An Empirical Analysis of Strategic Behavior Models

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Abstract

Existing strategic behavior models indicate that the strategic interaction of informed and liquidity traders leads to systematic intraday patterns on stock exchanges. This paper uses a unique database from the Helsinki Stock Exchange, which allows the parties of all trades to be identified so that their transactions can be tracked intra-day and over time. We classify traders as either informed or liquidity traders based on their stock picking ability. Consistent with previous research, we illustrate that volume and volatility are concentrated at the open and close of the trading day, while spreads are widest at these times. Both informed and liquidity traders concentrate trading at the open and close. We demonstrate that volume negatively affects spreads, while volatility and the proportion of informed traders positively affect spreads. A new result is the significant increase in the proportion of informed trading across the trading day. Consistent with the strategic behaviour models proposed by Foster and Viswanathan (1996) and Wang (1998), the results illustrate that a significant proportion of intraday patterns can be explained by strategic trading by informed and liquidity traders.

Keywords: Informed trading, liquidity trading, strategic behavior, intraday patterns

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1 Introduction

A plethora of empirical studies have demonstrated that returns, market depth, volume and volatility exhibit systematic patterns on numerous stock markets around the world. These empirical studies consistently find two distinct patterns depending on the trading mechanism. Specialist and limit order book markets exhibit concentration of volume and volatility at the open and close of the trading day, while spreads are widest at these times (Ahn and Cheung (1999), Andersen, Bollerslev and Cai (2000), Brockman and Chung (1998 & 1999), Chung, Van Ness and Van Ness (1999) Ding and Lau (2001), Foster and Viswanathan (1993b), Ke, Jiang and Huang (2004) and Madhavan, Richardson and Roomans (1997)). In contrast, dealer markets exhibit a decreasing spread through the trading day with concentrated volume and volatility at the open and close (Chan, Christie and Schultz (1995), Chung and Van Ness (2001), Levin and Wright (1999), Reiss and Werner (1995), and Werner and Kleidon (1996)). The consistency of these patterns across markets suggests that market imperfections allow these patterns to persist.

One market imperfection that could cause systematic patterns is information asymmetries between traders. Grossman (1976) and Grossman and Stiglitz (1976 & 1980) are some of the earliest papers that study the affect of acquiring costly information on financial markets. They demonstrate that two types of traders, informed and liquidity, interact to maximize their respective profits, if prices do not reflect all information. Kyle's (1985) seminal paper demonstrates that the interaction of informed and liquidity traders could potentially cause systematic patterns. Subsequently a large number of theoretical models have been developed to understand how the interaction of informed and liquidity traders cause systematic patterns on stock markets (Admati and Pfleiderer (1988), Back and Pedersen (1998), Foster and Viswanathan (1990, 1993a, 1994, 1996), Holden and

Subrahmanyam (1992), and Wang (1998)). These models suggest that studying the behavior of informed and liquidity traders is required for us to understand systematic patterns.

This paper utilizes a unique data set from the Helsinki Stock Exchange (HEX) that combines trade and quote data with the central register of shareholdings. The Finnish Central Securities Depository (FCSD) is the official register of most shareholdings in Finnish stocks and records all changes in shareholdings on an intraday basis. This database classifies investors into over twenty-seven different investor classes. Theoretical models propose that the strategic timing of trading by informed and liquidity traders is an important determinant of intraday patterns. The FCSD database allows traders to be classified as either informed or liquidity traders, facilitating an analysis of the variation in trading activity by trader type through the day. The FCSD database is combined with transaction data provided by HEX and Reuters to provide a detailed record of trades on HEX. This data set allows for an analysis of intraday variations in spreads, volume, volatility and informed and liquidity traders through the trading day. This makes this paper the first study to include the trading activity of informed and liquidity traders in explaining intraday patterns.

An analysis of intraday variations in bid-ask spreads, volume, volatility and the proportion of informed traders is undertaken for the period 12 April 1999 to 26 May 2000. The results illustrate systematic intraday variations on HEX with observed patterns for spreads, volume and volatility being similar to previous studies. The results demonstrate that informed and liquidity traders concentrate their trading at the open and close of the trading day, indicating strategic behavior. Volume, volatility and the

proportion of informed traders explain a significant proportion of the intraday variation in spread, a result consistent with the existing strategic behavior models in the literature.

2 Strategic behavior models

Strategic behavior models propose that the timing of trading by informed and liquidity traders is the cause of systematic intraday patterns on stock exchanges. The models suggest three possible patterns of how the proportion of informed traders changes through the trading day. First, Admati and Pfleiderer (1988), Back and Pedersen (1998) and Foster and Viswanathan (1990) propose that liquidity and informed traders enter the market simultaneously. As a result, there should be no systematic variation in the proportion of informed traders through the trading day.

Second, Foster and Viswanathan (1993a) and Holden and Subrahmanyam (1992) propose that the proportion of informed traders will decrease through the day. This occurs because informed traders have similar information. Informed traders compete at the opening of trading, to exploit their information advantage. This causes the information to be impounded into the price and trading by informed traders decreases throughout the day.

Third, Foster and Viswanathan (1994, 1996) and Wang (1998) propose that the proportion of informed traders will be highest at the open and close of trading. Similar to Foster and Viswanathan (1993a) and Holden and Subrahmanyam (1992) trading by informed traders occurs at the opening of trading so that informed traders can exploit their information advantage. Foster and Viswanathan (1994, 1996) and Wang (1998) propose that informed traders will also trade near the close of trading because of

divergent beliefs in the value of the asset (Foster and Viswanathan (1994, 1996)) or divergent beliefs on the distribution of the value of the asset (Wang (1998)). The difference in opinion causes the informed traders to trade at the close because they believe the market has not priced their information correctly. Foster and Viswanathan (1993a, 1994, 1996) Holden and Subrahmanyam (1992) and Wang (1998) do not model the behavior of liquidity traders and assume their trading is random.

Theoretical models suggest that bid-ask spreads will be related to the order flow of informed and liquidity traders, volume and volatility in various ways. The theