relatively thin trading indicators and return volatility. Quoted depths are significantly lower for market opens compared to the rest of the trading day.

[Insert Table 4-6 about Here]

Although the overall results for the VAR model are consistent with the findings in the previous section for models (4.6) and (4.7), which examined the

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[47] This result is consistent with Easley and O'Hara (1992b) and Lee, Mucklow and Ready (1993), and also consistent with the previous findings in the cross-sectional test, where a significant downward shift in depth immediately after the information events was identified as an information effect.

relationship between each current quote dimension and prior trading activities, the VAR system enhances the results by providing evidence on the endogenous relationships among the three dimensions of quote changes simultaneously. While spread and depth are endogenously and negatively related, quote level changes are not endogenously related to both spread and depth.

4.8 Concluding Remarks

The behaviors of three dimensions of quotes (relative spreads, quote level revisions and quoted depths) are examined separately and endogenously in response to previous trading activities and to (non-) information events proxied by (thin) heavy trading intervals. The average cross-sectional correlations between quote variables are quite low. A U-shape intraday pattern is found for relative spreads, trading volumes and numbers of trades, and a reversed U-shape for quoted depths. Quote levels exhibit a significant negative revision in the first 30 minutes of each trading day.

Quote level revisions are not significantly changed during (non-)information event periods compared to other periods, but significantly increased before the information events. The overall low (high) level of spreads and thick (thin) depths around (non-)information events suggest that market liquidity is much higner during information periods than non-information periods. The upward (downward) shifts of spread immediately after the (non-)information events and lowered depths immediately after the information events are consistent with the information hypothesis that market makers increase the spread and decrease the depth to protect themselves against trades with informed traders. Quoted depths immediately after (non-)information events are significantly thicker (thinner) than those in other periods and those in non-information periods, which suggests that quoted depth is posted for liquidity and not informational reasons. The behavior of depth imbalances suggests a higher liquidity in information event periods and a lower liquidity for non-information events. The overall findings suggest information (heavy trading) shocks are associated with higher information risk (larger spread) and higher market liquidity (thicker depth), and non-information (thin or no trading) periods are more associated with lower market liquidity supply (larger spread and thinner depth). The result is consistent with the theory of Easley and O'Hara (1992b) and the empirical findings by Lee, Mucklow and Ready (1993) for NYSE stocks that information arrival induces a wider spread.

A significant adverse selection component in bid-ask spreads is identified, which is consistent with the information effect hypothesis of bid-ask spreads found in the microstructure literature. Quote level revisions are significantly related to trading volume (measured by signed square-root trading volume), but not to number of trades and relatively heavy (thin) trading indicators. Relative spreads and quoted depths are significantly related to changes in the number of trades and relatively heavy (thin) trading indicators, but not with trading volume. This suggests that trading activity variables have different information contents for changes in each of the three dimensions of quotes. While trading volume is more informative for quote level revisions, the number of trades and heavy (thin) trading indicators are more informative for spread and depth changes.

The spread is found to be negatively related to prior relatively thin trading indicators as suggested by Easley and O'Hara (1992b) (i.e., spreads decrease as the time between trades increases). The spread is positively related to prior changes in number of trades and relatively heavy trading indicators, which suggests that market makers set the initial spread based on the ex ante probability of informed traders, and widen the spread in response to an unusually high number of trades and trading volumes. The quoted depth is found to be negatively related to prior changes in number of trades and relatively heavy trading indicators, as predicted by Easley and O'Hara (1992b) that depth decreases with high volume. These results for spread and depth are not consistent with Harris and Raviv (1993) who argue that high volume is associated with tighter spreads and increased depths. The quoted level is revised mainly based on information arrivals reflected by signed trading volumes. (Buy-) sell-initiated trades drive quote levels (up) down.

Similar to Lee, Mucklow and Ready (1993), spread and depth are found to be endogenously and negatively related. Quote level revisions are not endogenously related to both spread and depth, but are related to beliefs about the true value of the underlying firm. The evidence presented herein shows that market makers (or liquidity providers) use three dimensions of quote adjustment to fulfil their mandate to provide market liquidity and to protect themselves from disclosing information to informed traders. While quote level revision and spread are associated more with information and risk aversion, depth is related more to the supply of market liquidity.

Chapter 5

Major Findings, Implications and Directions for Future Research

Interactions between trades and quote revisions are significant. Private information is revealed in the market by the trading activities of informed traders. Market makers react quickly to such information by adjusting their quotes against increased (decreased) order flow because of their ability to observe total order flow by having access to the limit order book. Uninformed traders realize that market makers are better and more quickly informed than public traders, and learn such information from quote changes (i.e., "second hand"). Therefore, both trading activities and quote revisions are informative but for different market participants. While quotes are revised against the trading of informed traders [one-side increased (decreased) trades], subsequent trades from uninformed traders respond positively to the prior quote revisions.

Transaction costs make transaction price changes less predictable than quote revisions based on trading history. While quote revisions are related more sensitively to prior trading activities and market co-movement, transaction price changes are due mainly to the bid-ask bounce effect of previous trades. Technical analysis can consistently and accurately reveal the causes of significant changes in stock prices (what has happened), but has limited (incremental) power in predicting future short-run stock price movements based on both cross-sectional and time series tests. The empirical results imply that short-run stock prices are more efficient than quote movements if transaction costs are included.

Market makers can move quotes along three dimensions (spread, quote level and depth) to fulfil their dual role of supplying liquidity and trading for their own accounts. While market makers tend to use spread and quote level adjustments against information risk and depth adjustments for liquidity demands, both spread and depth are sensitive to (non-)information events and they are endogenously and negatively related to each other. Quote level revisions are not endogenously related to both spread and depth, but are related to market maker beliefs about the true value of the underlying firm and information arrivals reflected by signed trading volumes.

The electronic trading system has evolved dramatically since the CATS was introduced on the TSE in 1977. Although the TSE has hesitated to move to a fully automated trading system, this seems likely in the future given such a system's potential to improve informational efficiency and reduce trading costs [Glosten (1994)]. A major problem faced by a fully automated trading system is whether or not it can provide as much liquidity as can be expected in a dealership market, given the continuous and substantial liquidity requirements of frequently traded stocks.

Glosten (1994) argues that an electronic exchange is the only one that does not engender additional competing exchanges given a large population of potential liquidity suppliers and the small costs of running such an exchange. Evidence on the Tokyo Stock Exchange provided by Lehmann and Modest (1994) suggests that the presence of exchange-designated market makers is not a necessary condition for a well-functioning financial market. What is meant by "well-functioning" and "a large population of liquidity suppliers" is unclear if no market makers are present. The evidence for the TSE suggests that most orders continue to be sent to the floor instead of being entered electronically, although MOST and LOTS were developed to assist floor traders to trade efficiently. Furthermore, CATS is used on the TSE only for less traded stocks that have lower liquidity requirements.

The empirical results in this study support the notion that market makers play an important role in market making. Their involvement in the trading process is to provide a continuous supply of liquidity and to make the market price more efficient by revealing private information faster and with more accuracy. In turn, this shortens the price discovery process. This explains why the TSE keeps a "modified" (partially automated) floor as a parallel trading system with CATS although such an arrangement is more costly. It also helps to explain why some major stock exchanges, such as the NYSE, NASDAQ and London, prefer to remain as dealership markets. Market makers are able to handle orders more complicated than market orders and simple limit orders, such as block orders, stop orders, good-till-canceled orders and limit or better orders. The recent TSE proposal to narrow the spread from one-eighth to decimal increments is one further step towards fully automated trading, which should enhance competitiveness, increase trading volume and liquidity supply, and result in more efficient pricing. As computing technology (e.g., artificial intelligence) develops so that computers can simulate most (if not all) of a market maker's functions, a fully automated trading system will become able to maintain high price efficiency, continuous liquidity supply and low trading costs.

Future research can extend the work presented in this study in several directions. First, competitive market making on the TSE can be studied further by comparing the limit orders on LOTS with the RT quotations. Such results may be useful for designing a fully electronic trading mechanism which has no designated market makers. Second, a study of trading behavior on a fully automated trading system such as CATS may provide further insights on liquidity supply and the requirements for such supply for upcoming orders, especially around information events. Third, research on liquidity and informed risk trading for infrequently traded stocks on the TSE would be interesting.[48] Fourth, the predictive powers of technical trading rules can be investigated further for relatively longer time horizons such as daily or weekly. This would conform more closely to the practice of most non-professional traders. Finally, the research methodology and empirical models used in this study can be applied to the data from the NYSE, NASDAQ, and Tokyo Stock Exchange to further investigate market making, liquidity supply and informational efficiency.

[48] Easley, Kiefer, O'Hara and Paperman (1995) study the trading behavior of infrequently traded stocks on the NYSE. They find that since less active stocks face a greater risk of informed trading, they have larger spreads.

Appendix 1: Market Structure of the Toronto Stock Exchange [49]

The TSE is currently the second largest stock exchange in North America in terms of value and volume traded, with more than 1,200 listed companies. The dollar value traded on the TSE was $182.2 billion and the volume was 15.5 billion shares in 1994. The TSE accounted for 82% of the value of all shares traded in Canada during 1994. The TSE is currently innovating its trading system by moving to a remote order entry trading system and closing the equity trading floor. Both are expected to be accomplished during 1995. The Board of the TSE has decided to trade stocks in narrower decimal increments rather than in increments of one-eighth of a dollar for shares priced above $5 beginning in the fall of 1995. It is expected to be the first exchange in North America to do so. Narrowing the spread in this manner may result in more efficient pricing, enhance competitiveness, increase trading volume, and increase visibility and liquidity. It may also cut brokerage firm profits earned on the spread between prices at which shares are bought and sold, especially in the obscure "upstairs" market.

The Toronto Stock Exchange (TSE) is a non-profit organization owned by its members. Membership is acquired by purchasing one of the 136 presently authorized seats. At the end of 1994, the TSE had 93 member firms each with at least one seat.

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[49] The information in this appendix is based on various Toronto Stock Exchange publications such as Annual report (1994), Equities Trading Manual (1993), TIPs Brochure (1995), Designated Market Makers (1994), and Huang, R.D. and H.R. Stoll, *Major World Equity Markets: Current Structure and Prospects for Change*, New York University Salomon Center, 1991.

Ownership of a seat entitles the holder to place up to six traders on the floor. Of the approximately 500 traders working for member firms on the floor, 180 have been registered with the TSE as Registered Traders (RTs) [sometimes called Designated Market Makers (DMMs)]. Approximately 32 TSE member firms have committed sizable amounts of capital to enable their RTs to fulfil their market making function.

The RT is somewhat like the specialist on the New York Stock Exchange. Each stock listed on the market is assigned to a RT, who ensures that a reasonable, competitive, continuous, fair and orderly market exists for the stock at all times, even if no public orders to buy or sell the stock are active in the marketplace at a particular point in time. RTs do this primarily by buying and selling for their own accounts. The RT is granted this privilege in return for the responsibility to improve the quality, efficiency and liquidity of the market. The trading privilege is not restricted to assigned stocks, since the RTs can trade all stocks listed on the Exchange. RTs pay the Exchange very favorable trading fees for their trading activities. Based on trading floor observation, the RTs spend most of their time buying and selling stocks not assigned to them. Trading privileges are not granted to the other traders working on the floor, who may only buy or sell a stock through a registered representative with an approved member firm.

A reasonable quoted market always exists for listed stocks (except in special circumstances such as trading halts). RTs post bid and ask quotations which are tradeable against their own accounts if an offsetting order comes into the market. The prices quoted must bear a reasonable relationship to the price of the last reported trade on the stock, and the spread between the bid and the ask must be reasonably close. The Exchange establishes a spread goal for every listed stock, and the RT has the responsibility to keep the actual spread within the target spread. TSE statistics show that, on average, about 30 per cent of the time the best bid or offer on stocks is posted by the RTs. In 1985, almost 99% of all trades were completed within 1/4 point ($0.25) of the price of the previous trade in a given stock.

The TSE was the first exchange to offer fully automated stock trading through Computer Assisted Trading System (CATS), which was introduced in 1977 and has been exported to Paris, Madrid, Brussels and Sao Paulo. The CORES of Tokyo also is patterned after CATS. The CATS system has been developed in parallel to the existing floor system and has been used primarily for less actively traded securities on the TSE. Currently, more than 1/3 of all listed stocks trade on CATS. CATS creates a computer file in which limit orders are displayed. Investors trade against this limit order book by entering limit or market orders, where the latter are converted into limit orders at the best current quote. If insufficient volume is available in the book at these quotes, the market order is queued as a limit order at bid or ask prices assigned to it when the order was entered. Orders on the computer file are executed on the basis of price priority, and at time priority for orders at the same price. The RT in a CATS stock places orders from a terminal upstairs or on the floor, and has nearly equal standing with other traders in the system. CATS has provisions for special orders and allows an investor with a large order to display only part of the order (specifically, a minimum of 10 round lots). If the disclosed portion is executed, the remaining portion of the order loses time priority and queues behind other limit orders at the current price. CATS provides considerable information to investors.

Since all orders are converted into limit orders, bid and ask prices and respective aggregate depths are publicly displayed. They reflect the current demand and supply at each price level. The identity of each order and price and volume data on recent trades also are displayed.

The modified floor trading system on the TSE since the beginning of 1990 is based on a electronic limit order book much like CATS. The key difference is that the book is located on the floor and not in upstairs offices. Information on prices and volumes similar to that supplied in CATS is displayed. Orders from the floor and from upstairs have equal standing and can only be executed by placing them on the book. With the Limit Order Trading System (LOTS), brokers are able to place limit orders electronically, without having a trader present on the floor. The RT must ensure that orders entered through LOTS participate fully in the market. An execution delay of 20 seconds is allowed for orders entered from upstairs in order to give floor traders the opportunity to enter orders from the floor that were announced prior to entry of the upstairs order.[50] This procedure is similar to the NYSE procedures for handling DOT orders. Electronic orders may be reviewed by the RT before being executed against the standing limit orders (for the book or the RT's own account). The book on the floor accepts orders from all floor traders including the RT. The RT need not be present to maintain trading because any floor trader can enter an order on the book without the assistance of the RT. The major competitive

[50] For example, negotiation on the floor may lead to an order from a floor broker who requests that the RT enter the order in the book. Execution of an incoming electronic order can be delayed to give time to enter the order from the floor. In effect, this provision gives the RT time to review each electronic order before releasing it for execution to the book.

advantage to the RT is that the RT shares volume with other traders (above a minimum guaranteed fill) if the RT is at the same bid or offer as another limit order.

The RT executes odd lots and guarantees transactions in the automated small order execution system called the Market Order System of Trading (MOST). The RTs guarantee best bid and ask prices for at least 599 shares for market orders transmitted through the MOST automatic execution system. The guarantee applies to all stocks traded on the TSE floor and to some of the stocks traded in CATS. If no public orders exist to buy or sell at the quoted prices, the order is automatically filled against the RT's account. On certain very liquid stocks, RTs guarantee a fill of 2099 shares. TSE member firms enter MOST orders through their computerized order routing systems and authorized CATS terminals. Orders are electronically transmitted through MOST to the TSE trading floor for instant execution. Confirmation of a completed trade is sent back to the member firm within seconds after the order is input.

Each trading day the RTs are responsible for establishing the opening price in the various stocks for which they are responsible. Opening prices reflect all orders entered by 9:30 a.m., as well as the RT's judgement on the company's current business situation and the market for its stock against the background of overall market trends. Since 1990, the TSE uses an electronic opening in which the computer determines the volume of trade at each opening price. The RT can enter trades that close an imbalance, or on a discretionary basis, accept other orders that close an opening imbalance. For CATS stocks, the opening price is determined electronically on the basis of the order flow prior to the opening.

RTs are required to assist other traders in matching their orders and making trades. They bring buyers and sellers together by keeping track of firms interested in buying and selling stock at various prices. The TSE requires that at least 70% to 80% of a RT's trading be stabilizing trades which are against the trend of the market. RTs are responsible for posting the size of the market (total number of shares to be bought or sold) on an ongoing basis in order to give traders, brokers and investors an indication of market depth. Although MOST and LOTS were developed to assist floor traders to trade efficiently, orders continue to be sent to the floor rather than be entered electronically. In part this is due to the low volume and the desire to keep floor traders fully employed. The electronic system is also not capable of handling orders more complicated than market orders or simple limit orders.

Appendix 2: Description of The Toronto 35 Index and TIPs

The Toronto 35 Index was created by the TSE in 1987 to facilitate the creation of derivative products specially designed to meet the trading and hedging needs of private investors and professional fund managers. This index is composed of 35 Canadian stocks chosen for their liquidity, size of publicly held float and inclusion in the TSE 300 Composite Index. The value of the index is updated every 15 seconds. The index is designed to closely track the movements of the TSE 300 Index. All of the industry groups represented in the broader TSE 300 Index (excluding Real Estate) are directly represented in the Toronto 35 Index. During a period from May 1987 to March 31, 1995, a 94.5% correlation existed between movements of the Toronto 35 Index and the TSE 300 Composite Index based on daily data. The constituent companies of the Toronto 35 Index are some of Canada's largest and the most heavily traded stocks on the TSE. In 1994, each stock traded in excess of 10 million shares and $100 million. All but one of the companies had a market capitalization in excess of $1 billion, all but two stocks had listed options, and 18 of the stocks were interlisted with New York, AMEX, London, NASDAQ, or Tokyo.

Toronto 35 Index Participation Units (TIPs) is a traded security representing the diversified portfolio of stocks comprising the Toronto 35 Index. The trust units are created by the TSE. The trust, which is administrated by the Montreal Trust Company of Canada holds baskets of stocks included in the Toronto 35 Index. The value of each unit approximates 1/10th of the Index level. TIPs trade in board lots of

100 units. Since September of 1991, the minimum spread was reduced to 5 cents from the traditional 12.5 cents, with a Minimum Guaranteed Fill (MGF) of 15,000 units. Dividends received by the trust are distributed to unit holders quarterly. Investors holding a minimum of the prescribed number of TIPs, may redeem their TIPs for the underlying basket of stocks at any time and vote the shares by proxy. The prescribed number of TIPs is currently about 54,058 units with an approximate value of $1.2 million, based on stock market prices as of March 1995. Investors holding less than a basket of TIPs may redeem for cash on a predetermined sliding scale outlined in the TIPs Prospectus. Voting and other shareholder decisions are determined on behalf of the trust by a specially appointed Discretions Committee. The shares held in the trust of any one constituent company of the Toronto 35 Index do not comprise 10% or more of the market capitalization of that company or 10% or more of the total assets of the trust. As of March 31, 1995, 43,895,096 TIPs valued at over $1 billion were issued and outstanding. Since its inception in March of 1990, TIPs has been one of the most active issues on the TSE with a daily average of about 240,000 units traded.

Toronto 35 Index Composition for July 1990

No.	Company	Ticker	Shares	Price ($)	Weight (%)
1.	Alcan	AL	1500	27.875	4.38
2.	BCE Inc.	B	1500	37.625	5.92
3.	Bank of Montreal	BMO	1000	27.000	2.83
4.	Bank of Nova Scotia	BNS	1000	14.625	1.53
5.	Bow Valley Industrial	BVI	1000	13.750	1.44
6.	CAE Industrials	CAE	1500	6.250	0.98
7.	Canadian Imperial Bank	CM	1500	27.250	4.29
8.	Canadian Pacific Ltd	CP	2000	20.000	4.19
9.	Canadian Tire Class A	CTR.A	2000	20.250	4.25
10.	Echo Bay Mines	ECO	1000	15.000	1.57
11.	Gulf Canada Resources	GOU	1000	16.000	1.68
12.	Imperial Oil Class A	IMO.A	500	61.375	3.22
13.	IMASCO Ltd	IMS	1000	36.500	3.83
14.	Lac Minerials	LAC	750	12.000	0.94
15.	Laidlaw Class B	LDM.B	1500	25.250	3.97
16.	Macmillan Bloedel	MB	1000	18.125	1.90
17.	Moore Corp	MCL	1000	33.125	3.47
18.	Inco Limited	N	1000	36.125	3.79
19.	National Bank	NA	1000	10.000	1.05
20.	Noranda Inc.	NOR	1000	20.000	2.10
21.	Northern Telecom	NTL	1000	31.250	3.28
22.	Nova Corp of Alberta	NVA	3000	8.625	2.71
23.	Placer Dome	PDG	2100	19.375	4.27
24.	Power Corp	POW	1000	14.875	1.56
25.	Ranger Oil	RGO	3000	7.875	2.48
26.	Royal Bank	RY	2000	24.125	5.06
27.	Sears Canada	SCC	1500	11.375	1.79
28.	Stelco Series A	STE.A	500	16.375	0.86
29.	Southam Inc.	STM	750	22.375	1.76
30.	Transalta Utilities	TAU	2000	11.625	2.44
31.	Toronto-Dominion Bank	TD	2000	19.250	4.04
32.	Teck Corp Class B	TEK.B	1000	25.875	2.71
33.	The Thomson Corporation	TOC	2000	14.375	3.01
34.	Transcanada Pipelines	TRP	1000	15.625	1.64
35.	Seagram	VO	500	97.000	5.08
	Total				**100**

Basket Quoted Market Value (QMV) = $953,906.25		Index = 193.54
P/E = 14.70	Base = 4928	Yield = 3.73

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Table 2-1: Transaction Statistics

TSE 35 Stocks, 1990 7 - 1991 6. Total of 3276 observations (30-minute)

	Ticker	Transaction Price C$				Transaction Return (%)				Trade Volume (No. of Shares)				Number of Trades				No Trading Periods
		Mean	*S D*	*Min*	*Max*	*Mean*	*S D*	*Min*	*Max*	*Mean*	*S D*	*Max* $(\times 10^5)$	*Total* $(\times 10^7)$	*Mean*	*S. D.*	*Max*	*Total*	
1	AL	24.09	1.94	19.63	28.13	-0.0019	0.45	-3.64	4.42	27,583	45,121	8.8165	9.0363	14.86	14.04	137	48,668	150
2	B	39.61	2.27	34.86	43.70	0.0037	0.20	-1.46	1.57	23,058	55,950	23.8581	7.5539	29.68	22.52	279	97,229	10#
3	BMO	30.94	4.15	24.58	38.35	0.0082	0.29	-3.71	2.32	20,961	164,863	90.7100	6.8670	14.74	12.89	195	48,295	70
4	BNS	14.03	2.02	10.61	18.15	0.0072	0.48	-2.69	4.10	33,125	67,507	20.3300	1.0852	33.22*	27.28	311	108,813	18
5	BVI	14.13	0.82	12.46	16.25	0.0015	0.53	-3.79	4.21	3,593	17,309	5.1160	1.1772	1.66	2.68	24	5,427	1662
6	CAE	5.81#	0.87	4.00	7.25	0.0025	1.03	-14.04	8.45	12,164	59,048	22.3100	3.9900	4.89	7.25	111	16,026	631
7	CM	27.75	3.39	21.65	32.88	0.0044	0.34	-3.19	2.29	15,309	35,565	10.5400	5.0154	9.48	8.04	57	31,045	162
8	CP	19.81	1.28	17.33	23.24	-0.0008	0.40	-3.46	3.21	35,327	52,410	11.0100	11.5730	22.78	18.73	162	74,639	35
9	CTR.A	22.10	1.88	19.25	25.23	0.0072	0.42	-2.26	2.87	6,621	20,132	3.6900	2.1690	5.88	6.78	90	19,266	451
10	ECO	11.59	2.54	8.18	17.89	-0.0104	0.92	-12.59	5.59	9,153	20,806	4.6500	2.9990	4.97	6.45	65	16,279	753
11	GOU	12.00	2.90	8.07	17.11	-0.0158	0.75	-6.12	4.25	6,065	37,701	17.8200	1.9869	3.02	4.05	34	9,883	1090
12	IMO.A	58.93	3.64	53.00	67.32	0.0002	0.27	-1.52	2.53	5,364	11,309	1.9270	1.7573	6.11	6.14	76	20,025	276
13	IMS	30.15	3.22	25.50	37.36	-0.0042	0.37	-3.37	4.36	5,904	16,519	4.4990	1.9340	4.03	4.38	36	13,200	683
14	LAC	9.52	1.31	7.47	13.09	-0.0030	0.89	-9.52	5.16	20,630	49,989	7.8818	6.7587	9.20	10.81	233	30,147	335
15	LDM.B	19.39	4.20	11.36	28.01	-0.0245	0.76	-20.18	4.45	60198*	217,989	91.4896	19.7210	30.67	46.24	835	100,472	50
16	MB	17.98	1.81	37.00	22.54	0.0056	0.47	-3.24	2.28	8,023	22,529	5.0085	2.6283	6.97	7.54	92	22,831	328
17	MCL	28.58	2.56	24.38	35.00	-0.0030	0.37	-3.58	2.15	9,661	23,563	5.1800	3.1650	5.71	5.65	44	18,720	404
18	N	34.05	4.23	26.91	41.15	0.0079	0.39	-4.74	2.49	23,691	327,622	185.3200	7.7615	10.03	9.99	86	32,863	256
19	NA	9.17	1.25	7.00	11.50	0.0056	0.73	-3.94	3.48	10,892	44,199	13.7742	3.5684	7.97	8.82	69	26,100	421
20	NOR	17.62	1.63	14.13	21.38	0.0015	0.51	-3.09	3.14	12,195	37,124	10.3310	3.9953	6.42	6.62	70	21,023	382
21	NTL	33.53	5.00	25.63	43.63	0.0084*	0.39	-4.86	5.64	13,833	24,527	3.3050	4.5320	8.39	8.03	114	27,473	244
22	NVA	8.44	0.51	7.25	9.50	-0.0006	0.76	-7.29	3.84	31,041	71,965	11.3517	1.0169	16.19	15.13	13*	53,053	74
23	PDG	17.38	1.89	13.64	22.49	-0.0029	0.59	-6.93	3.80	29,749	50,657	11.4990	9.7456	18.37	18.33	171	60,196	104
24	POW	15.99	1.01	14.00	18.13	0.0040	0.43	-2.24	3.21	3,858	10,620	1.5700	1.2641	3.61	4.11	37	11,818	811
25	RGO	8.01	0.50	7.00	9.63	0.0037	0.77	-4.94	5.70	20,100	260,159	105.6210	6.5848	4.65	7.36	81	15,233	1113
26	RY	23.65	1.84	19.83	27.00	0.0020	0.36	-2.80	2.89	19,761	86,165	44.7300	6.4740	12.90	10.37	93	42,272	96
27	SCC	11.28	1.10	9.38	14.25	0.0056	0.69	-5.02	4.58	3,763	32,627	10.7500	1.2330	1.37#	2.22	31	4,495	1715*
28	STE.A	11.26	3.20	6.13	16.80	-0.0292#	0.73	-9.65	9.64	4,743	14,781	2.5040	1.5539	4.68	5.85	77	15,338	695
29	STM	19.40	1.98	16.25	25.38	-0.0094	0.49	-3.94	4.88	3,177#	16,746	7.2740	1.0408	1.94	2.50	27	6,347	1249
30	TAU	12.35	0.40	11.23	13.78	0.0023	0.53	-1.96	2.42	12,311	35,763	11.4400	4.0330	13.32	12.26	109	43,652	182
31	TEK.B	22.42	1.99	18.52	28.35	-0.0017	0.45	-4.11	4.73	8,076	25,777	4.7136	2.6458	3.03	4.24	48	9,939	1185
32	TD	17.61	1.28	14.54	19.75	0.0017	0.46	-4.33	3.12	25,466	75,925	34.4000	8.3427	18.33	17.99	378	60,061	48
33	TOC	15.72	1.19	13.12	18.25	0.0013	0.47	-3.02	1.87	12,391	29,944	4.0060	4.0596	4.64	4.42	35	15,202	462
34	TRP	16.79	0.74	15.03	18.00	0.0034	0.43	-9.31	2.17	17,851	53,302	16.1100	5.8483	9.61	10.14	97	31,494	271
35	VO	101.59*	10.78	84.54	125.22	0.0070	0.36	-10.79	10.35	3,957	9,465	3.0970	1.2964	4.29	4.24	38	14,055	489
	Ave	22.36	2.32	18.96	27.30	-0.0004	0.53	-5.47	4.06	15,988	61,019	23.3324	4.6975	10.22	10.40	128	33,474	483
	S.D	17.43	1.89	15.26	21.00	0.0086	0.20	4.04	2.04	12,173	72,071	38.2405	3.8719	8.39	8.60	149	27,475	462

Note (1) Transaction price is the average price of all trades within a 30-minute interval. Transaction return is the log difference of transaction price at t and t-1. Trade volume is the total number of shares traded in a 30-minute interval. Number of trades is the total number of transactions in a 30-minute interval, and No trading periods are the number of no transaction intervals in sample period.

(2) "*" indicates the maximum in the category; and "#" indicates the minimum in the category.

Table 2-2 Quotation Statistics TSE 35 Index Stocks, 1990 7 - 1991 6 Total of 3276 observations (30-minute)

	Ticker	Quote Mid-point Price C$				Quote Return (%)				Depth (=DA+DB) (board lot)				Spread C$			NT
		Mean	S. D.	Min	Max	Mean	S. D.	Min	Max	Mean	S. D.	Min	Max	Mean	S. D.	Max	at MQ
1	AL	24.08	1.94	19.63	28.06	-0.0031	0.4610	-3.86	3.87	357.20	215.77	21	1,643	0.1482	0.0490	0.375	125
2	B	39.62	2.27	34.81	43.69	0.0017	0.2143	-2.15	1.94	507.37	261.76	33	1,940	0.1389	0.0593	0.750	22
3	BMO	30.95	4.16	24.56	38.31	0.0061	0.2739	-2.69	1.97	341.54	209.53	12	1,380	0.1384	0.0392	0.500	64
4	BNS	14.03	2.04	10.56	18.19	0.0050	0.4765	-4.63	4.06	860.45	415.50	53	1,998	0.1294	0.0229	0.250	15#
5	BVI	14.14	0.83	12.69	16.31	0.0016	0.3471	-2.88	3.46	183.83	118.22	8	854	0.1679	0.0628	0.375	109
6	CAE	5.81*	0.87	3.95	7.31	0.0017	0.8067	-13.50	7.74	514.53	357.71	20	1,880	0.1118#	0.0435	0.500	58
7	CM	27.76	3.40	21.69	32.94	0.0031	0.3400	-4.89	2.78	305.80	180.61	7	1,224	0.1409	0.0486	1.625	78
8	CP	19.81	1.29	17.31	23.19	-0.0021	0.4067	-3.65	3.40	754.85	318.49	39	1,998	0.1371	0.0370	0.250	61
9	CTR A	22.11	1.88	19.31	25.19	0.0068	0.3318	-2.72	2.62	185.60	137.15	8	1,328	0.1631	0.0605	1.000	145
10	ECO	11.59	2.54	8.25	17.94	-0.0106	0.0873	-14.36	5.22	274.22	167.19	13	1,460	0.1597	0.0563	0.375	236*
11	GOU	12.00	2.90	8.13	17.06	-0.0169	0.5417	-5.68	3.90	194.00	140.43	9	1,152	0.1675	0.0614	0.375	126
12	IMO A	58.93	3.64	52.94	67.19	-0.0006	0.2628	-1.74	3.30	83.83	60.00	2	476	0.2258	0.0939	2.000	123
13	IMS	30.15	3.23	25.69	37.31	-0.0054	0.3125	-3.08	3.62	131.12	102.94	3	888	0.1808	0.0708	1.000	172
14	LAC	9.52	1.30	7.44	13.06	-0.0038	0.8040	-7.51	4.92	513.55	258.77	30	1,943	0.1406	0.0414	0.250	131
15	LDM.B	19.39	4.21	11.31	28.06	-0.0250	0.7600	-20.18	4.45	577.00	320.00	27	1,998	0.1415	0.0423	0.250	71
16	MB	18.00	1.81	14.50	22.50	0.0041	0.3827	-3.38	2.59	232.40	181.56	10	1,627	0.1521	0.0519	0.500	101
17	MCL	28.58	2.59	24.38	35.00	-0.0037	0.3399	-3.58	2.07	174.19	130.32	7	1,240	0.1643	0.0620	1.000	172
18	N	34.05	4.23	26.94	41.25	0.0068	0.4038	-4.34	2.80	209.52	138.35	11	1,389	0.1609	0.0567	0.375	185
19	NA	9.16	1.26	6.94	11.44	0.0032	0.5361	-3.15	3.31	559.07	339.22	12	1,962	0.1371	0.0370	0.250	98
20	NOR	17.63	1.64	14.06	21.44	0.0000	0.4221	-2.09	4.01	275.96	207.15	6	1,754	0.1547	0.0541	0.625	155
21	NTL	33.53	5.00	25.69	43.56	0.0080*	0.3950	-5.52	5.40	221.84	142.43	8	1,441	0.1526	0.0521	0.500	157
22	NVA	8.45	0.51	7.31	9.56	-0.0028	0.5649	-8.00	3.25	1402.38*	392.18	253	1,998	0.1296	0.0235	0.250	26
23	PDG	17.38	1.89	13.69	22.56	-0.0035	0.5907	-6.98	4.72	507.20	249.47	56	1,599	0.1417	0.0430	0.500	113
24	POW	16.01	1.01	14.06	18.06	0.0024	0.2886	-2.13	2.33	233.81	148.57	7	1,018	0.1454	0.0471	0.500	107
25	RGO	8.02	0.50	6.94	9.56	0.0030	0.5930	-4.69	6.11	698.00	376.55	70	1,998	0.1316	0.0280	0.250	49
26	RY	23.65	1.85	19.81	27.06	0.0006	0.3358	-2.98	2.12	389.81	226.17	13	1,879	0.1373	0.0372	0.250	71
27	SCC	11.30	1.11	9.44	14.13	0.0044	0.5140	-3.62	7.02	151.52	149.09	4	1,199	0.1886	0.0829	1.000	97
28	STE A	11.26	3.21	6.06	16.81	-0.0297#	0.7807	-9.03	8.86	158.29	114.68	5	1,040	0.1584	0.0577	1.000	169
29	STM	19.40	1.99	16.25	25.44	-0.0094	0.4033	-5.73	3.75	93.65	83.03	2	552	0.1871	0.0820	0.750	131
30	TAU	12.34	0.40	11.19	13.75	0.0000	0.3408	-2.47	2.53	640.63	356.04	27	1,998	0.1329	0.0305	0.250	58
31	TEK B	22.42	1.99	18.56	28.25	-0.0020	0.3918	-2.81	4.12	170.37	139.32	7	1,204	0.1757	0.0723	0.500	146
32	TD	17.62	1.29	14.56	19.75	0.0004	0.4529	-4.24	3.19	506.56	279.96	14	1,827	0.1339	0.0321	0.250	40
33	TOC	15.72	1.18	13.06	18.19	0.0001	0.3361	-2.32	1.76	432.58	253.20	12	1,889	0.1361	0.0357	0.250	69
34	TRP	16.79	0.73	15.13	17.94	0.0022	0.3092	-8.53	1.91	983.40	477.36	21	1,998	0.1319	0.0285	0.250	59
35	VO	101.59*	10.78	84.38	125.44	0.0064	0.2510	-2.57	2.32	37.91#	30.31	4	1,019	0.2682*	0.1021	1.000	103
	Ave	22.37	2.33	18.32	27.30	-0.0015	0.4302	-5.19	3.76	396.11	219.40	24	1,508	0.1546	0.0510	0.561	104
	SD	17.43	1.89	14.92	21.02	0.0083	0.1698	3.97	1.69	290.67	109.95	43	451	0.0295	0.0193	0.415	52

Note (1) Quote mid-point price is the the average of last bid and ask price in a 30-minute interval. Quote return is the log difference of quote mid-point price at t and t-1; Depth is the sum of last quoted size at bid and at ask in a 30-minute interval. Spread is the difference between the bid and ask prices in a 30-minute interval, and NT at MQ is the number of intervals where the transaction price equals the previous quote mid-point price in the sample period (2) "*" indicates the maximum in the category; and "#" indicates the minimum in the category

Figure 2-1: Intraday Patterns of Selected Variables

Panel 1 plots the intraday pattern of transaction price changes (returns), Panel 2 plots intraday patterns of quote mid point changes (returns), Panel 3 plots the intraday pattern of quoted depth imbalance (depth in ask - depth in bid), Panel 4 plots intraday pattern of trading volume, Panel 5 plots the intraday pattern of number of trades, and Panel 6 plots the intraday pattern of signed trading volume

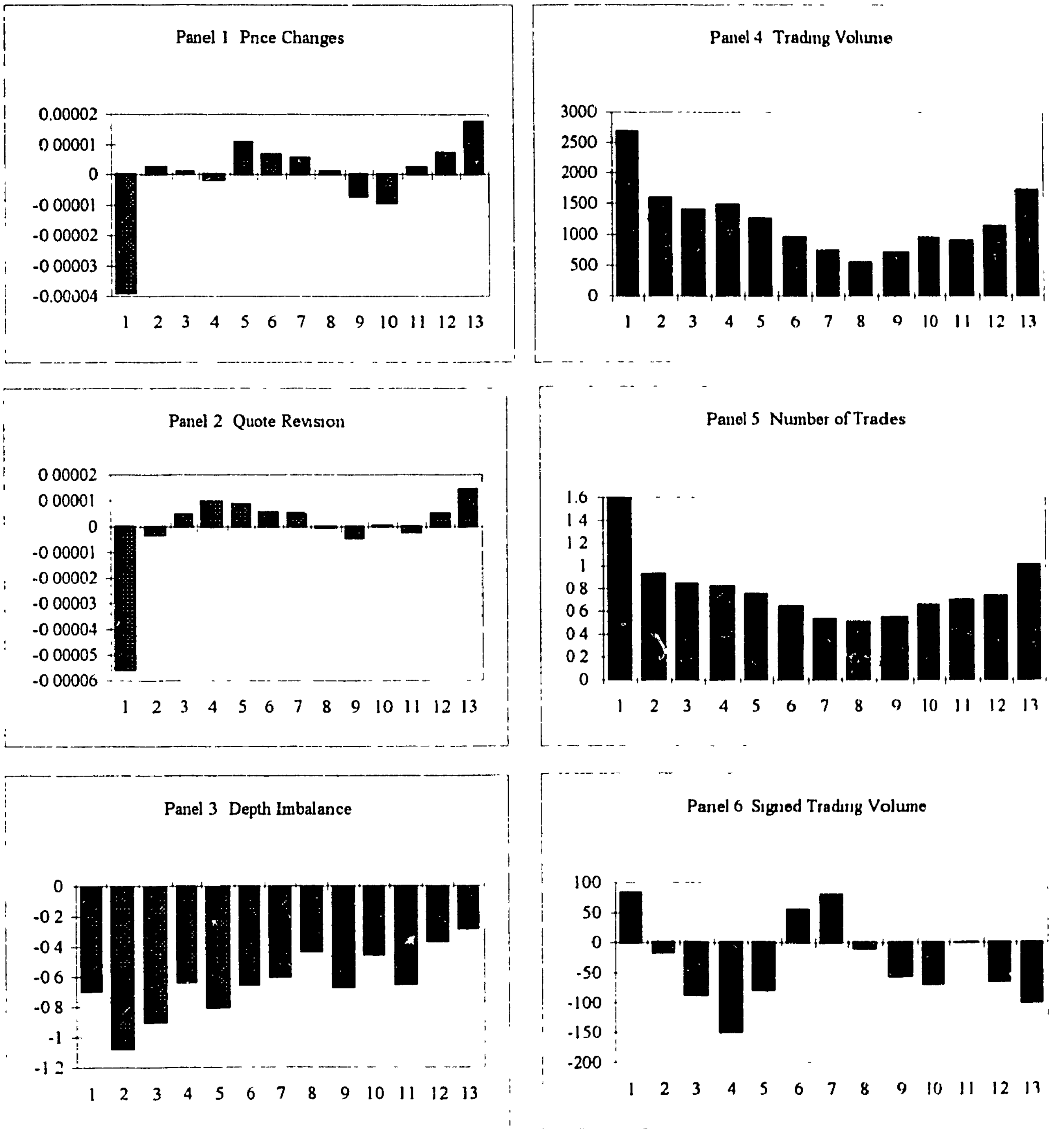


Table 2-3 Quote Revision Model (Equation 2.1) — TSE 35 Stocks, 1990.7 - 1991.6 Total of 3276 observations (30-minute)

(2.1) $RQ(t) = a0 + a1*Z(t) + a2*TRP(t) + a3*SX(t) + a4*RNT(t) + a5*RHT(t) + a6*RTT(t) + a7*RQ(t-1) + a8*DI(t-1) + a9*QO(t) + a10*MQO(t) + e(t)$

coefficient x 1000

	Constant	*Z(t)*	*TRP(t)*	*SX(t)*	*RNT(t)*	*RHT(t)*	*RTT(t)*	*RQ(t-1)*	*DI(t-1)*	*QO(t)*	*MQO(t)*	*adj-R-sq*	*D-W*	*F-stat*
Ave Coeff	0.0480	484.09	71.629	0.0091	0.0102	0.0533	0.0765	-11.2238	-0.0024	-0.3415	0.0477	0.4468	1.9217	314.00
Ave t-stat	0.7856	**13.681**	**3.3545**	**5.6512**	0.6840	0.2084	0.6911	-0.5961	**-6.7287**	-0.8925	0.1508			
Max Coeff	0.6514	1013.4	150.16	0.0228	0.1931	1.0065	0.7274	49.4720	0.0001	0.4283	2.4989	0.7429	2.0300	947.38
Max t-stat	**9.9353**	**29.636**	**7.2353**	**12.644**	**3.1429**	**3.3664**	**7.0096**	**2.8104**	0.5124	**1.4323**	**2.4657**			
Med Coeff	0.0785	458.01	76.889	0.0079	0.0031	0.0532	0.0586	-12.906	-0.0022	-0.3518	0.1015	0.4256	1.9250	253.30
Med t-stat	1.0053	**12.423**	**3.4236**	**5.1160**	0.7883	0.1686	0.4625	-0.6822	**-6.8798**	-1.0824	0.1835			
Min Coeff	-0.2890	138.89	-38.474	0.0003	-0.0440	-1.4026	-0.6036	-89.089	-0.0092	-1.8354	-2.6407	0.2001	1.8200	82.92
Min t-stat	**-4.3106**	**1.8584**	-0.8587	0.1891	**-2.9165**	**-2.7848**	**-3.1677**	**-4.2891**	**-12.091**	**-3.1277**	**-2.3807**			
No Signif	12+, 7-	35+, 0-	30+, 0-	33+, 0-	13+, 2-	4+, 3-	10+, 3-	2+, 10-	0+, 33-	1+, 13-	5+, 1-			

Table 2-4 Depth Imbalance Innovation Model (Equation 2.2) — TSE 35 Stocks, 1990.7 - 1991.6 Total of 3276 observations (30-minute)

(2.2) $DI(t) = b0 + b1*Z(t) + b2*TRP(t) + b3*SX(t) + b4*RNT(t) + b5*RHT(t) + b6*RTT(t) + b7*RQ(t-1) + b8*DI(t-1) + b9*QO(t) + b10*MQO(t) + e(t)$

	Constant	*Z(t)*	*TRP(t)*	*SX(t)*	*RNT(t)*	*RHT(t)*	*RTT(t)*	*RQ(t-1)*	*DI(t-1)*	*QO(t)*	*MQO(t)*	*adj-R-sq*	*D-W*	*F-stat*
Ave. Coeff	-2.1738	4951.5	500.48	-0.0116	-0.0411	-2.6056	-0.1275	-2534.5	0.5620	0.2502	1.2769	0.3315	2.1169	217.44
Ave. t-stat	-0.4564	**4.4935**	0.3373	-0.2947	0.0085	-0.1755	-0.0332	**-2.3981**	**25.952**	0.0182	-0.0562			
Max Coeff	13.777	16894.0	3369.3	0.2343	0.5488	27.747	25.271	201.1	0.8835	12.844	220.02	0.7867	2.2735	1208.7
Max t-stat	**4.1563**	**8.0021**	**2.2118**	**2.3354**	**2.0892**	**2.4880**	**2.4761**	0.7478	**50.973**	**2.4570**	**2.5465**			
Med Coeff	-1.4265	3207.2	165.25	-0.0158	0.0097	-0.5720	0.3996	-1673.8	0.6045	1.2517	-1.7600	0.3426	2.1132	178.48
Med t-stat	-0.3476	**4.3786**	0.2843	-0.4817	0.0344	-0.2493	0.1425	**-2.2222**	**26.552**	0.0270	-0.0204			
Min Coeff	-24.986	94.580	-1506.6	-0.1311	-0.8253	-43.722	-33.671	-10565.0	0.1988	-101.08	-92.800	0.0383	2.0248	14.047
Min t-stat	**-6.4592**	0.8273	**-1.4353**	**-2.2525**	**-2.4323**	**-1.6990**	**-3.1833**	**-5.9380**	**2.4925**	**-2.7337**	**-1.6466**			
No Signif	8+, 8-	32+, 0-	6+, 1-	4+, 4-	4+, 3-	1+, 4-	4+, 6-	0+, 25-	35+, 0-	5+, 5-	2+, 2-			

Note (1) The Bolded numbers indicate significance at a level of 90% or above
(2) Number significant indicates the number of stocks out of the TSE 35 stocks with a + (or -) [i.e., positive (negative)] and significant coefficient estimates

Table 2-5 Signed Square-root Trading Volume Innovation Model (Equation 2.3) TSE 35 Stocks, 1990 7 - 1991.6 Total of 3276 observations (30-minute)

(2 3) $SX(t) = c0 + c1*Z(t-1) + c2*TRP(t-1) + c3*SX(t-1) + c4*RNT(t-1) + c5*RHT(t-1) + c6*RTT(t-1) + c7*RQ(t-1) + c8*DI(t-1) + c9*TO(t) + c10*TC(t) + c11*MTO(t) + e(t)$

	Constant	Z(t-1)	TRP(t-1)	SX(t-1)	RNT(t-1)	RHT(t-1)	RTT(t-1)	RQ(t-1)	DI(t-1)	TO(t)	TC(t)	MTO(t)	adj-R-sq	D-W	F-stat
Ave Coeff	0 0499	2166 2	918.62	0 0398	0 0301	0 0781	-1.9410	-2509 2	-0 0389	-0 5019	1 6802	-5 9372	0 0232	1 9997	8.179
Ave t-stat	0 1756	**2.7871**	1 3383	1 3203	0 1606	0.0640	-0.4923	**-3.0631**	**-3.8072**	0 0081	0 2901	-0 3773			
Max Coeff	11 002	8563 1	2798 5	0 1049	0 4811	21 056	5 3445	2652 5	0 0483	27 155	27 267	50 445	0 0651	2 0112	21 721
Max t-stat	**5.5314**	**7.0656**	**2.9951**	**3.4659**	**2.1059**	**2.2572**	1 3216	**1.5493**	**1.6007**	**1.6711**	**3.0367**	**2.3625**			
Med Coeff	0 0004	1508 6	868 37	0 0387	0 0576	1 4321	-1 0460	-2596 3	-0 0447	-0 1494	1 7782	-8.1025	0 0179	2.0007	6 437
Med t-stat	0 0065	**2.8600**	**1.3527**	1 3043	0 2158	0 1909	-0 3058	**-3.4016**	**-3.9289**	-0 0070	0 2170	-0.4760			
Min Coeff	-12 219	-94.325	-613 99	-0 021	-0 613	-23 476	-18 323	-10977	-0 095	-33 650	-23 653	-64.419	0 0030	1.9772	1 909
Min t-stat	**-3.9573**	-0 0565	-0 6445	-0 7606	**-1.6692**	**-2.6686**	**-2.9156**	**-6.8331**	**-10.251**	**-1.9997**	**-2.2388**	**-2.1001**			
No Signif	8+, 7-	29+, 0-	18+, 0-	18+, 0-	2+, 3-	3+, 3-	0+, 6-	1+, 29-	1+, 27-	5+, 1-	7+, 6-	1+, 6-			

Table 2-6 Changes in Number of Trades Innovation Model (Equation 2 4) TSE 35 Stocks, 1990 7 - 1991 6 Total of 3276 observations (30-minute)

(2 4) $RNT(t) = d0 + d1*Z(t-1) + d2*TRP(t-1) + d3*SX(t-1) + d4*RNT(t-1) + d5*RHT(t-1) + d6*RTT(t-1) + d7*RQ(t-1) + d8*DI(t-1) + d9*TO(t) + d10*TC(t) + d11*MTO(t) + e(t)$

	Constant	Z(t-1)	TRP(t-1)	SX(t-1)	RNT(t-1)	RHT(t-1)	RTT(t-1)	RQ(t-1)	DI(t-1)	TO(t)	TC(t)	MTO(t)	adj-R-sq	D-W	F-stat
Ave Coeff	-1 2990	27 903	20 201	-0 0018	-0 3827	-5 2696	4 4819	26 460	0 0002	10 873	4 9135	-2 9614	0 3022	2 2451	130 52
Ave t-stat	**-6.7730**	0 1127	0 2166	-0 6946	**-15.083**	**-8.0429**	**10.857**	0 5508	0 1021	**10.063**	**7.1022**	**-1.6638**			
Max Coeff	-0 5191	506 60	175 51	0 0079	-0 3067	-1 3861	11 519	196 85	0 0021	43 708	15 229	2 3067	0 3620	2 3000	169 93
Max t-stat	**-3.3538**	**3.0241**	**2.2137**	**2.2346**	**-7.2864**	**-4.9671**	**16.357**	**2.5996**	**3.3728**	**15.939**	**10.816**	0 9366			
Med Coeff	-0 9355	7 3233	6 4712	-0 0018	-0 3846	-4 1377	3 3668	28 371	0 0000	7 4634	3 5871	-2 3367	0 3011	2 2525	129 33
Med t-stat	**-6.4566**	0 3315	0 1496	-0 7908	**-16.114**	**-8.1352**	**10.576**	0 7025	-0 1181	**9.5247**	**6.9983**	**-1.7870**			
Min Coeff	-3 8312	-233 03	-76 296	-0 0134	-0 4603	-14 286	1 3232	-613 83	-0 0008	1 4231	0 7341	-19 043	0 2424	2.0400	96.26
Min t-stat	**-10.514**	**-3.9256**	**-1.5589**	**-3.3026**	**-21.448**	**-11.748**	**5.7488**	**-1.3904**	-1 2359	**4.8034**	**3.8090**	**-3.9738**			
No Signif	0+, 35-	5+, 5-	5+, 1-	1+, 7-	0+, 35-	0+, 35-	35+, 0-	5+, 1-	3+, 0-	35+, 0-	35+, 0-	0+, 23-			

Note See Table 2-4

Table 2-7 Quote Revision Model (Equation 2.5) TSE 35 Stocks, 1990.7 - 1991.6 Total of 3276 observations (30-minute)

(2.5) $RQ(t) = a0 + a1*RQ(t-1) + a2*RQ(t-3) + a3*RQ(t-4) + a4*RQ(t-12) + a5*RQ(t-13)$
$+ b0*SX(t) + b1*SX(t-1) + b2*SX(t-2) + b3*SX(t-12) + b4*SX(t-13) + b5*QO(t) + b6*MQO(t) + e(t)$

coefficient x 1000

	Constant	*RQ(t-1)*	*RQ(t-2)*	*RQ(t-3)*	*RQ(t-12)*	*RQ(t-13)*	*SX(t)*	*SX(t-1)*	*SX(t-2)*	*SX(t-12)*	*SX(t-13)*	*QO(t)*	*MQO(t)*	*adj-R-sq*	*D-W*	*F-stat*
Ave Coeff	0.0409	-79.739	-18.004	-3.9118	13.515	20.268	0.0216	0.0018	0.0003	0.0000	-0.0002	-0.6629	-0.0019	0.2797	1.9946	110.43
Ave t-stat	0.8168	**-3.2697**	-0.9094	-0.2502	0.6664	0.7727	**16.293**	**2.0364**	0.3110	-0.1334	-0.4245	-1.1167	-0.0046			
Max Coeff	0.2954	38.723	47.686	43.867	50.404	83.303	0.0558	0.0081	0.0045	0.0014	0.0038	0.4170	5.0150	0.4216	2.0000	199.91
Max t-stat	**4.5441**	**1.5881**	**2.4124**	**2.7895**	**2.4634**	**2.9672**	**30.076**	**4.5569**	**3.7552**	**1.4547**	**1.8445**	0.9572	**2.7558**			
Med Coeff	0.0500	-74.431	-24.698	-6.8332	11.574	18.986	0.0199	0.0015	0.0002	0.0001	-0.0004	-0.5011	-0.0717	0.2644	1.9925	99.471
Med t-stat	0.9248	**-3.4519**	-1.1083	-0.4440	0.5513	0.7562	**17.754**	**2.1898**	0.1429	0.1678	-0.7336	-1.1749	-0.0728			
Min Coeff	-0.1526	-188.48	-80.450	-37.222	-26.418	-29.847	0.0085	-0.0008	-0.0010	-0.0018	-0.0023	-3.2591	-3.2603	0.1201	1.9800	38.261
Min t-stat	**-1.9288**	**-7.5353**	**-3.6605**	**-2.1970**	**-1.3535**	**-1.4164**	**3.6738**	-1.0505	**-1.3414**	**-2.2511**	**-3.0318**	**-3.4612**	**-2.5741**			
No. of Signif	12+, 4-	1+, 28-	4+, 14-	2+, 8-	6+, 1-	10+, 1-	35+, 0-	22+, 0-	4+, 1-	1+, 3-	3+, 7-	0+, 14-	5+, 4-			

Table 2-8 Trade Innovation Model (Equation 2.6) TSE 35 Stocks, 1990.7 - 1991.6. Total of 3276 observations (30-minute)

(2.6) $SX(t) = a0 + a1*RQ(t-1) + a2*RQ(t-3) + a3*RQ(t-4) + a4*RQ(t-12) + a5*RQ(t-13)$
$+ b1*SX(t-1) + b2*SX(t-2) + b3*SX(t-3) + b4*SX(t-12) + b5*SX(t-13) + b6*TO(t) + b7*TC(t) + b8*MTO(t) + e(t)$

	Constant	*RQ(t-1)*	*RQ(t-2)*	*RQ(t-3)*	*RQ(t-12)*	*RQ(t-13)*	*SX(t-1)*	*SX(t-2)*	*SX(t-3)*	*SX(t-12)*	*SX(t-13)*	*TO(t)*	*TC(t)*	*MTO(t)*	*adj-R-sq*	*D-W*	*F-stat*
Ave Coeff	-0.2986	-2493.5	-330.40	-108.33	284.28	333.24	0.0854	0.0293	0.0242	0.0111	0.0088	0.8153	1.7496	-6.4034	0.0140	2.0019	4.6034
Ave t-stat	-0.1314	**-3.1712**	-0.6112	-0.1544	0.2141	0.5504	**3.2112**	1.2677	0.8852	0.5107	0.3737	0.1147	0.2924	-0.3907			
Max Coeff	8.2141	2371.6	1177.3	1177.7	2995.6	2463.3	0.1952	0.0697	0.1773	0.0621	0.0738	23.478	26.224	56.972	0.0419	2.0059	12.0280
Max t-stat	**4.2189**	**1.8035**	**1.6062**	**1.6234**	**2.0617**	**3.2576**	**7.4330**	**2.9440**	**3.9047**	**2.6147**	**3.3021**	**1.7360**	**2.7473**	**2.4729**			
Med Coeff	-0.4744	-2133.9	-206.08	61.362	80.072	201.42	0.0792	0.0280	0.0170	0.0174	0.0089	1.4818	1.0643	-8.1196	0.0118	2.0022	4.0186
Med t-stat	-0.2546	**-2.9760**	-0.5303	0.0622	0.1273	0.3771	**3.1297**	1.1877	0.8107	0.8506	0.3412	0.1097	0.1326	-0.5648			
Min Coeff	-10.655	-10781	-2695.8	-2627.3	-1261.7	-1263.1	0.0153	-0.0072	-0.0282	-0.0678	-0.0412	-31.272	-21.664	-61.317	0.0018	1.9948	1.4540
Min t-stat	-4.1898	-7.7214	**-4.2514**	**-3.1624**	**-2.1168**	-1.1819	0.6198	-0.3174	-1.2009	**-2.7619**	**-1.5688**	**-1.9795**	**-2.0435**	**-2.1141**			
No. of Signif	6+, 10-	2+, 27-	4+, 7-	4+, 5-	6+, 1-	8+, 0-	30+, 0-	16+, 0-	13+, 0-	9+, 2-	4+, 2-	5+, 3-	7+, 6-	1+, 6-			

Note: See Table 2-4

Table 2-9 Quote Revision Model (Equation 2.7) TSE 35 Stocks, 1990.7 - 1991.6. Total of 3276 observations (30-minute)

coefficient x 1000

(2.7) $RQ(t) = a0 + a1*RQ(t-1) + a2*RQ(t-3) + a3*RQ(t-4) + a4*RQ(t-12) + a5*RQ(t-13)$
$+ b0*RNT(t) + b1*RNT(t-1) + b2*RNT(t-2) + b3*RNT(t-12) + b4*RNT(t-13) + b5*QO(t) + b6*MQO(t) + e(t)$

	Constant	*RQ(t-1)*	*RQ(t-2)*	*RQ(t-3)*	*RQ(t-12)*	*RQ(t-13)*	*RNT(t)*	*RNT(t-1)*	*RNT(t-2)*	*RNT(t-12)*	*RNT(t-13)*	*QO(t)*	*MQO(t)*	*adj-R-sq*	*D-W*	*F-stat*
Ave Coeff	0.0437	-73.906	-11.819	4.0493	19.433	25.573	0.0197	0.0136	0.0058	-0.0001	0.0030	-0.7660	-0.0774	0.0335	1.9974	7.1005
Ave t-stat	0.7623	**-2.9768**	-0.6096	0.1521	0.9555	0.9743	0.9177	0.6584	0.3354	0.1312	0.1432	-1.1431	-0.1286			
Max Coeff	0.3222	67.849	60.455	59.582	59.696	106.46	0.2544	0.1831	0.1343	0.0573	0.1146	0.2376	4.8668	0.0977	2.0100	26.832
Max t-stat	**2.6588**	**2.7011**	**2.9304**	**2.4601**	**2.9253**	**2.8597**	**4.8429**	**3.3226**	**2.8989**	**2.3582**	**3.4475**	0.7001	**2.1690**			
Med. Coeff	0.0524	-74.141	-10.051	5.3468	20.030	28.299	0.0088	0.0083	0.0025	0.0008	0.0011	-0.5495	-0.2441	0.0258	2.0000	6.1558
Med. t-stat	0.7866	**-3.1353**	-0.4838	0.2316	1.0089	1.0329	0.4407	0.6910	0.3304	0.0713	-0.0215	-0.8765	-0.2540			
Min Coeff	-0.2820	-202.63	-85.770	-39.513	-6.1503	-31.054	-0.1914	-0.1443	-0.1241	-0.0600	-0.0414	-4.7619	-3.2743	0.0101	1.9800	1.5284
Min t-stat	**-1.9461**	**-8.2730**	**-3.9164**	**-2.2180**	-0.2943	-1.1963	**-3.6428**	**-3.3442**	**-3.4921**	**-2.4937**	**-2.6649**	**-4.4178**	**-2.4788**			
No. of Signif	10+, 2-	1+, 24-	6+, 9-	4+, 5-	9+, 0-	13+, 0-	15+, 3-	14+, 4-	10+, 3-	5+, 3-	6+, 5-	0+, 13-	4+, 4-			

Table 2-10 Trade (Changes in Number of Trades) Innovation Model (Equation 2.8) TSE 35 Stocks, 1990.7 - 1991.6 Total of 3276 observations (30-minute)

(2.8) $RNT(t) = a0 + a1*RQ(t-1) + a2*RQ(t-3) + a3*RQ(t-4) + a4*RQ(t-12) + a5*RQ(t-13)$
$+ b1*RNT(t-1) + b2*RNT(t-2) + b3*RNT(t-3) + b4*RNT(t-12) + b5*RNT(t-13) + b6*TO(t) + b7*TC(t) + b8*MTO(t) + e(t)$

	Constant	*RQ(t-1)*	*RQ(t-2)*	*RQ(t-3)*	*RQ(t-12)*	*RQ(t-13)*	*RNT(t)*	*RNT(t-1)*	*RNT(t-2)*	*RNT(t-12)*	*RNT(t-13)*	*TO(t)*	*TC(t)*	*MTO(t)*	*adj-R-sq*	*D-W*	*F-stat*
Ave. Coeff	-1.2401	10.147	-20.651	-1.6990	27.864	-3.0030	-0.6436	-0.4090	-0.2102	0.0333	0.0439	11.445	5.1768	-2.8715	0.3592	2.0635	143.19
Ave. t-stat	**-7.3276**	0.3735	-0.1919	-0.1439	0.5565	0.1409	**-26.426**	**-15.612**	**-9.2438**	**1.6007**	**2.1763**	**10.930**	**7.6498**	**-1.7478**			
Max Coeff	-0.1826	126.29	55.535	180.03	197.89	163.45	-0.3896	-0.1459	-0.0971	0.0685	0.1084	41.662	16.511	3.0068	0.4369	2.1000	196.43
Max t-stat	**1.4855**	**1.7723**	**2.0507**	**2.2153**	**2.2285**	**2.3541**	**-7.3679**	**-2.5169**	**-1.6930**	**3.6221**	**4.6053**	**16.661**	**11.558**	0.7928			
Med. Coeff	-0.8963	12.274	-13.378	-9.1343	17.623	2.4301	-0.6476	-0.4228	-0.2100	0.0335	0.0463	8.1162	3.8995	-2.3328	0.3574	2.0600	141.16
Med. t-stat	**-7.5421**	0.4926	-0.2992	-0.3190	0.5680	0.1234	**-27.006**	**-16.023**	**-9.8207**	**1.6603**	**2.3886**	**10.493**	**7.5127**	**-1.7341**			
Min Coeff	-3.7492	-382.85	-295.55	-223.65	-102.53	-174.80	-0.7106	-0.4656	-0.2673	-0.0215	-0.0136	1.3892	0.7906	-18.582	0.2364	1.9700	78.99
Min t-stat	**-10.493**	**-1.6462**	**-1.5304**	**-3.0087**	**-2.0363**	**-1.5529**	**-35.246**	**-20.865**	**-13.549**	-1.1594	-0.6339	**4.8229**	**4.1742**	**-4.7637**			
No. of Signif	0+, 35-	7+, 1-	3+, 2-	5+, 6-	10+, 3-	5+, 2-	0+, 35-	0+, 35-	0+, 35-	23+, 0-	29+, 0-	35+, 0-	35+, 0-	0+, 23-			

Note See Table 2-4

Table 2-11. Granger Causal Direction Tests — TSE 35 Stocks, 1990.7 - 1991 6. Total of 3276 observations (30-minute)

Likelihood Ratio Test. ***LR = N*ln[sigma(r)**2/sigma(u)**2] ~ chi**2 (u-r)***

LR Test	*RQ caused by T*	*DI caused by T*	*SX caused by Q*	*RNT caused by Q*	*RQ caused by SX*	*SX caused by RQ*	*RQ caused by RNT*	*RNT caused by RQ*
Ave	148.18*	3.40	59 85*	1.16	1051.04*	26.19*	23.73*	5.47
S D.	124.69	7.32	54.04	4.25	316.85	23.87	44.15	9 50
Max	564.07*	31.01*	200.07*	18.07*	1722 60*	92.08*	247.86*	49.39*
Top 25%	208.15*	3.96	74.33*	1.56	1270.75*	39.77*	34.94*	7.19
Median	112.83*	0.72	40.08*	-0.49	1051 10*	24.19*	7.69	2.82
Low 25%	57.59*	-0 80	21.81*	-1 34	810.84*	6.70	1.00	0.76
Min	2.85	-2.94	-0.43	-1.97	389.03*	-1.16	-3.95	-2.62
No. Significant	34	3	30	2	35	23	16	3

Note (1) T and Q represent all trade and quote variables, respectively. Other variables are defined before.
(2) * indicate significance at a level of 95% or above

Table 3-1 Quote Revision Model (Equation 3.1) — TSE 35 Stocks, 1990.7 - 1991.6 Total of 3276 observations (30-minute)

(3.1) $RQ(t) = a0 + a1*TRP(t) + a2*Z(t) + a3*SX(t) + a4*RNT(t) + a5*RIIT(t) + a6*RTT(t) + a7*RQ(t-1) + a8*DI(t-1) + a9*QO(t) + a10*MQO(t) + u(t)$

coefficient x 1000

	Constant	*TRP(t)*	*Z(t-1)*	*SX(t)*	*RNT(t)*	*RIIT(t)*	*RTT(t)*	*RQ(t-1)*	*DI(t-1)*	*QO(t)*	*MQO(t)*	*adj-R-sq*	*D-W*	*F-stat*
Ave Coeff	0.0480	71.629	484.09	0.0091	0.0102	0.0533	0.0765	-11.2238	-0.0024	-0.3415	0.0477	0.4468	1.9217	314.00
Ave t-stat	0.7856	**3.3545**	**13.681**	**5.6512**	0.6840	0.2084	0.6911	-0.5961	**-6.7287**	-0.8925	0.1508			
Max Coeff	0.6514	150.16	1013.4	0.0228	0.1931	1.0065	0.7274	49.4720	0.0001	0.4283	2.4989	0.7429	2.0300	947.38
Max t-stat	**9.9353**	**7.2353**	**29.636**	**12.644**	**3.1429**	**3.3664**	**7.0096**	**2.8104**	0.5124	**1.4323**	**2.4657**			
Med. Coeff	0.0785	76.889	458.01	0.0079	0.0031	0.0532	0.0586	-12.906	-0.0022	-0.3518	0.1015	0.4256	1.9250	253.30
Med t-stat	1.0053	**3.4236**	**12.423**	**5.1160**	0.7883	0.1686	0.4625	-0.6822	**-6.8798**	-1.0824	0.1835			
Min Coeff	-0.2890	-38.474	138.89	0.0003	-0.0440	-1.4026	-0.6036	-89.089	-0.0092	-1.8354	-2.6407	0.2001	1.8200	82.917
Min t-stat	**-4.3106**	-0.8587	**1.8584**	0.1891	**-2.9165**	**-2.7848**	**-3.1677**	**-4.2891**	**-12.091**	**-3.1277**	**-2.3807**			
No signif	12+, 7-	30+, 0-	35+, 0-	33+, 0-	13+, 2-	4+, 3-	10+, 3-	2+, 10-	0+, 33-	1+, 13-	5+, 1-			

Table 3-2 Price Changes Prediction Model (Equation 3.2) — TSE 35 Stocks, 1990.7 - 1991.6 Total of 3276 observations (30-minute)

(3.2) $RP(t) = b0 + b1*TRP(t-1) + b2*Z(t-1) + b3*SX(t-1) + b4*RNT(t-1) + b5*RIIT(t-1) + b6*RTT(t-1) + b7*RQ(t-1) + b8*DI(t-1) + b9*TO(t) + b10*TC(t) + b11*MTO(t) + v(t)$

coefficient x 1000

	Constant	*TRP(t)*	*Z(t-1)*	*SX(t)*	*RNT(t)*	*RIIT(t)*	*RTT(t)*	*RQ(t-1)*	*DI(t-1)*	*TO(t)*	*TC(t)*	*MTO(t)*	*adj-R-sq*	*D-W*	*F-stat*
Ave Coeff	-0.1000	34.796	-711.36	0.0001	-0.0024	0.0945	-0.1490	725.44	-0.0025	-0.5274	0.1901	0.0225	0.2743	2.0070	115.61
Ave t-stat	-0.0951	**1.3745**	**-23.604**	0.5277	-0.0408	0.3738	-0.8309	**23.311**	**-6.3189**	-0.6411	0.6911	-0.0860			
Max Coeff	0.9634	102.52	-328.21	0.0025	0.0274	0.7839	0.3177	985.48	0.0002	0.5611	1.1187	4.5074	0.3938	2.0500	194.39
Max t-stat	**10.652**	**3.1239**	**-14.294**	**2.7247**	**1.7944**	**2.2024**	0.8900	**33.3421**	0.2658	**1.6101**	**2.8186**	**2.0570**			
Med Coeff	-0.0550	31.061	-748.86	0.0006	0.0003	0.0897	-0.1118	715.64	-0.0023	-0.3256	0.2703	0.1025	0.2757	2.0050	114.32
Med t-stat	-0.8245	**1.3669**	**-24.466**	0.7380	0.0367	0.4991	-0.6551	**23.622**	**-6.4771**	-0.5502	1.1136	0.0535			
Min Coeff	-1.4692	-14.546	-949.06	-0.0066	-0.0992	-0.4784	-0.6559	377.88	-0.0063	-3.6889	-1.2200	-1.6115	0.1612	1.9600	58.204
Min t-stat	**-11.821**	-0.3462	**-32.110**	**-1.8489**	**-2.5202**	**-1.4819**	**-3.7080**	**10.6000**	**-14.070**	**-2.9628**	**-2.7391**	**-2.0201**			
No Signif	9+, 15-	18+, 0-	0+, 35-	9+, 4-	2+, 2-	4+, 1-	0+, 10-	35+, 0-	0+, 33-	1+, 8-	13+, 4-	2+, 4-			

Note (1) The Bolded numbers indicate significance at a level of 90% or above

(2) Number significant indicates that the coefficient is significant for the number of stocks out of TSE 35 stocks + (or -) indicates positive (negative) significance

Table 3-3 Prediction of Quote Revisions with Technical Analysis Indicators TSE 35 Stocks, 1990 7 - 1991 6 Total of 3276 observations (30-minute)

$$RQ(t) = a0 + a1*Z(t) + a2*TRP(t) + a3*SX(t) + a4*RNT(t) + a5*RHT(t) + a6*RTT(t) + a7*RQ(t-1) + a8*DI(t-1) + a9*QO(t) + a10*MQO(t)$$
$$+ bo*BSi(t) + B1*BSi(t-1) + B2*BSi(t-2) + B4*BSi(t-6) + B5*BSi(t-13) + B6*BSi(t-26)$$
$$+ s0*SSi(t) + S1*SSi(t-1) + S2*SSi(t-2) + S4*SSi(t-6) + S5*SSi(t-13) + S6*SSi(t-26) + e(t)$$

where BSi and SSi indicate buy and sell signals, respectively, i = 1, 2, 3, ..7 Other variables are as defined before

coefficient x 1000

BS1 = MAB1 and SS1 = MAS1 MAB1 and MAS1 are buy and sell indicators based on daily-weekly average price crossings
BS2 = MAB2 and SS2 = MAS2 MAB2 and MAS2 are buy and sell indicators based on daily-monthly average price crossings
BS3 = MAB3 and SS3 = MAS3 MAB3 and MAS3 are buy and sell indicators based on 30-minute-monthly average price crossings
BS4 = TRBB1 and SS4 = TRBS1 TRBB1 and TRBS1 are buy and sell indicators based on 30-minute to weekly maximum or minimum price breaks.
BS5 = TRBB2 and SS5 = TRBS2 TRBB2 and TRBS2 are buy and sell indicators based on 30-minute to monthly maximum or minimum price breaks
BS6 = RSI1 and SS6 = 0 RSI1 is a relative strength scale measure (from -100 to 100 by definition) based on daily sums of positive or negative price changes
BS7 = RSI2 and SS7 = 0 RSI2 is a relative strength scale measure (from -100 to 100 by definition) based on weekly sums of positive or negative price changes.

The following Panels A, B, C, D, E, F and G report only the coefficients for those technical analysis indicators and their significance in the above prediction model

Panel A	MAB1(t)	MAB1(t-1)	MAB1(t-2)	MAB1(t-6)	MAB1(t-13)	MAB1(t-26)	MAS1(t)	MAS1(t-1)	MAS1(t-2)	MAS1(t-6)	MAS1(t-13)	MAS1(t-26)	adj-R-sq	D-W	F-stat
Ave Coeff	0.0349	-0.0729	0.1138	0.0210	0.1340	0.0499	0.1230	-0.0604	-0.1279	0.1215	-0.2206	-0.1651	0.4466	1.9221	143.18
Ave. t-stat	0.0146	-0.1708	0.2769	-0.1190	0.2768	0.0383	0.1692	-0.0908	-0.2875	0.2760	-0.4372	-0.3776			
Max Coeff	1.0806	1.0322	2.0634	1.9456	0.9213	1.4603	1.3673	2.0072	1.1705	2.1966	1.3822	1.1579	0.7423	2.0300	429.75
Max t-stat	**1.8010**	**1.8435**	**2.5853**	1.3386	**1.6786**	**2.5228**	**2.7458**	**2.1864**	**1.6062**	**3.1712**	**1.6726**	**1.8734**			
Med. Coeff.	0.0215	0.0093	0.0837	-0.0135	0.1247	0.0514	0.0379	0.0013	-0.2405	0.0720	-0.1670	-0.1518	0.4253	1.9250	115.59
Med. t-stat	0.0445	0.0075	0.2406	-0.0197	0.2929	0.0925	0.0911	0.0064	-0.5043	0.1458	-0.4499	-0.3584			
Min Coeff.	-1.1243	-1.3635	-1.3208	-1.8461	-0.9524	-0.9316	-0.7632	-1.2144	-1.3597	-1.1811	-3.0884	-0.9737	0.1992	1.8100	38.033
Min t-stat	**-1.9833**	**-2.6882**	**-1.8587**	**-3.0248**	-1.3376	**-1.5756**	**-1.6469**	**-3.3620**	**-2.5334**	**-2.6022**	**-2.9099**	**-2.3694**			
No Signf	1+/4-	1-/2-	6+/1-	0+/4-	3+/0-	3+/1-	3+/1-	2+/3-	5+/8-	6+/3-	2+/5-	2+/5-			

Note See Table 3-2

Table 3-3 Continued 1

Panel B	MAB2(t)	MAB2(t-1)	MAB2(t-2)	MAB2(t-6)	MAB2(t-13)	MAB2(t-26)	MAS2(t)	MAS2(t-1)	MAS2(t-2)	MAS2(t-6)	MAS2(t-13)	MAS2(t-26)	adj-R-sq	D-W	F-stat
Ave Coeff	0.1848	0.0549	0.0409	-0.0720	0.0676	-0.0672	-0.3003	-0.1365	-0.0713	0.0629	-0.0552	0.0733	0.4469	1.9231	143.35
Ave t-stat	0.0288	0.0491	0.0647	-0.2026	-0.0197	-0.1285	-0.1121	-0.3193	-0.0827	0.1758	0.0304	0.1475			
Max Coeff	2.5987	1.2908	1.8692	0.8688	2.8897	0.8960	2.5163	0.8791	1.4627	1.4767	1.0328	1.2209	0.7425	2.0300	430.28
Max t-stat	**2.5037**	**2.2141**	**2.3244**	1.0891	**2.6705**	**1.7954**	**2.0655**	1.0556	**2.0649**	**2.1903**	**2.1065**	**1.6797**			
Med Coeff	0.0871	0.0117	-0.0146	-0.1148	-0.0763	-0.1004	-0.3175	-0.1215	0.0350	0.1205	0.0786	0.0755	0.4266	1.9250	115.99
Med t-stat	0.1107	0.0020	-0.0702	-0.2380	-0.0706	-0.1770	-0.3979	-0.2539	0.0934	0.1897	0.0754	0.1439			
Min Coeff	-1.6866	-1.1232	-1.6580	-1.3931	-1.2625	-1.2831	-2.9455	-1.3300	-1.9829	-0.9410	-2.5678	-0.8405	0.1992	1.8200	38.022
Min t-stat	**-2.7582**	**-1.5789**	**-1.6420**	**-2.3940**	**-2.5747**	**-2.0038**	**-2.1618**	**-2.4504**	**-2.5116**	-1.2753	**-2.3491**	**-1.9101**			
No Signif	4+/6-	2+/3-	5+/4-	0+/4-	3+/3-	2+/3-	4+/2-	0+/5-	3+/7-	4+/1-	2+/4-	2+/2-			

Panel C	MAB3(t)	MAB3(t-1)	MAB3(t-2)	MAB3(t-6)	MAB3(t-13)	MAB3(t-26)	MAS3(t)	MAS3(t-1)	MAS3(t-2)	MAS3(t-6)	MAS3(t-13)	MAS3(t-26)	adj-R-sq	D-W	F-stat
Ave Coeff	0.0073	-0.1896	0.0705	0.0032	0.0166	0.0160	0.2793	0.1250	-0.0718	-0.0640	0.0317	-0.0205	0.4473	1.9210	143.54
Ave t-stat	-0.0192	-0.5090	0.2491	0.0928	0.0179	-0.0549	0.5722	0.2966	-0.2030	-0.2833	0.1111	0.0695			
Max Coeff	1.8696	0.7459	0.9067	0.6108	0.7630	0.9184	2.3002	0.8314	0.6557	1.5443	1.1992	0.7930	0.7426	2.0200	430.57
Max t-stat	**1.7903**	**2.1815**	**2.9087**	**2.2393**	**2.2814**	**2.1311**	**2.9384**	**2.3842**	**2.2708**	**2.2612**	**2.2400**	**2.8186**			
Med Coeff	0.0056	-0.1753	0.0151	0.0311	0.0380	-0.0428	0.1874	0.0967	0.0109	-0.0481	0.0035	0.0330	0.4284	1.9175	116.62
Med t-stat	0.0497	-0.4702	0.0505	0.1394	0.1010	-0.1584	0.4531	0.3108	-0.0278	-0.1612	0.0103	0.1323			
Min Coeff	-1.4384	-0.9717	-0.4974	-1.7871	-1.1874	-0.8529	-1.1708	-0.4671	-1.0085	-0.5840	-0.6383	-0.8348	0.2003	1.8100	38.290
Min t-stat	**-2.0291**	**-2.3643**	-1.0214	**-2.5223**	**-1.7794**	**-1.9260**	**-1.6007**	**-1.8006**	**-3.5706**	**-2.2295**	**-1.9590**	**-1.9299**			
No Signif	5+/4-	3+/7-	7+/0-	4+/5-	4+/3-	3+/2-	9+/2-	6+/3-	3+/7-	1+/6-	4+/3-	3+/2-			

Panel D	TRBB1(t)	TRBB1(t-1)	TRBB1(t-2)	TRBB1(t-6)	RBB1(t-13)	RBB1(t-26)	TRBS1(t)	TRBS1(t-1)	TRBS1(t-2)	TRBS1(t-6)	RBS1(t-13)	RBS1(t-26)	adj-R-sq	D-W	F-stat
Ave Coeff	1.3971	-0.2442	-0.1020	0.0569	-0.0343	-0.1073	-1.3889	0.1935	-0.0059	-0.0488	0.1450	0.1103	0.4541	1.9470	146.56
Ave t-stat	**3.1706**	-0.6973	-0.3889	0.1499	-0.1129	-0.1850	**-2.9023**	0.6536	0.0629	-0.1625	0.2627	0.3778			
Max Coeff	3.8150	0.9046	0.5377	0.7861	0.6905	0.4951	-0.2108	0.9926	0.7577	1.2938	1.2515	0.9091	0.7436	2.0500	432.68
Max t-stat	**5.1827**	**2.7252**	1.0947	**2.5608**	**1.3843**	**2.6238**	-0.7934	**2.4392**	**3.4954**	**1.7374**	**2.7396**	**2.6342**			
Med Coeff	1.2643	-0.1819	-0.1021	0.0613	-0.0096	-0.0512	-1.3005	0.2981	0.0107	-0.0795	0.0499	0.0738	0.4320	1.9375	118.85
Med t-stat	**3.2185**	-0.7900	-0.4509	0.2056	-0.0518	-0.2003	**-2.9258**	0.7396	-0.0002	-0.1714	0.2715	0.2616			
Min Coeff	0.3709	-2.3212	-0.7013	-0.9123	-0.7984	-1.0712	-4.2124	-0.6618	-0.6773	-0.5758	-0.7466	-0.5833	0.2194	1.8500	42.839
Min t-stat	0.8902	**-4.3784**	**-1.8081**	**-2.2014**	**-2.5141**	**-2.0672**	**-5.5710**	**-1.8200**	**-1.8706**	**-1.7101**	**-2.5896**	**-1.9730**			
No Signif	33+/0-	1+/8-	0+/3-	4+/2-	1+/1-	4+/5-	0+/32-	9+/1-	3+/4-	2+/2-	7+/3-	6+/2-			

Table 3-3 Continued 2

Panel E	TRBB2(t)	TRBB2(t-1)	TRBB2(t-2)	TRBB2(t-6)	RBB2(t-13)	RBB2(t-26)	TRBS2(t)	TRBS2(t-1)	TRBS2(t-2)	TRBS2(t-6)	RBS2(t-13)	RBS2(t-26)	adj-R-sq	D-W	F-stat
Ave Coeff	1.5492	-0.3612	-0.0776	-0.0253	-0.1094	-0.0873	-1.7156	0.3084	0.0197	0.0187	0.1274	0.0937	0.4522	1.9388	145.89
Ave t-stat	**2.5505**	-1.0172	-0.3059	-0.1248	-0.0655	-0.2154	**-2.2549**	0.8098	0.1164	0.1153	0.1214	0.2454			
Max Coeff	4.7259	0.8935	0.7875	0.7176	0.6316	0.4640	0.3448	1.2671	0.8490	1.0588	1.4535	0.8357	0.7446	2.0400	435.04
Max t-stat	**4.9559**	**2.0506**	**3.1138**	**1.8662**	**2.3763**	**1.6212**	0.6603	**3.3055**	**3.7064**	**1.9828**	**1.8498**	**1.9268**			
Med. Coeff	1.1570	-0.3371	-0.0594	-0.0372	-0.0511	-0.1016	-1.5957	0.2413	-0.0033	-0.0253	0.0793	0.0934	0.4314	1.9350	118.94
Med t-stat	**2.7009**	-1.0635	-0.1945	-0.0938	-0.0916	-0.3203	**-2.0569**	0.8702	-0.0029	-0.1202	0.2984	0.3566			
Min Coeff	-0.1327	-1.3818	-0.7962	-0.7888	-1.3353	-0.7716	-5.0615	-0.5318	-0.8633	-0.8368	-0.8034	-0.5371	0.2151	1.8400	41.794
Min t-stat	-0.0888	**-3.3914**	**-2.8656**	**-2.6075**	**-1.8879**	**-1.7747**	**-5.7984**	-0.8495	**-3.4177**	**-2.5341**	**-2.8076**	**-1.9054**			
No Signf	30+/0-	1+/15-	1+/7-	3+/5-	1+/1-	4+/3-	0+/31-	8+/0-	4+/2-	6+/2-	3+/1-	5+/3-			

Panel F	RSI1(t)	RSI1(t-2)	RSI1(t-1)	RSI1(t-2)	RSI1(t-13)	RSI1(t-26)	adj-R-sq	D-W	F-stat
Ave. Coeff	-0.0007	-0.0004	0.0021	0.0011	-0.0008	0.0000	0.4478	1.9233	197.38
Ave. t-stat	0.0557	-0.2760	0.6252	0.4197	-0.2892	0.1189			
Max Coeff.	0.0174	0.0219	0.0137	0.0075	0.0058	0.0030	0.7437	2.0200	594.89
Max t-stat	**2.8155**	**2.7889**	**3.0506**	**3.1838**	**2.6129**	**2.1021**			
Med. Coeff	-0.0005	0.0018	0.0020	0.0013	-0.0006	0.0002	0.4268	1.9200	159.31
Med t-stat	-0.1421	-0.4244	0.6541	0.5431	-0.3320	0.1294			
Min Coeff	-0.0197	-0.0136	-0.0052	-0.0083	-0.0089	-0.0062	0.2033	1.8200	53.229
Min t-stat	**-2.3234**	**-2.9093**	**-1.9696**	**-2.2891**	**-2.2804**	**-2.1968**			
No. Signf.	5+/4-	4+/8-	12+/1-	6+/2-	3+/6-	4+/2-			

Panel G	RSI2(t)	RSI2(t-1)	RSI2(t-2)	RSI2(t-6)	RSI2(t-13)	RSI2(t-26)	adj-R-sq	D-W	F-stat
Ave Coeff	0.0247	-0.0258	0.0049	0.0044	-0.0054	-0.0019	0.4484	1.9378	197.57
Ave. t-stat	1.1997	-1.2041	0.3085	0.2785	-0.4775	-0.2102			
Max Coeff.	0.1238	0.0590	0.0502	0.0457	0.0174	0.0182	0.7429	2.0100	592.44
Max t-stat	**4.4794**	**2.4172**	**2.7604**	**3.3517**	**1.5266**	**2.4599**			
Med. Coeff.	0.0243	-0.0286	0.0041	0.0028	-0.0032	0.0001	0.4259	1.9400	158.84
Med. t-stat	1.1885	-1.0478	0.3054	0.2356	-0.2202	-0.0049			
Min Coeff.	-0.0337	-0.0967	-0.0294	-0.0337	-0.0460	-0.0408	0.2076	1.8500	54.610
Min t-stat	-1.2932	**-3.8374**	**-1.6998**	**-2.0675**	**-2.6486**	**-2.8135**			
No Signf.	16+/0-	2+/15-	4+/2-	4+/3-	2+/10-	2+/7-			

Table 3-4 Prediction of Price Changes with Technical Analysis Indicators — TSE 35 Stocks, 1990.7 - 1991.6. Total of 3276 observations (30-minute)

$$RP(t) = a0 + a1*Z(t-1) + a2*TRP(t-1) + a3*SX(t-1) + a4*RNT(t-1) + a5*RHT(t-1) + a6*RTT(t-1) + a7*RQ(t-1) + a8*DI(t-1) + a9*TO(t) + a10*TC(t) + a11*MTO(t)$$
$$+ b1*BSi(t-1) + b2*BSi(t-2) + b3*BSi(t-4) + b4*BSi(t-6) + b5*BSi(t-13) + b6*BSi(t-26)$$
$$+ s1*SSi(t-1) + s2*SSi(t-2) + s3*SSi(t-4) + s4*SSi(t-6) + s5*SSi(t-13) + s6*SSi(t-26) + e(t)$$

coefficient x 1000

where BSi and SSi indicate buy and sell signals, respectively, i = 1, 2, 3, ..7 Other variables are as defined before

BS1 = MAB1 and SS1 = MAS1 MAB1 and MAS1 are buy and sell indicators based on daily-weekly average price crossings
BS2 = MAB2 and SS2 = MAS2 MAB2 and MAS2 are buy and sell indicators based on daily-monthly average price crossings
BS3 = MAB3 and SS3 = MAS3 MAB3 and MAS3 are buy and sell indicators based on 30-minute-monthly average price crossings
BS4 = TRBB1 and SS4 = TRBS1 TRBB1 and TRBS1 are buy and sell indicators based on 30-minute to weekly maximum or minimum price breaks
BS5 = TRBB2 and SS5 = TRBS2 TRBB2 and TRBS2 are buy and sell indicators based on 30-minute to monthly maximum or minimum price breaks.
BS6 = RSI1 and SS6 = 0 RSI1 is a relative strength scale measure (from -100 to 100 by definition) based on daily sums of positive or negative price changes
BS7 = RSI2 and SS7 = 0 RSI2 is a relative strength scale measure (from -100 to 100 by definition) based on weekly sums of positive or negative price changes

The following Panels A, B, C, D, E, F and G report only the coefficients for those technical analysis indicators and their significance in the above prediction model

Panel A	MAB1(t-1)	MAB1(t-2)	MAB1(t-4)	MAB1(t-6)	MAB1(t-13)	MAB1(t-26)	MAS1(t-1)	MAS1(t-2)	MAS1(t-4)	MAS1(t-6)	MAS1(t-13)	MAS1(t-26)	adj-R-sq	D-W	F-stat
Ave Coeff.	0.1679	0.2178	0.2868	0.2080	-0.0276	-0.0305	-0.3104	-0.2319	-0.0171	-0.1476	-0.1990	0.0592	0.2743	2.0071	55.823
Ave t-stat	0.3079	0.3447	0.2779	0.2432	0.0115	-0.1260	-0.4889	-0.2912	-0.1911	-0.2360	-0.2774	0.073[illegible]			
Max Coeff	2.0601	1.9563	2.7138	3.7134	1.9806	2.7248	1.4868	1.1857	2.8741	2.2536	1.8154	1.6666	0.3920	2.0500	92.811
Max t-stat	**2.0951**	**2.2491**	**2.9312**	**2.3944**	**3.2796**	**2.5319**	**1.3932**	1.3043	**2.3206**	**2.6688**	**2.2237**	**2.0789**			
Med. Coeff	0.2676	0.2766	0.1731	0.1197	0.0068	-0.0837	-0.4085	-0.0494	-0.0276	-0.2633	-0.2647	0.0089	0.2760	2.0025	55.297
Med. t-stat	0.4662	0.4912	0.3247	0.1899	0.0013	-0.0922	-0.5324	-0.0933	-0.0898	-0.3139	-0.4731	-0.0053			
Min Coeff	-3.1007	-1.4911	-1.4407	-3.5266	-2.3751	-3.6336	-2.8744	-2.7373	-1.5390	-2.5654	-1.7810	-1.5428	0.1615	1.9600	28.432
Min t-stat	**-2.9576**	**-1.9577**	**-1.7854**	**-1.5101**	**-2.1063**	**-2.8209**	**-3.1832**	**-2.2057**	**-2.4933**	**-3.9371**	**-1.7714**	**-2.3088**			
No Signif	7+/3-	5+/3-	4+/3-	7+/1-	1+/3-	4+/6-	1+/8-	0+/5-	3+/4-	4+/5-	2+/4-	3+/3-			

Note See Table 3-2

Table 3-4 Continued

Panel B	MAB2(t-1)	MAB2(t-2)	MAB2(t-4)	MAB2(t-6)	MAB2(t-13)	MAB2(t-26)	MAS2(t-1)	MAS2(t-2)	MAS2(t-4)	MAS2(t-6)	MAS2(t-13)	MAS2(t-26)	adj-R-sq	D-W	F-stat
Ave Coeff	0.1269	0.4449	0.1588	0.1890	0.2056	-0.0285	-0.0666	-0.4362	-0.0303	-0.3520	-0.1763	0.0202	0.2744	2.0071	55.844
Ave t-stat	0.2502	0.4459	0.0634	0.2032	0.3174	0.0143	-0.0287	-0.4614	0.1218	-0.4617	-0.2466	-0.0370			
Max Coeff	3.3932	3.5021	3.5727	1.7471	2.2878	1.6591	1.4727	1.0790	1.4299	1.9099	1.8756	2.1397	0.3938	2.0500	93.487
Max t-stat	**3.6131**	**3.1078**	**2.2500**	**1.6165**	**2.7553**	**2.5406**	**1.6127**	**1.7683**	**2.6120**	**2.0750**	**2.1243**	**2.2575**			
Med Coeff	0.1587	0.2443	0.0524	0.1486	0.2272	0.0993	-0.0041	-0.2179	-0.0384	-0.4244	-0.1336	-0.1585	0.2762	2.0075	55.350
Med t-stat	0.1784	0.2790	0.1162	0.3324	0.3779	0.1467	0.2441	-0.3370	-0.0642	-0.5442	-0.2113	-0.1751			
Min Coeff	-2.3461	-1.0056	-1.4399	-2.0512	-1.9416	-2.2061	-3.1965	-3.7642	-2.9237	-2.2713	-2.5109	-1.4470	0.1593	1.9600	27.987
Min t-stat	**-3.1789**	-1.2707	**-1.5397**	**-2.5975**	**-1.7727**	**-2.2993**	**-3.1079**	**-3.0250**	**-2.3583**	**-2.1834**	**-2.5625**	**-2.3307**			
No Signif	5+/3-	11+/0-	3+/2-	2+/2-	5+/1-	3+/4-	2+/5-	2+/10-	6+/2-	2+/5-	2+/5-	4+/4-			

Panel C	MAB3(t-1)	MAB3(t-2)	MAB3(t-4)	MAB3(t-6)	MAB3(t-13)	MAB3(t-26)	MAS3(t-1)	MAS3(t-2)	MAS3(t-4)	MAS3(t-6)	MAS3(t-13)	MAS3(t-26)	adj-R-sq	D-W	F-stat
Ave Coeff	-0.1606	-0.0388	0.2441	-0.0719	0.1129	0.1183	0.1899	0.0103	-0.1140	-0.0854	-0.0871	-0.1292	0.2748	2.0060	56.030
Ave t-stat	-0.4319	0.0392	0.5269	-0.2222	0.1903	0.0981	0.3709	-0.0227	-0.2110	-0.1415	-0.1168	-0.1117			
Max Coeff	1.3044	1.4811	1.0864	1.1143	2.3158	2.3392	1.1567	1.2327	1.0097	0.6929	1.3111	0.8704	0.4096	2.0500	99.796
Max t-stat	**2.3001**	**2.4719**	**3.0738**	**1.6125**	**1.4057**	**1.8934**	**1.8134**	**1.7871**	**2.3941**	**1.4259**	**1.5867**	**1.7957**			
Med Coeff	-0.1193	0.1447	0.2609	-0.1213	0.0600	0.0609	0.1742	0.0648	-0.1223	-0.0978	-0.0289	-0.0886	0.2758	2.0050	55.227
Med t-stat	-0.1978	0.4093	0.7727	-0.3816	0.1830	0.1444	0.3891	0.2511	-0.2534	-0.1796	-0.0852	-0.1871			
Min Coeff	-1.9191	-1.7073	-0.8043	-0.8186	-1.0457	-1.0340	-1.1797	-1.3874	-0.9727	-1.3793	-2.4129	-2.2924	0.1612	1.9600	28.368
Min t-stat	**-4.0972**	**-2.3728**	**-1.4824**	**-1.8445**	-1.3093	**-2.0591**	**-2.1900**	**-2.6573**	**-2.6923**	**-2.2575**	**-1.5670**	**-1.4526**			
No Signif	2+/9-	4+/6-	6+/1-	2+/3-	1+/0-	3+/3-	3+/2-	3+/4-	2+/4-	1+/1-	1+/2-	1+/2-			

Panel F	RBB1(t-1)	TRBB1(t-2)	TRBB1(t-4)	TRBB1(t-6)	RBB1(t-13)	RBB1(t-26)	RBS1(t-1)	TRBS1(t-2)	TRBS1(t-4)	TRBS1(t-6)	TRBS1(t-13)	TRBS1(t-26)	adj-R-sq	D-W	F-stat
Ave Coeff	0.2716	0.3802	0.0222	0.2332	-0.0020	-0.0119	-0.0948	-0.0335	-0.1548	-0.1051	0.0471	0.1273	0.2762	2.0071	56.327
Ave t-stat	0.5620	0.8161	0.2234	0.4908	-0.0623	-0.1345	-0.1654	-0.0813	-0.3733	-0.3929	0.2368	0.4349			
Max Coeff	1.6427	1.8013	0.8589	1.9660	1.2190	0.9099	1.9971	1.3393	1.2456	1.6011	1.5449	1.1814	0.3938	2.0500	93.515
Max t-stat	**2.6705**	**3.5395**	**2.5819**	**2.5420**	**2.4528**	**2.0645**	**3.1193**	**2.8785**	**1.8799**	**2.2472**	**2.3840**	**3.4039**			
Med Coeff	0.2336	0.2971	0.0721	0.1493	-0.0177	0.0214	-0.0652	-0.1193	-0.1296	-0.1388	0.0607	0.1946	0.2779	2.0100	55.812
Med t-stat	0.6527	0.6908	0.1243	0.4347	-0.0872	0.1525	-0.1364	-0.2278	-0.4802	-0.5714	0.3031	0.4353			
Min Coeff.	-0.8672	-0.4826	-1.0475	-0.9041	-0.8288	-1.3164	-1.8669	-0.7087	-1.7361	-1.9626	-1.7977	-0.7807	0.1605	1.9600	28.225
Min t-stat	**-1.6764**	-1.0104	**-2.3784**	-1.0993	**-1.9944**	**-2.7715**	**-2.7450**	**-1.8106**	**-2.1267**	**-2.4214**	**-2.1690**	-1.2565			
No Signif	6+/1-	9+/0-	7+/3-	8+/0-	1+/4-	2+/6-	3+/5-	2+/2-	1+/4-	3+/7-	5+/1-	6+/0-			

Table 3-4 Continued 2

Panel E	RBB2(t-1)	TRBB2(t-2)	TRBB2(t-4)	TRBB2(t-6)	RBB2(t-13)	RBB2(t-26)	RBS2(t-1)	TRBS2(t-2)	TRBS2(t-4)	TRBS2(t-6)	TRBS2(t-13)	TRBS2(t-26)	adj-R-sq	D-W	F-stat
Ave. Coeff	0 1956	0 1600	0 1690	0 0250	-0 0563	-0 0702	-0 2082	-0.0264	-0.1144	-0 1575	0.0682	0.0733	0 2754	2.0065	56.106
Ave t-stat	0 4069	0 3346	0 4381	-0 0315	-0 2078	-0 3562	-0 2314	-0.0884	-0.2182	-0.3880	0 2668	0 3657			
Max Coeff	2 8122	1 2727	1 1013	1 3423	2 4463	1 2559	1.5879	1 3460	1.3943	1.3534	0.9174	1.3438	0.3944	2.0500	93.726
Max t-stat	**3.8037**	**3.5872**	**2.1770**	**1.7844**	**2.2908**	**2.1919**	**2.0659**	**2.0428**	**1.8375**	**2.5719**	**1.8789**	**3.1030**			
Med. Coeff.	0 1509	0 2013	0 1528	-0.0186	-0.0229	-0.1005	-0 0246	-0.0115	-0 0972	-0.1355	0.0667	0.0721	0.2774	2.0050	55.655
Med t-stat	0 3244	0 4963	0 3987	-0 0108	-0.0700	-0.1717	-0 0850	-0 0417	-0 2528	-0 3976	0.1750	0 1510			
Min Coeff	-1.1296	-1.0548	-0 8899	-1.3563	-0 9296	-1 4974	-2.7792	-1 2474	-1.2165	-1 8659	-1.9842	-1 3217	0.1592	1.9600	27.958
Min t-stat	**-1.9527**	**-1.5753**	-1 2185	**-2.7034**	**-1.7903**	**-2.7253**	**-2.7597**	**-2.0777**	**-1.6340**	**-1.9493**	**-1.8382**	**-2.2731**			
No Signif.	7+/1-	3+/4-	5+/0-	2+/4-	2+/7-	2+/8-	4+/7-	2+/2-	1+/2-	1+/1-	6+/1-	10+/3-			

Panel D	RSI1(t-1)	RSI1(t-2)	RSI1(t-4)	RSI1(t-6)	RSI1(t-13)	RSI1(t-26)	adj-R-sq	D-W	F-stat
Ave. Coeff.	-0.0010	0 0037	0 0006	0 0018	-0 0006	0 0001	0 2763	2.0033	75.886
Ave. t-stat	-0.0910	0 6801	0 0637	0.4160	-0.1159	-0.1393			
Max Coeff.	0 0214	0 0148	0 0143	0 0167	0 0069	0.0133	0.3952	2 0400	126 87
Max t-stat	**2.6989**	**2.6068**	**1.8988**	**2.6857**	**2.3377**	**2.8708**			
Med Coeff.	-0.0002	0.0040	0.0005	0.0012	0.0000	-0 0006	0.2782	2.0000	75.256
Med. t-stat	-0 0600	0.9144	0.1017	0 4553	-0.0163	-0 4245			
Min Coeff	-0 0276	-0 0118	-0 0166	-0 0094	-0 0147	-0 0071	0.1601	1 9700	37.729
Min t-stat	**-3.6582**	**-1.8458**	**-2.1237**	**-2.6980**	**-3.7234**	**-1.8859**			
No. Signif.	8+/7-	13+/2-	4+/4-	8+/1-	5+/5-	4+/6-			

Panel G	RSI2(t-1)	RSI2(t-2)	RSI2(t-4)	RSI2(t-6)	RSI2(t-13)	RSI2(t-26)	adj-R-sq	D-W	F-stat
Ave. Coeff	-0.0181	0.0308	0 0024	0 0020	-0 0126	-0.0014	0 2759	2.0010	75.770
Ave t-stat	-0.5809	1 0100	0.0811	0 0420	-0 9219	-0 2956			
Max Coeff	0 0472	0 1200	0 0577	0 0375	0 0207	0 0660	0 3951	2 0500	126 820
Max t-stat	**1.7532**	**3.3973**	**1.8429**	**1.5890**	1 1245	**3.4160**			
Med. Coeff	-0.0159	0 0239	-0 0010	0 0015	-0 0109	-0 0025	0 2782	1 9975	75 253
Med t-stat	-0 7787	0 9864	-0 0502	0 0835	-0 7700	-0 4478			
Min Coeff	-0 1350	-0 0367	-0 0308	-0 0346	-0 0819	-0 0233	0 1605	1 9600	37.827
Min t-stat	**-4.0979**	-1 3031	**-1.5103**	**-1.7835**	**-3.3022**	**-3.0712**			
No Signif	3-/10	11+/0-	4-/1-	3+/3-	0+/11-	3-/7-			

Table 3-5 Cross-Sectional Tests of Microstructure Variable Behaviors around Technical Signals

T-test: difference between pre-signal 10 days (130 periods) and post-signal 10 days.

Sign-test: numbers of increased post-signal vs. numbers of decreased post-signal compared to pre-signal

		Price Return			Volume		Signed Volume		Number of Trades		Quote Return			Relative Spread		Depth Imbalance	
		Mean	*SD*	*CAR*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD.*	*CAR*	*Mean*	*SD*	*Mean*	*SD.*
MAB1	*Difference*	0.0004	-0.0001	0.0091	-3,066	-7,700	1,627	-8,334	-0.7359	-0.8537	0.0003	-0.0003	0.0082	0.0002	0.0001	-0.0641	-0.0055
(1206 obs)	*T-test*	**11.23**	-1.17	**11.06**	**-3.84**	**-2.11**	**2.08**	**-2.29**	**-4.71**	**-5.62**	**10.44**	**-4.31**	**10.34**	**3.25**	1.60	**-4.08**	-0.62
	Sign-test	**11.57**	-1.34	**11.18**	**-4.61**	**-3.34**	**2.74**	**-3.71**	**-5.41**	**-5.38**	**10.35**	**-3.68**	**10.95**	**4.38**	1.40	**-3.43**	0.37
MAB2	*Difference*	0.0006	0.0002	0.0153	-568	784	1,551	772	-0.5915	-0.3412	0.0006	0.0001	0.0513	0.0001	0.0001	-0.0721	0.0040
(2475 obs)	*T-test*	**23.22**	**5.13**	**23.11**	-1.75	0.63	**4.63**	0.62	**-6.39**	**-2.95**	**23.36**	**1.99**	**23.20**	**2.24**	**2.10**	**-6.08**	0.68
	Sign-test	**19.41**	**3.15**	**19.09**	**-3.90**	**2.89**	**5.71**	**-3.50**	**-8.23**	**-4.90**	**19.46**	**3.48**	**19.62**	**7.52**	0.74	-1.69	0.88
MAB3	*Difference*	0.0000	-0.0002	-0.0004	-1,795	-4,064	-353	-4,226	-0.6556	-0.7341	0.0000	-0.0002	0.0005	0.0000	0.0000	-0.0312	-0.0410
(2054 obs)	*T-test*	-0.60	**-3.60**	-0.72	**-3.91**	**-3.05**	-1.02	**-3.07**	**-6.10**	**-5.84**	1.04	**-3.89**	0.88	0.99	0.34	**-2.45**	-1.89
	Sign-test	1.00	**-2.34**	1.11	**-4.44**	**-3.42**	-1.52	**-2.76**	**-5.89**	**-5.50**	**2.57**	**-3.15**	**3.22**	1.40	0.05	-1.17	-1.04
TRBB1	*Difference*	0.0009	-0.0002	0.0235	-2,888	-2,752	4,414	-4,186	-1.9488	-0.9135	0.0010	-0.0002	0.0253	0.0002	0.0000	-0.0248	-0.0104
(5770 obs)	*T-test*	**50.79**	**-8.55**	**50.44**	**-8.05**	**-2.33**	**12.15**	**-3.55**	**-22.58**	**-11.68**	**54.86**	**-7.41**	**54.54**	**9.38**	**2.19**	**-3.82**	**-3.15**
	Sign-test	**43.12**	**-7.15**	**42.97**	**-10.60**	**-5.42**	**19.94**	**-7.54**	**-19.67**	**-7.37**	**46.21**	**-6.03**	**47.16**	**17.41**	**5.89**	-1.90	**-3.08**
TRBB2	*Difference*	0.0010	-0.0003	0.0259	-2,183	876	5,718	-1,131	-2.4259	-0.7228	0.0011	-0.0001	0.0280	0.0002	0.0000	-0.0145	-0.0138
(2782 obs)	*T-test*	**39.21**	**-7.12**	**38.90**	**-6.28**	0.94	**15.85**	-1.21	**-17.26**	**-5.74**	**42.29**	**-3.93**	**42.05**	**6.92**	1.76	-1.65	**-2.91**
	Sign-test	**31.96**	**-4.66**	**31.88**	**-6.81**	**-1.97**	**17.27**	**-4.57**	**-14.89**	-1.73	**34.20**	**-2.46**	**34.97**	**13.10**	**4.87**	-0.47	-1.78
MAS1	*Difference*	-0.0003	-0.0001	-0.0091	54	-13	-1,293	-37	0.2245	0.0132	-0.0003	-0.0002	-0.0078	-0.0001	0.0000	0.0546	-0.0005
(2434 obs)	*T-test*	**-16.95**	**-2.30**	**-17.16**	0.07	0.00	-1.61	-0.01	**2.11**	0.14	**-14.96**	**-3.36**	**-15.17**	**-2.89**	-0.24	**4.89**	-0.08
	Sign-test	**-13.48**	-0.97	**-12.34**	-1.32	-1.32	**-4.24**	-1.16	0.96	-0.79	**-11.21**	**-2.08**	**-9.33**	**-5.24**	-1.57	**3.51**	1.16
MAS2	*Difference*	-0.0005	0.0001	-0.0136	1,910	8,874	-4,002	8,874	-0.1671	-0.0510	-0.0005	0.0001	-0.0134	-0.0002	-0.0001	0.0232	-0.0098
(992 obs)	*T-test*	**-13.83**	0.74	**-13.86**	1.57	1.96	**-2.82**	**1.98**	-0.73	-0.21	**-13.74**	0.87	**-13.96**	**-3.77**	-1.14	1.20	-0.97
	Sign-test	**-11.10**	0.16	**-11.19**	0.48	0.00	**-3.65**	0.60	-0.35	-0.10	**-10.87**	0.88	**-10.16**	**-5.63**	**-3.47**	1.81	-1.62
MAS3	*Difference*	0.0001	-0.0002	0.0013	-1,921	-5,032	1,126	-5,230	-0.4749	-0.5756	0.0000	-0.0002	-0.0006	-0.0001	0.0000	0.0122	-0.0112
(2054 obs)	*T-test*	**2.26**	**-4.66**	**2.14**	**-3.43**	**-2.90**	**2.89**	**-2.92**	**-3.87**	**-4.20**	-0.93	**-4.48**	-1.08	-1.93	-0.94	0.95	-1.51
	Sign-test	**2.35**	**-2.71**	**2.95**	**-2.65**	**-2.41**	**2.01**	**-1.96**	**-3.30**	**-3.16**	-0.40	**-2.90**	-0.05	**-2.82**	-1.11	1.02	-1.94
TRBS1	*Difference*	-0.0009	-0.0005	-0.0225	-1,288	-1,863	-4,023	-2,650	-1.0059	-0.4243	-0.0010	-0.0002	-0.0245	-0.0003	-0.0001	0.0087	-0.0173
(5688 obs)	*T-test*	**-44.66**	**-13.62**	**-45.13**	-1.75	-0.53	**-5.29**	-0.76	**-7.33**	**-3.04**	**-47.83**	**-5.32**	**-48.06**	**-15.47**	**-4.90**	1.27	**-5.10**
	Sign-test	**-43.28**	**-13.77**	**-42.40**	0.20	0.54	**-21.89**	-0.08	**-3.70**	2.75	**-47.73**	**-7.47**	**-44.72**	**-17.23**	**-8.79**	0.28	**-3.81**
TRBS2	*Difference*	-0.0011	-0.0006	-0.0281	-4,221	-15,374	-2,286	-16,520	-1.6406	-0.4619	-0.0012	-0.0003	-0.0304	-0.0003	-0.0001	0.0024	-0.0073
(2423 obs)	*T-test*	**-30.33**	**-9.66**	**-30.67**	**-3.35**	**-2.64**	-1.83	**-2.84**	**-6.44**	-1.89	**-32.26**	**-3.67**	**-32.38**	**-9.91**	**-2.46**	0.23	-1.51
	Sign-test	**-30.28**	**-10.74**	**-29.98**	-1.50	-0.77	-16.17	-1.50	**-5.09**	1.83	**-32.97**	**-5.55**	**-30.96**	**-11.30**	**-6.38**	-0.75	-0.93

Note 1 The difference is pre- minus post- signal average, t-test is t-stat, sign-test is the Z-score CAR is the accumulated average return

2 Negative Z-score means that the cases of post-signal variable mean greater than pre-signal one are more than the cases of post-signal variable mean smaller than pre-signal one

3 The Bolded numbers indicate significance at a level of 90% or above

Figure 3-1. Mean and Standard Deviation of Price Changes Around Buy & Sell Signals

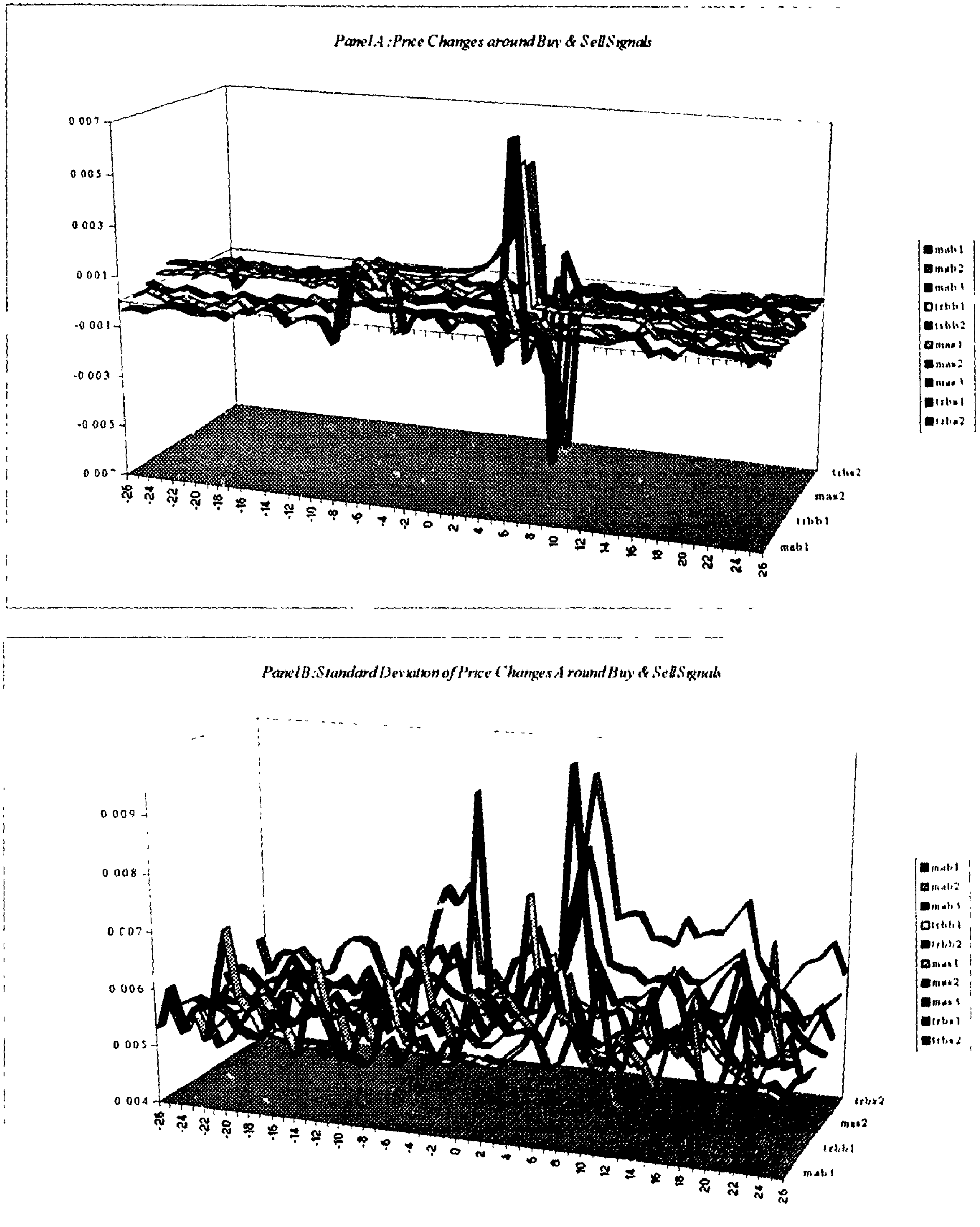
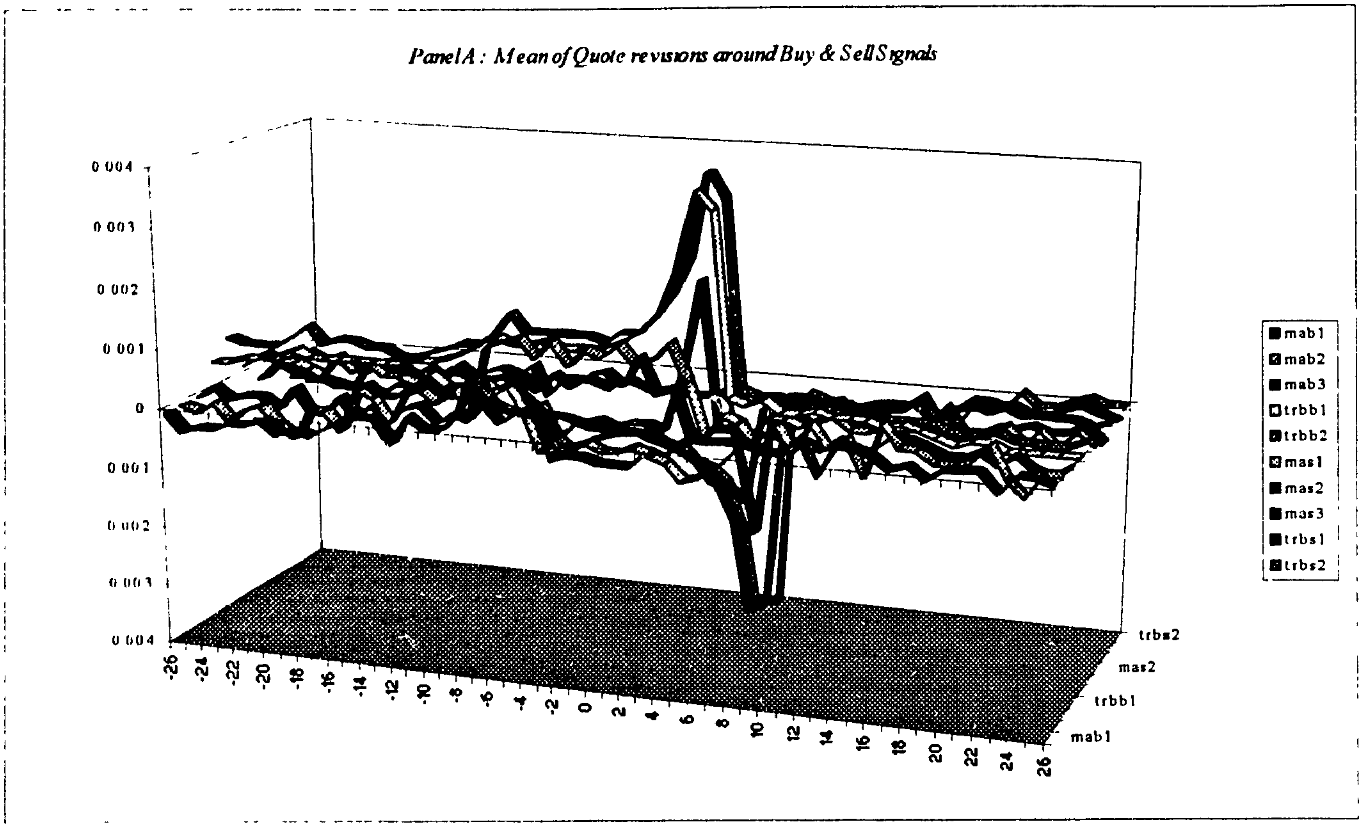


Figure 3-2. Mean and Standard Deviation of Quote Revisions Around Buy & Sell Signals.



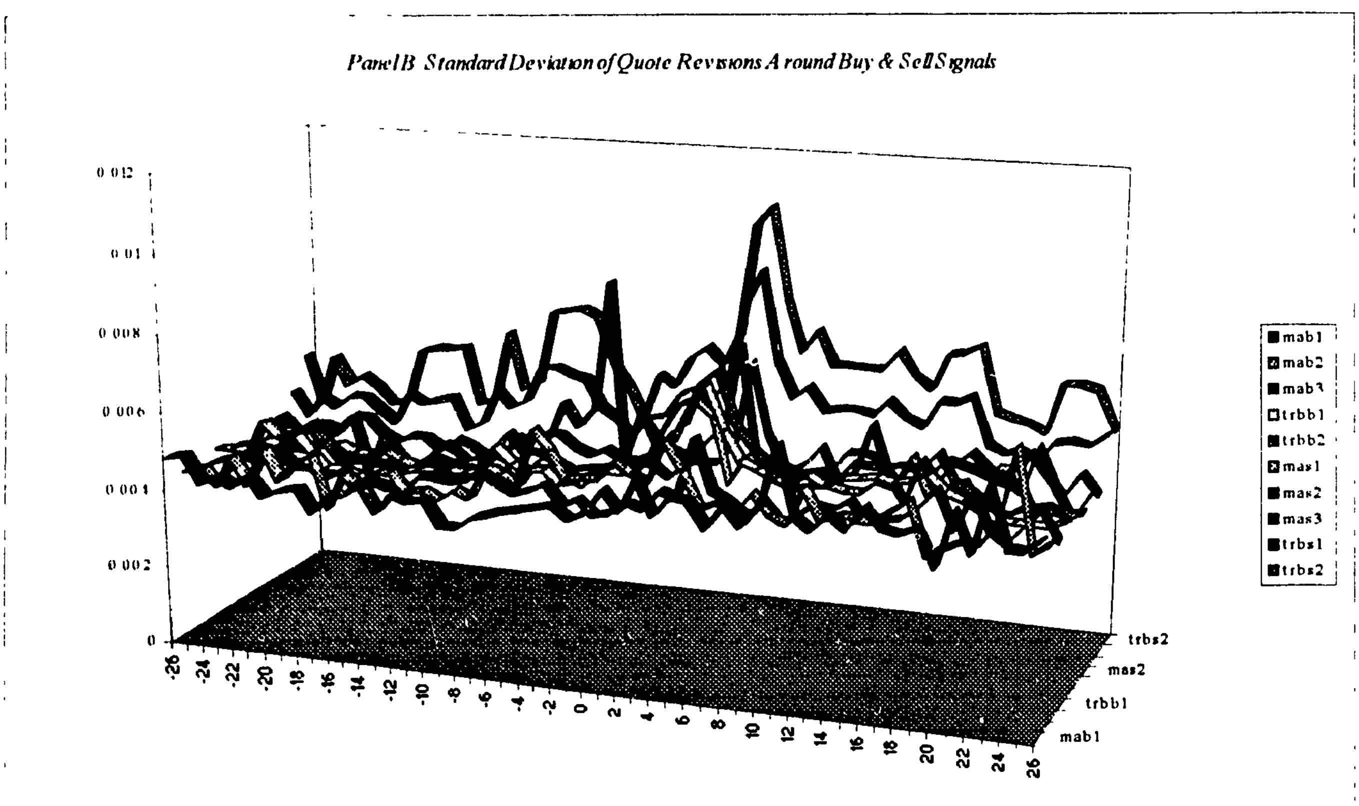


Figure 3-3: Mean of Trading Volumes, Number of Trades & Signed Trading Volumes Around Buy & Sell Signals

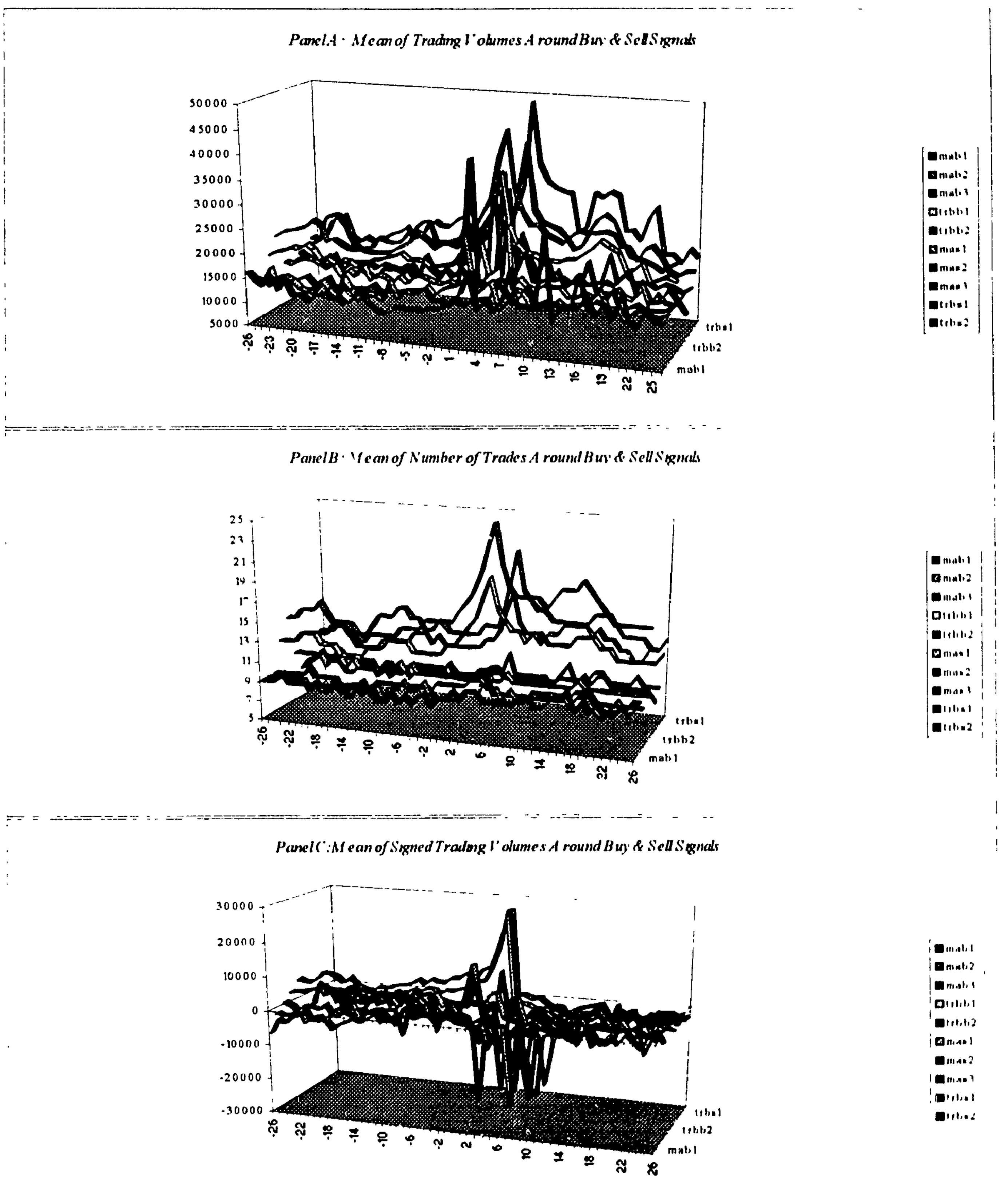
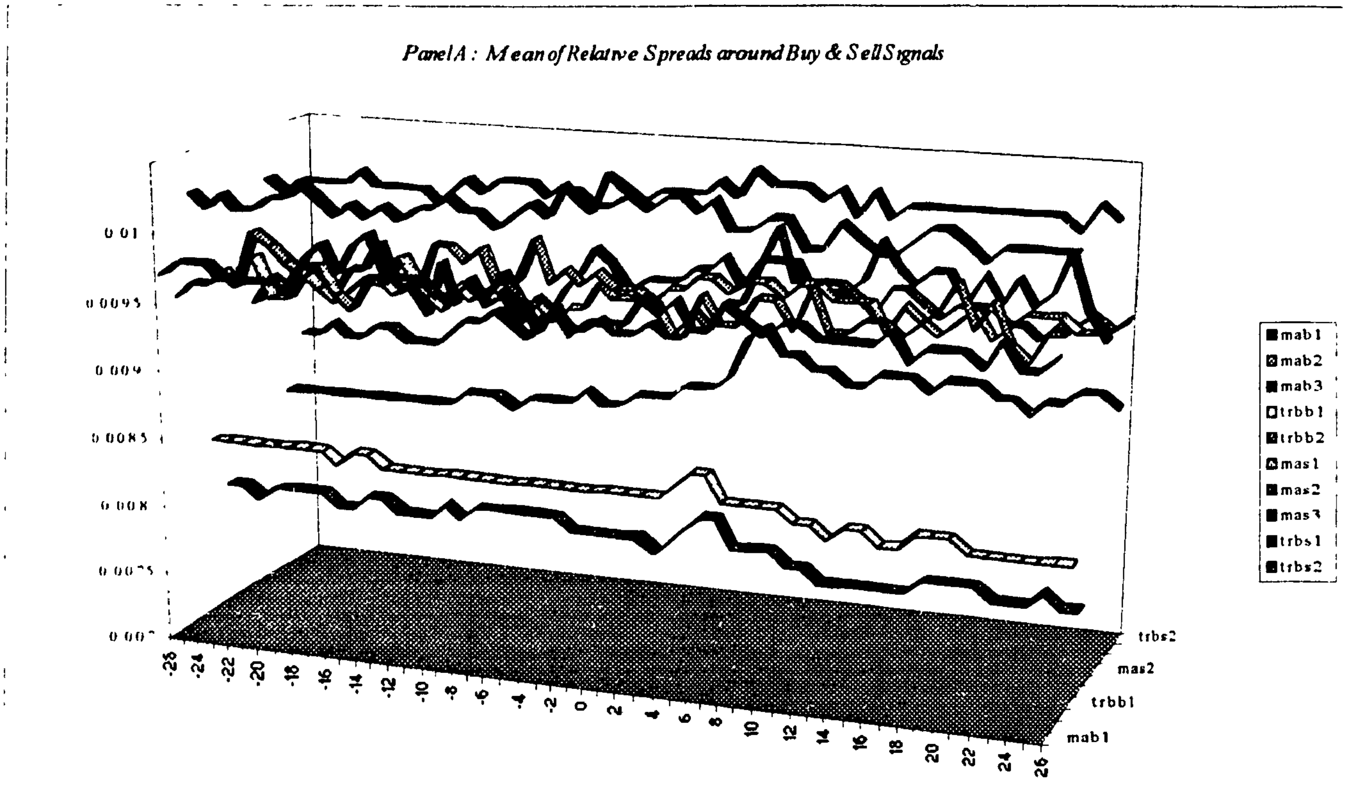


Figure 3-4 Mean of Relative Spreads and Depth Imbalances Around Buy & Sell Signals.



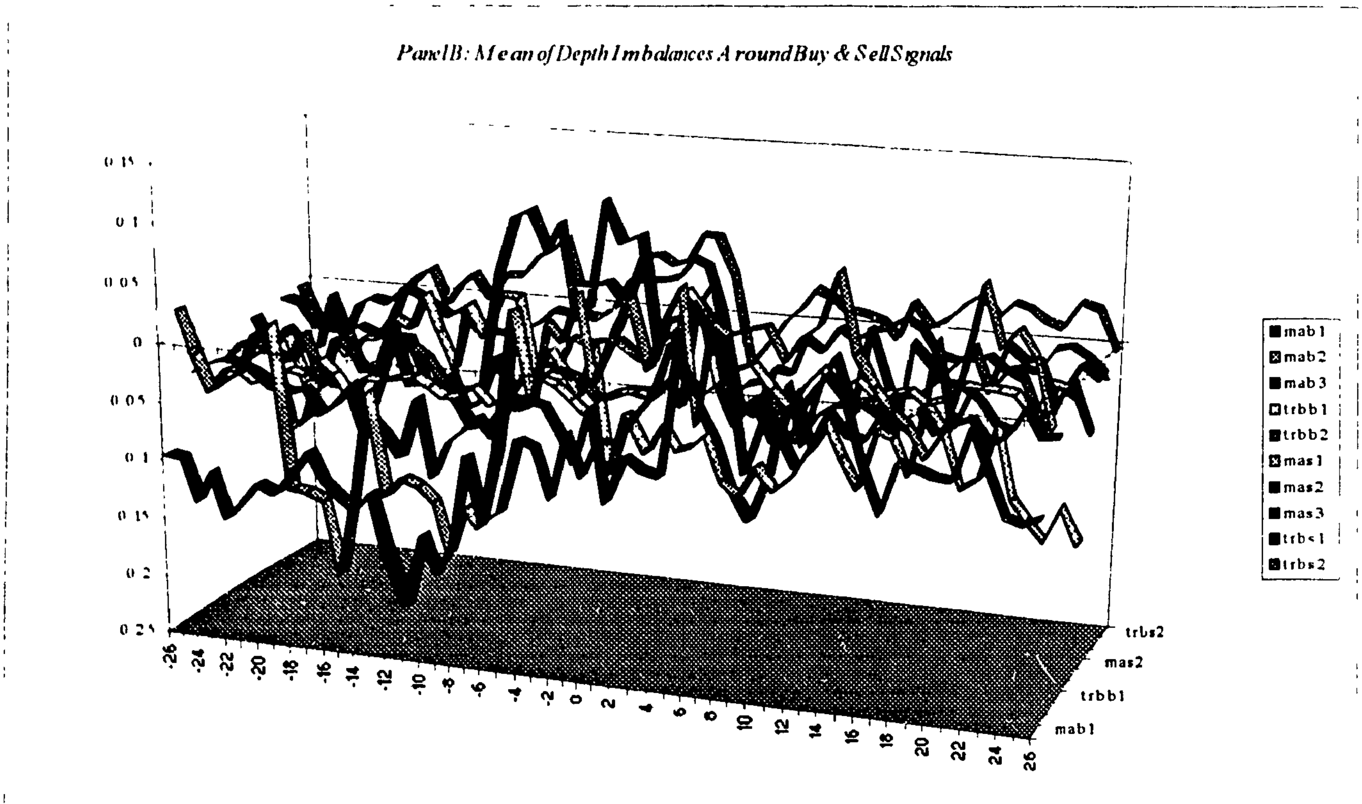


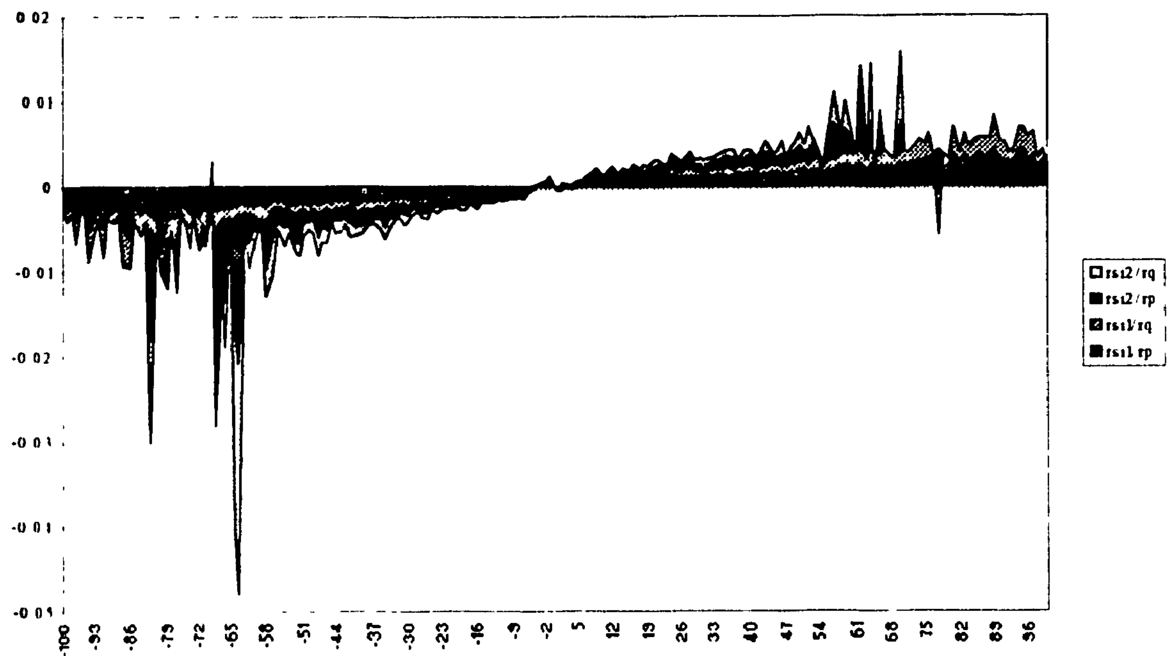
Table 3-6. Tests of Simulated Program Trading Results

Period	Order		*MAB1*	*MAB2*	*MAB2*	*TRBB1*	*TRBB2*	*MAS1*	*MAS2*	*MAS3*	*TRBS1*	*TRBS2*
ONE DAY	Limit Order	*R*	-0.0032	-0.0024	-0.0066	0.0041	0.0045	0.0070	-0.0003	-0.0004	0.0021	0.0015
		T-test	**-6.2900**	**-3.3100**	**-18.0700**	**8.9100**	**5.4900**	**19.5400**	-1.2300	-1.0700	**7.1300**	**2.7300**
		Sign-test	**7.6065**	**5.7104**	**19.6898**	**9.4117**	**7.1919**	**19.3352**	**5.4880**	**3.5869**	**14.5437**	**7.8582**
		AR	0.0008	-0.0068	-0.0020	0.0028	0.0024	0.0051	0.0029	0.0025	0.0007	-0.0001
		T-test	**1.7300**	**2.2400**	**-5.7100**	**6.2100**	**3.0400**	**14.3000**	**12.6300**	**7.7200**	**2.6000**	-0.2400
		Sign-test	**2.0810**	1.6995	**5.5131**	**5.8580**	**3.9796**	**4.6256**	1.4412	**6.8260**	**6.6412**	**3.1203**
	Market Order	*R*	-0.0076	-0.0025	-0.0097	0.0076	0.0081	0.0095	-0.0041	-0.0043	0.0060	0.0060
		T-test	**-14.7100**	**-9.2300**	**-27.4600**	**16.5300**	**10.4200**	**26.5400**	**-16.8100**	**-12.2200**	**20.5100**	**10.8600**
		Sign-test	**15.7251**	**10.6908**	**27.7375**	**16.6089**	**11.7269**	**27.1550**	**20.2132**	**14.0582**	**28.1973**	**17.5181**
		AR	-0.0014	-0.0069	-0.0028	0.0015	0.0015	0.0027	0.0016	0.0011	-0.0001	-0.0004
		T-test	**-2.9700**	-0.8500	**-8.3500**	**3.3600**	**1.9500**	**7.6360**	**7.0500**	**3.4700**	-0.4400	-0.7800
		Sign-test	**3.1381**	1.4360	**8.8702**	**2.0490**	**2.3883**	**7.8162**	**6.4659**	**3.1100**	**1.7815**	**1.8953**
TWO DAYS	Limit Order	*R*	-0.0027	-0.0049	-0.0068	0.0033	0.0041	0.0066	-0.0003	0.0004	0.0018	0.0019
		T-test	**-3.7900**	**-2.3200**	**-13.4000**	**4.9600**	**3.7800**	**13.1000**	-0.9000	0.7400	**4.4900**	**2.5800**
		Sign-test	**5.7551**	**3.6543**	**16.3906**	**5.5027**	**3.7059**	**14.0799**	**5.1355**	**1.9764**	**11.3024**	**6.3959**
		AR	0.0014	-0.0093	-0.0020	0.0026	0.0024	0.0049	0.0024	0.0020	0.0008	0.0000
		T-test	**2.1300**	**1.9300**	**-4.3700**	**4.1800**	**2.3800**	**10.3200**	**7.7600**	**4.5200**	**2.1300**	0.0400
		Sign-test	1.3717	**2.5052**	**2.6419**	**3.2563**	**2.8876**	**11.8884**	**8.1481**	**4.6766**	**7.8314**	**3.4812**
	Market Order	*R*	-0.0070	-0.0066	-0.0099	0.0068	0.0077	0.0090	-0.0041	-0.0036	0.0057	0.0063
		T-test	**-9.8400**	**-6.4300**	**-19.8100**	**10.3100**	**7.2400**	**18.0200**	**-12.2200**	**-7.4100**	**14.3500**	**8.8000**
		Sign-test	**12.3017**	**7.5889**	**22.4461**	**10.9474**	**8.1888**	**20.2939**	**15.1632**	**8.9266**	**21.7431**	**13.5428**
		AR	-0.0008	-0.0097	-0.0029	0.0013	0.0014	0.0025	0.0011	0.0006	-0.0001	-0.0002
		T-test	-1.2500	-0.2400	**-6.2400**	**2.1000**	1.4500	**5.2700**	**3.5500**	1.3900	-0.1600	-0.3700
		Sign-test	0.9648	0.1843	**6.1057**	1.1481	**1.9519**	**6.8095**	**5.4630**	**2.9665**	**3.4701**	**2.2738**
FIVE DAYS	Limit Order	*R*	-0.0031	-0.0068	-0.0071	0.0023	0.0019	0.0062	-0.0024	0.0003	0.0030	0.0043
		T-test	**-2.8200**	**-2.8900**	**-8.5200**	**2.0400**	1.0000	**7.2600**	**-4.6000**	0.4300	**4.8700**	**4.3300**
		Sign-test	**3.5964**	**3.2383**	**9.9824**	**1.8485**	**2.4378**	**6.6439**	**4.4525**	0.5354	**7.6073**	**5.4470**
		AR	0.0016	-0.0099	-0.0026	0.0026	0.0005	0.0042	0.0001	-0.0002	0.0014	0.0007
		T-test	1.6800	-0.0500	**-3.4800**	**2.5200**	0.2700	**5.4600**	0.1500	-0.3800	**2.5300**	0.7200
		Sign-test	**2.0969**	0.7759	**2.9822**	**2.6123**	**2.1018**	**5.7827**	**3.9546**	1.6892	**8.4523**	**3.8608**
	Market Order	*R*	-0.0074	-0.0071	-0.0102	0.0058	0.0055	0.0087	-0.0062	-0.0037	0.0068	0.0087
		T-test	**-6.7800**	**-5.4700**	**-12.2800**	**5.1200**	**2.9800**	**10.1200**	**-12.1100**	**-5.0700**	**11.3000**	**8.8300**
		Sign-test	**8.0193**	**6.2594**	**14.2867**	**4.8608**	**4.3383**	**10.8028**	**11.2960**	**4.9617**	**13.7310**	**9.9546**
		AR	-0.0006	-0.0102	-0.0035	0.0012	-0.0005	0.0019	-0.0012	-0.0016	0.0006	0.0004
		T-test	-0.6400	-1.3900	**-4.6000**	1.2300	-0.3200	**2.3900**	**-2.7300**	**-2.5400**	0.9800	0.4200
		Sign-test	0.7559	0.4560	**3.6699**	0.8203	1.1955	**2.6062**	**2.3970**	0.0762	**5.3548**	**2.9449**

Note: Bolded values of t-test and sign-test (Z-score) indicate significance at a level of 95% or above

Figure 3-5: Mean and Standard Deviation of Price Changes and Quote Revisions Across Relative Strength Indicators (RSI) of [-100, +100].

Panel A: Mean of Price Changes and Quote Revisions across RSI Scales of [-100, +100]



Panel B: Standard Deviation of Price Changes and Quote Revision Across RSI Scales of [-100, +100]

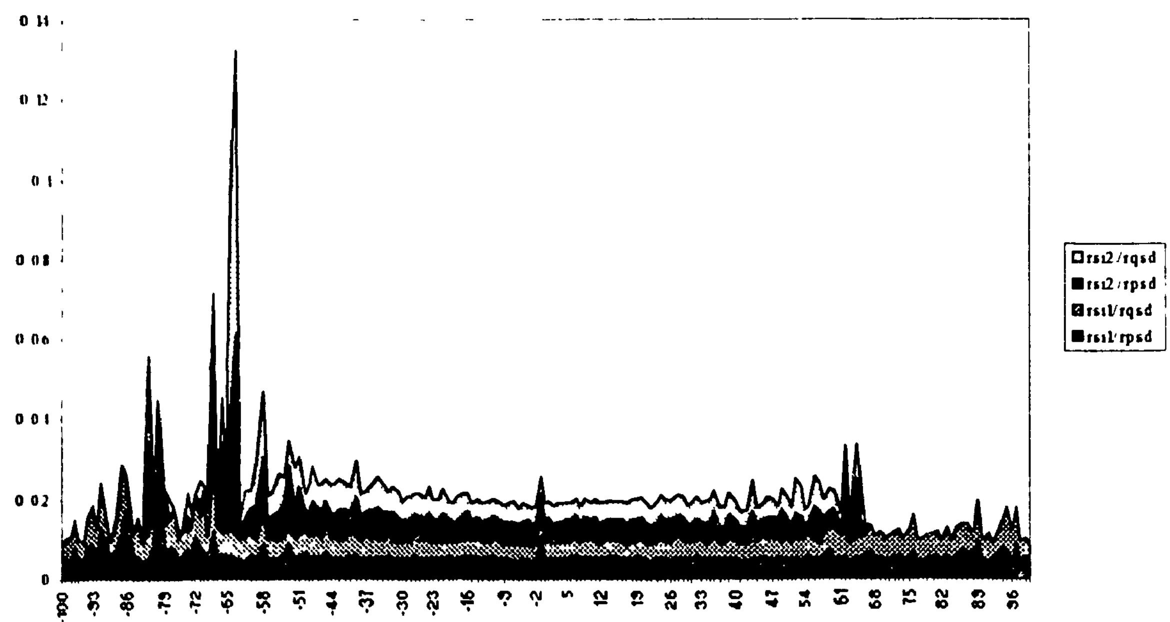


Figure 3-6: Behaviors of Trading Volume, Number of Trades, Relative Spreads and Depth Imbalance Across Relative Strength Indicator Scale of [-100, +100].

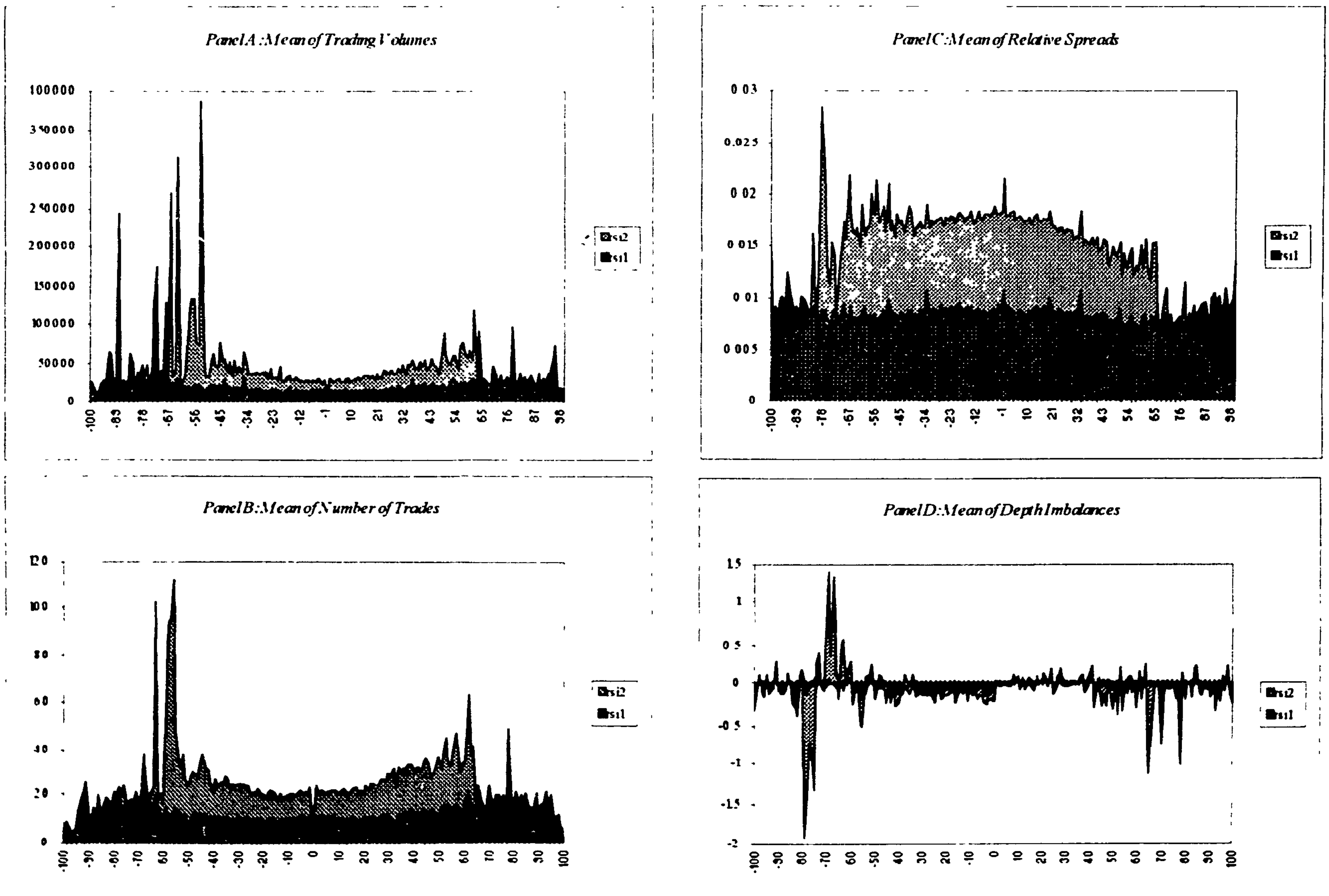


Table 4-1: Correlation Structure of Quote and Trade Variables

The correlation coefficients reported below are averages for TSE 35 stocks over one year period from 1990.7.1 to 1991.6.30, total of 3276x35 observations.

Panel A. Correlation Structure of Quote Variables

Where RQ is Quote level revision; RS is relative spread; D is quoted depth.

	RQ	*RS*
RS	-0.0153	
D	0.0017	0.1278

Panel B: Correlation Structure of Trade Variables.

Where SX is Signed square-root trading volume; RNT is Changes in number of trades; RHT (RTT) is relatively heavy (thin) trading indicator.

	SX	*RNT*	*RHT*
RNT	0.0169		
RHT	-0 0056	0.2574	
RTT	0 0005	-0.2124	-0.1597

Figure 4-1: Intraday Distribution of Six Quote Variables.

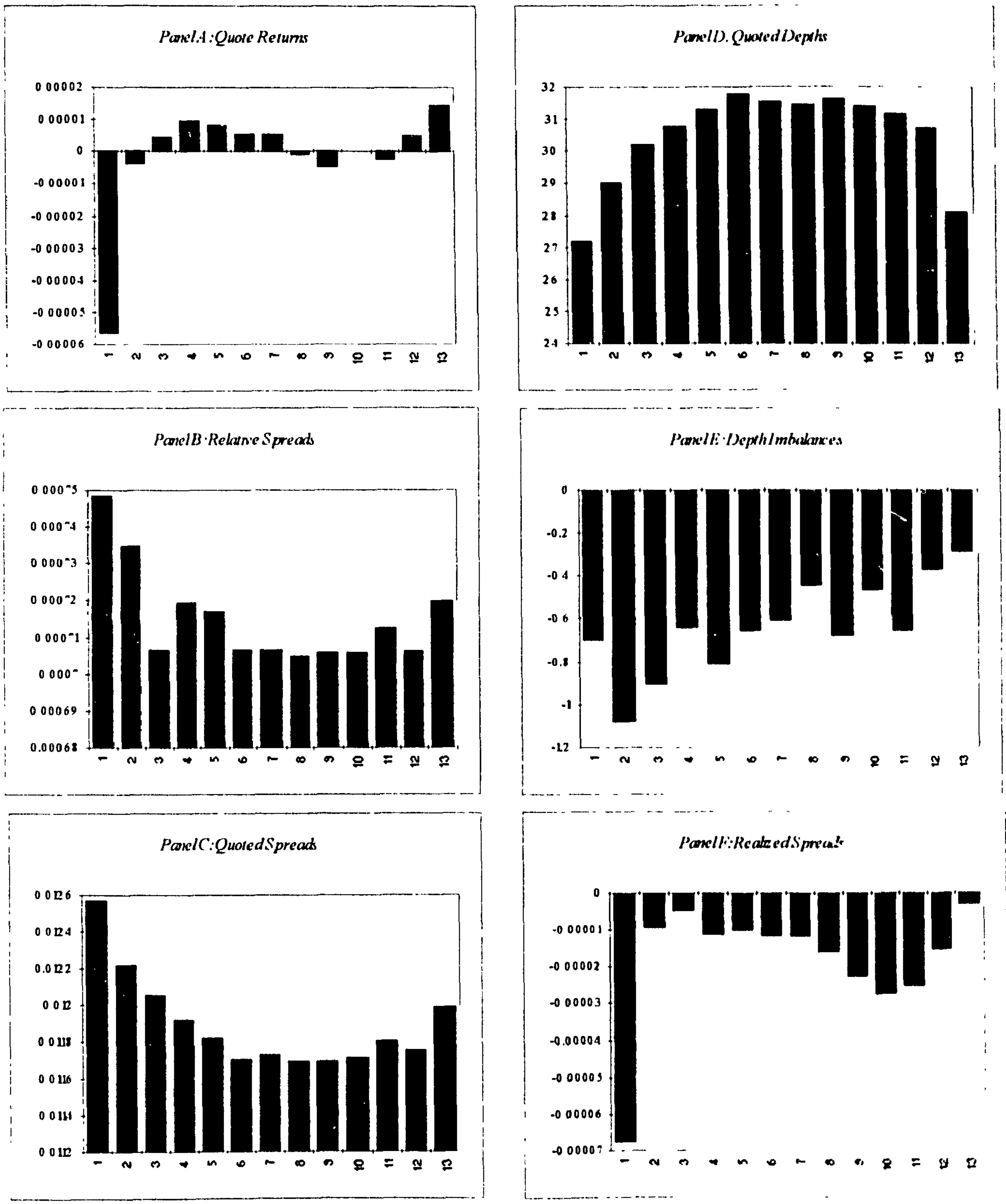


Figure 4-2 Intraday Distribution of Four Trade Variables

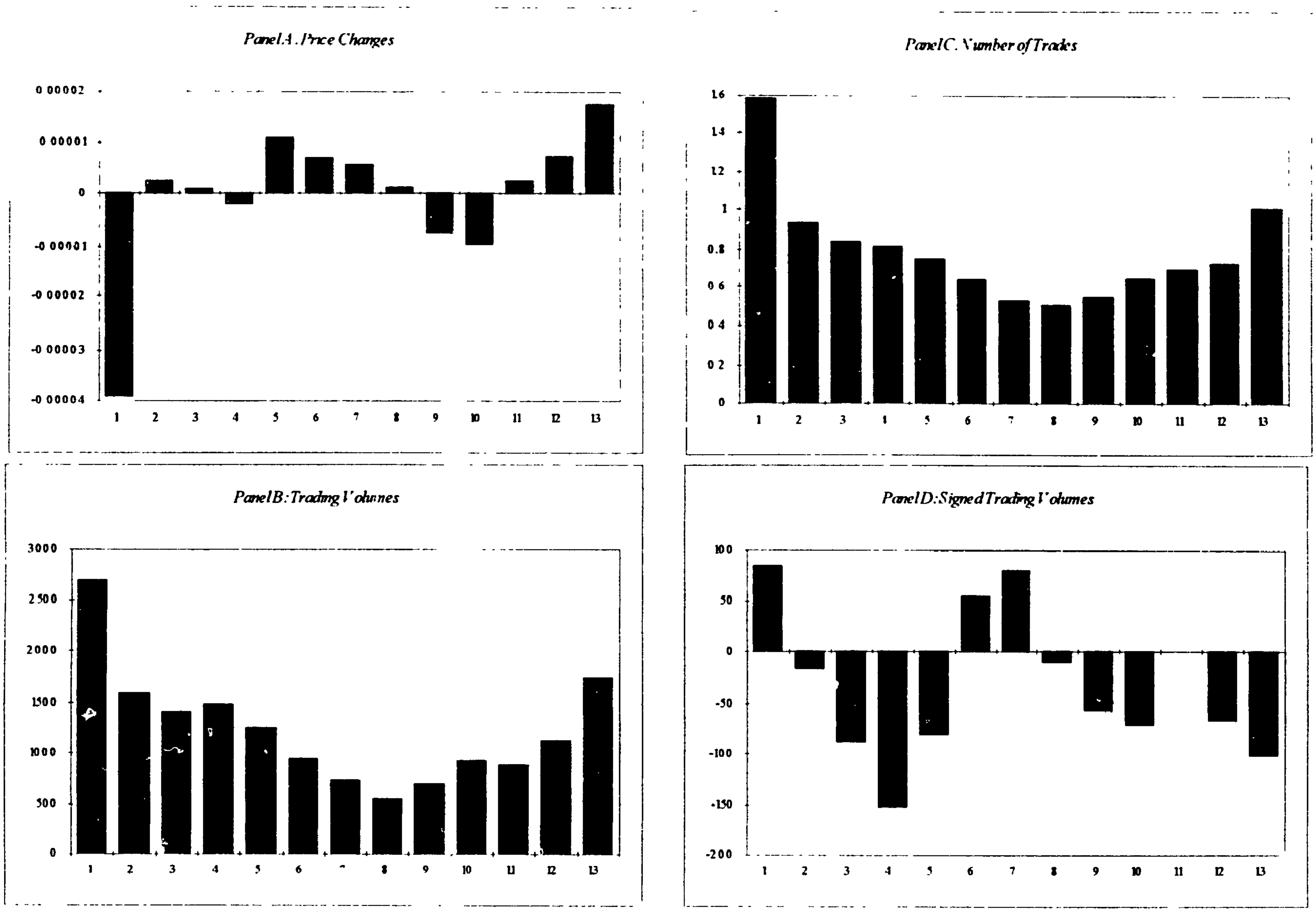


Table 4-2: Comparision of Quote Behaviors Immediately After (Non)-information Events and in Other periods.

Three hypotheses for each of four quote varianbles are tested herein.
the mean quote immediately after the (non-)information event is different from the mean quote in other periods.
the mean quote immediately after the information event is different from the mean quote immediately after the non-information events
In the Table below, the values under HT (TT) period indicate the means immediately after (non-)information events proxied by heavy (thin) trading intervals; the values under Others indicate the means in other periods [excluding those in HT (TT) periods].

		Information Events		Non-Information Events	
		HT period	*Others*	*TT period*	*Others*
	Number of Observations	9,803	104,857	20,269	94,391
Relative Spreads	*Mean*	0.0097	0.0093	0.0104	0.0091
	S.D.	0 006	0.006	0.006	0.006
	Hypothesis (t-value)	HT vs. Others	(6.46)*~	TT vs Others	(29 18)*~
		HT vs TT	(-9 58)*~		
Quote Returns	*Mean*	0 0001	0	0	0
	S D.	0.01	0 004	0.002	0 005
	Hypothesis (t-value)	HT vs. Others	(1 13)~	TT vs Others	(-0.68)~
		HT vs TT	(1.15)~		
Quote Depths	*Mean*	418	394	317	413
	S.D	380	376	324	385
	Hypothesis (t-value)	HT vs. Others	(6.09)*	TT vs. Others	(-37.11)*~
		HT vs. TT	(22.75)*~		
Depth Imbalances	*Mean*	-3.22	-8.74	-14.27	-6.98
	S.D	278	252	211	262
	Hypothesis (t-value)	HT vs Others	(1.91)~	TT vs Others	(-4.25)*~
		HT vs TT	(3.49)*~		

Notes (1) The t-test is based on pooled variance estimates if the variances for the two samples are not significantly different, and on the seperate variance estimates if they are significantly different

(2) * indicates significance at a level of 99%; and ~ indicates that the test is based on the seperate variance estimates

Figure 4-3 The Mean Frequencies of Three Dimension Quote Variables Around (Non-)Information Event Intervals

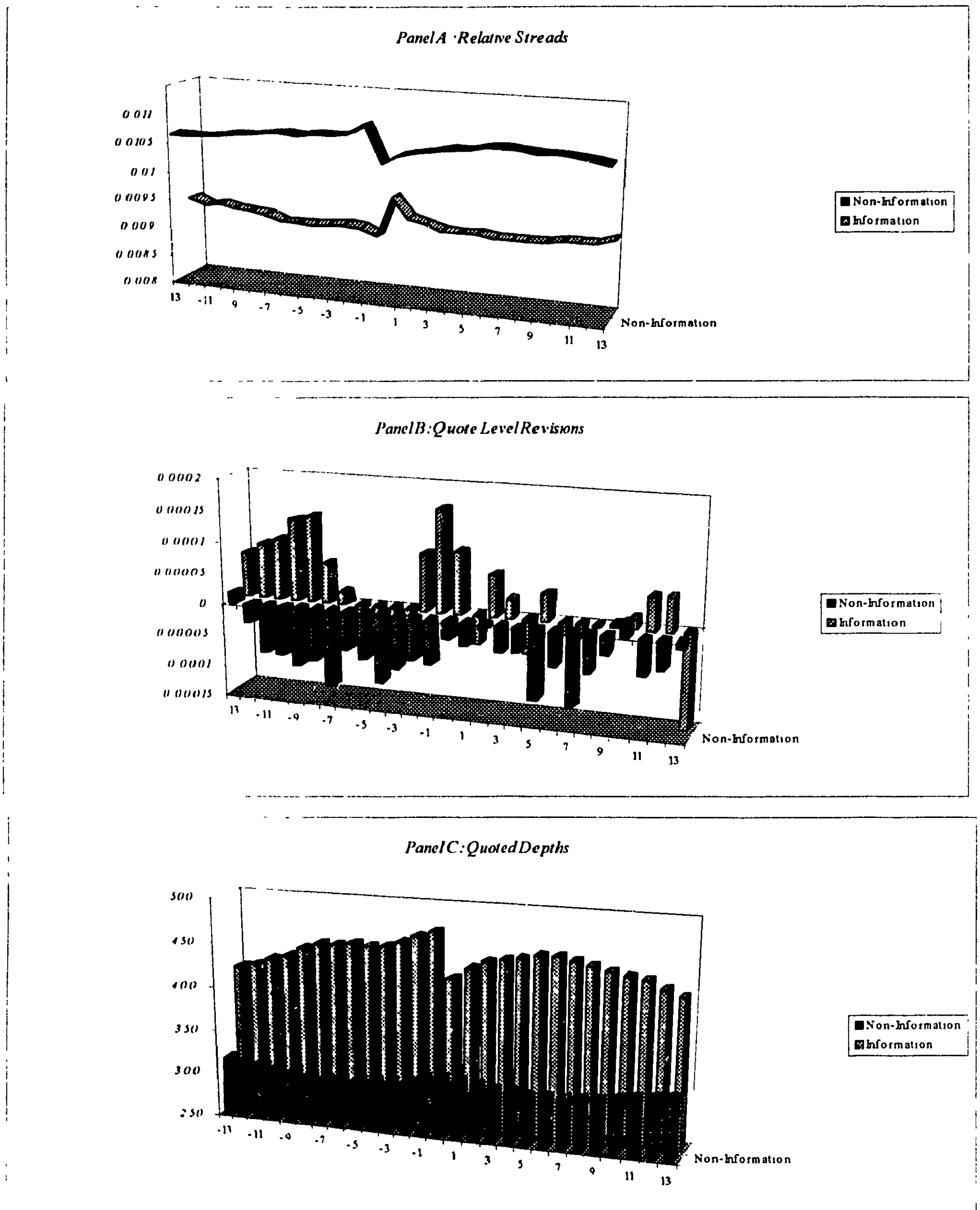


Table 4-3· Comparison of The Quote and Trade Behaviors Pre- and Post- (Non-)Information Events

		Information Events (Heavy Trading Interval)					Non-Information Events (Thin Trading Interval)				
		Pre-	*Post-*	*Difference*	*t-value*	*Z-score*	*Pre-*	*Post-*	*Difference*	*t-value*	*Z-score*
Number of Events		9,449					18,432				
Relative Spreads	*Mean*	0.0091	0.0091	0.0000	-1.33	0.35	0 0107	0.0106	0.0000	2 16*	1 23
	S.D	0.0021	0 0022	0.0000	-1.43	0.00	0.0027	0 0027	0 0000	2 32*	1 68
Quote Returns	*Mean*	0.0001	0.0000	0.0001	2 36*	6.59**	-0 0001	0 0000	0 0000	-2 3*	4 21**
	S.D.	0.0042	0.0044	0.0002	5 12**	1.68	0 0037	0 0038	-0 0001	-5 29**	2.35*
Quote Depths	*Mean*	451	442	4.32	2.07*	1 42	319	322	-2 90	-2 81*	1 22
Depth Imbalances	*Mean*	-0.06	-0.20	0.14	0.07	0.23	-14.17	-13.87	-0 30	-0 26	0 66
Price Changes	*Mean*	0.0001	0.0000	0.0001	2.27*	6 07**	-0.0001	0.0000	0 0000	-3 57**	4 13**
Trading Volume	*Mean*	25,483	24,521	962	1.29	0 51	9,755	10,534	-779	-2.95**	2 81**
Number of Trades	*Mean*	14.18	14.35	0.17	-1 30	0.74	5 88	6.04	-0 17	-6 99**	3 7**
Signed Volume	*Mean*	-1,012	-1,157	145	0.19	3.11**	-765	-590	-175	-0 66	1 69

Note * indicates significance at a level of 95% ** indicates significance at a level of 99%

Table 4-4: Test Results of The Adverse Selection Components of The Bid-Ask Spread

(4 4) *RQ(t) = a0 + a1*Q(t) + a2*SX(t) + e(t)*

(4.5) *e(t) = rho*e(t-1) + u(t)*

Coefficient x 1000

Where RQ(t) is quote return at t close, Q(t) is the direction of trade at t, SX(t) is signed square-root trading volume at t, Rho is the AR(1) parameter, and u(t) is assumed to be i.i.d. normal with zero mean and constant variance

	Constant	*Q(t)*	*SX(t)*	*Rho*	*adj-R-sq*	*D-W*	*F-value*
Ave. Coeff.	0.0101	0.7568	0.0167	-67.002	0.2833	1.9996	667.77
Ave. t-value	0.3921	6.8919*	18.230*	-3.8572*			
Max Coeff	0.3696	2.2081	0.0423	40.912	0.4113	2.0200	1145.2
Max t-value	6.6338*	19.387*	26.002*	2.3426*			
Median Coef	0.0112	0.6419	0.0145	-63.055	0.2773	2.0000	632.38
Median t-val	0.2418	6.2320*	17.821*	-3 6151*			
Min Coeff	-0.2491	-0 1992	0 0063	-172.89	0.1568	1.9800	305 61
Min t-value	-3.2866*	-1 7661*	7.9273*	-10.036*			
No Signf.	10+/9-	32+/1-	35+/0-	1+/27-			

Notes (1) * indicates significance at a level of 90% or above

(2) "No of signf" indicates the number of stocks out of TSE 35 stocks for which the estimated coefficient is significant + (or -) indicate positive (negative) significance

Table 4-5: The Regressions of Three-Dimensional Quotes on prior Trade variables

(4 6) $Q(t) = b0 + b1*SX(t) + b2*RNT(t) + b3*RHT(t) + b4*RTT(t) + e(t)$

(4.7) $e(t) = Rho*e(t-1) + u(t)$

Where Q(t) = RQ(t), RS(t) and D(t), seperately, at t close, RQ(t) is quote level revisions, RS(t) is relative spread, D(t) is quoted depth, SX(t) is signed square-root trading volume, RNT is changes in number of trades, RHT (RTT) is relatively heavy (thin) trading indicator, at t, Rho is the AR(1) parameter, and u(t) is assumed to be i.i d normal with zero mean and constant variance

	Constant	*SX(t)*	*RNT(t)*	*RHT(t)*	*RTT(t)*	*Rho*	*adj-R-sq*	*D-W*	*F-value*
Panel A RQ(t) as the Dependent Variable			Coefficient x 1000						
Ave. Coeff	0.1426	29.788	4.1435	0 0350	0.0419	-36 088	0 2831	2 0252	231 94
Ave t-value	-0.0262	16.531*	0.1415	0.1251	8.3401*	-1 8997*			
Max Coeff	10.664	43.379	96 352	0.8288	0.4986	0 2200	0.4344	2.1100	558 10
Max t-value	4 4881*	47 217*	5 9629*	3.0558*	26.405*	2 7576*			
Med. Coeff	-0.1607	26 580	1 7898	0 0334	0 0472	-32 476	0 2671	2 0250	213 91
Med t-value	-0.2887	16.041*	0 0570	-0 0253	9.2633*	-1 6484*			
Min Coeff.	-6 3118	-146.80	-48 638	-0 3758	-0.4508	-138 04	0.1301	1 9900	45 513
Min t-value	-2 8206*	-8 4969*	-15.341*	-1.9876*	-1.3882*	-7.9727*			
No. Signif	7+/6-	35+/0-	12+/8-	8+/3-	2+/2-	1+/32-			
Panel B: RS(t) as the Dependent Variable.			Coefficient x 1000						
Ave. Coeff	9 4109	-0.0004	0 0071	0.3895	-0.4027	350 64	0 0911	2.0916	8 5493
Ave. t-value	118 01*	-0 6341	1 4061*	2 4190*	-2 9772*	22 574*			
Max Coeff	18.962	0.0018	0.0341	1 1096	-0 0699	651.47	0.2994	2 3100	26 266
Max t-value	227 67*	1.9143*	3.3224*	6.8570*	-1 1364	49.350*			
Med Coeff	8 1575	-0 0002	0 0055	0.3286	-0.3372	343 00	0 0810	2 0775	7 6798
Med. t-value	118.25*	-0.4119	1.5301*	2.2521*	-2.8394	20 910*			
Min Coeff	2 6647	-0.0032	-0.0115	-0.0600	-1 0882	84 294	0.0112	2 0000	1 8857
Min t-value	58 179*	-3.1974*	-0.8492	-0.2310	-5.3712	4 8389*			
No Signif	35+/0-	2+/12-	18+/0-	25+/0-	0+/34-	35+/0-			
Panel C. D(t) as the Dependent Variable.									
Ave. Coeff	404.41	-0.0084	-0.3418	-21.731	-2.6774	0.6898	0.0850	2 2382	8 0794
Ave. t-value	40 033*	-0.3589	-1.8369*	-2.5440*	-0.2983	60.208*			
Max Coeff	1413.0	0 0418	0 7397	32.189	8.2407	0 8859	0.3992	2.4000	35 033
Max t-value	85.944*	2.4026*	2.2890*	3.3869*	1 6743*	108 74*			
Med. Coeff.	344.05	-0.0011	-0.3286	-17.353	-2 7352	0 7099	0 0562	2.2275	5 6196
Med t-value	37.368*	-0 0731	-1.9206*	-2 9977*	-0.3759	58.414*			
Min Coeff.	37 363	-0.0964	-1.7935	-91.828	-24.570	0 3019	-0.0031	2 0800	0 7483
Min t-value	14.358*	-3 8724*	-7.2490*	-7.6135*	-2.1974*	18.118*			
No. Signif	35+/0-	5+/9-	3+/22-	5+/24-	1+/5-	35+/0-			

Note See Notes for Table 4-4

Table 4-6 Estimation Results for VAR Model for Three-Dimensional Quote Movements — TSE 35 Stocks, 1990 7 - 1991 6 Total of 3276 observations (30-minute)

(4 8) $Q(t) = a0 + a1*RQ(t-1) + a2*RS(t-1) + a3*D(t-1) + a4*SV(t) + a5*RNT(t) + a6*RHT(t) + a7*RTT(t) + a8*LP(t) + a9*RPSQ(t) + a10*QO(t) + a11*QMO(t) + e(t)$

Where Q(t) = [RQ(t), RS(t), D(t)] is the quote vector, LP(t) is log transaction price, RPSQ(t) is transaction return volatility, QO(t) is dummy for daily opens, QMO(t) is dummy for Monday opens, and other variables are as defined in Table 4-5

	Constant	*RQ(t-1)*	*RS(t-1)*	*D(t-1)*	*SX(t)*	*RNT(t)*	*RHT(t)*	*RTT(t)*	*LP(t)*	*RPSQ(t)*	*QO(t)*	*QMO(t)*	*adj-R-sq*	*D-W*	*F-value*
Panel A RQ(t) as the Dependent Variable				Coefficient of D(t-1) x 1000,000, all other coefficients except for RPSQ(t) x 1000											
Ave Coeff	-0.2304	-55.755	15.618	-0.0483	0.0217	0.0106	0.2017	0.0022	0.0006	-1.8749	0.1164	-0.0003	0.2935	2.0474	131.65
Ave t-value	-0.2262	-2.8450*	0.4298	0.0654	17.101*	0.5611	0.5431	0.0936	0.2097	-1.4598*	0.3253	-0.4324			
Max Coeff	10.664	43.379	96.352	0.8440	0.0551	0.2200	1.7915	0.5291	2.7820	16.036	0.9019	0.0008	0.5564	2.1100	374.43
Max t-value	2.9040*	2.1592*	3.1439*	2.2118*	30.995*	4.0215*	3.5985*	4.7022*	3.5923*	1.8146*	2.8938*	1.3623*			
Med Coeff.	-0.2861	-52.786	12.324	0.0280	0.0200	0.0036	0.1287	-0.0168	0.0827	-0.8247	0.0548	-0.0001	0.2706	2.0500	111.82
Med. t-value	-0.1653	-2.7355*	0.3810	0.0412	18.332*	0.4688	0.3784	-0.1201	0.1836	-0.2228	0.2686	-0.1878			
Min Coeff	-7.8507	-146.80	-48.638	-1.6010	0.0086	-0.0527	-0.7388	-0.3078	-4.8904	-14.292	-0.5725	-0.0032	0.1301	1.9700	45.513
Min t-value	-3.2142*	-8.4969*	-1.6082*	-1.9615*	3.6323*	-3.2369*	-1.1724	-2.8514*	-3.0724*	-22.005*	-3.5536*	-3.5303*			
No Signf	4+/6-	31+/1-	7+/2-	6+/4-	35+/0-	11+/1-	6+/0-	7+/6-	5+/4-	2+/8-	7+/4-	2+/6-			
Panel B: RS(t) as the Dependent Variable.				Coefficient of D(t-1) x 1000,000, all other coefficients except for RPSQ(t) x 1000											
Ave Coeff	23.146	-3.6103	273.73	-1.6401	-0.0005	0.0151	0.4080	-0.3686	-5.8348	1.2702	0.0473	0.0001	0.22	2.04	93.351
Ave. t-value	15.949*	-0.2499	11.811*	-5.3658*	-0.4825	1.9676*	2.0291*	-3.5556*	-12.554*	0.7209	0.0006	0.0375			
Max Coeff	40.249	46.294	642.52	-0.3290	0.0013	0.0839	1.1139	-0.0364	8.7035	6.4869	1.1339	0.0015	0.4441	2.2200	238.85
Max t-value	36.536*	2.3116*	34.421*	-2.7499*	1.7557*	4.7598*	4.9250*	-0.1616	11.342*	6.9212*	4.2312*	2.6903*			
Med Coeff.	23.020	-2.1395	270.30	-1.0923	-0.0002	0.0077	0.3148	-0.3389	-5.9795	0.9573	-0.0185	0.0001	0.1891	2.0325	70.618
Med t-value	15.137*	-0.3518	9.6974*	-5.2523*	-0.5106	2.1718*	1.9923*	-3.0743*	-12.140*	0.9889	-0.1935	0.3277			
Min Coeff.	-5.7989	-58.265	45.210	-5.7360	-0.0038	-0.0054	0.0188	-1.1203	-12.072	-0.8699	-0.5296	-0.0006	0.0590	1.9900	19.684
Min t-value	-5.9781*	-3.0642*	1.8350*	-9.3532*	-3.0200*	-0.4574	0.1894	-7.8115*	-30.983*	-2.8681*	-2.5875*	-5.3373*			
No. Signf	34+/1-	4+/6-	35+/0-	0+/35-	1+/9-	24+/0-	28+/0-	0+/34-	1+/34-	14+/8-	6+/7-	2+/4-			
Panel C: D(t) as the Dependent Variable.															
Ave. Coeff.	592.43	264.67	-16336	712.77	0.0011	-1.3007	-19.544	-6.1389	-119.06	8634.7	-29.793	-0.0054	0.5243	2.1863	418.51
Ave. t-value	6.1305*	0.2839	-11.091*	42.574*	0.1309	-3.8159*	-1.3591*	-0.9338	-3.8413*	0.0744	-2.6199*	-0.4401			
Max Coeff	2066.9	2861.2	-948.22	878.55	0.0924	0.4471	44.931	13.118	251.58	227610	1.4880	0.0234	0.7862	2.3100	1096.0
Max t-value	20.596*	3.1266*	-3.0226*	104.698*	2.7751*	0.7224	3.0164*	1.7925*	9.5288*	9.4775*	0.4318	1.6188*			
Med. Coeff.	472.90	157.21	-12701.4	726.65	0.0017	-1.0764	-18.425	-5.1454	-85.840	2607.0	-24.165	-0.0067	0.5313	2.1800	346.07
Med t-value	5.9071*	0.3598	-10.872*	39.312*	0.1101	-3.7850*	-1.7108*	-1.0697	-3.3334*	0.1435	-2.5650*	-0.4445			
Min Coeff.	-240.78	-1426.2	-60353	300.48	-0.0821	-4.3463	-89.296	-25.633	-492.08	-192100	-84.379	-0.0538	0.1088	2.0800	37.341
Min t-value	-6.1552*	-2.2798*	-17.501*	2.8452*	-2.3351*	-9.9483*	-5.5075*	-3.8329*	-16.413*	-5.6428*	-6.1283*	-2.8077*			
No Signf.	33+/1-	5+/4-	0+/35-	35+/0-	5+/4-	0+/29-	5+/20-	2+/16-	1+/30-	4+/8-	0+/28-	1+/7-			

Note See Notes for Table 4-4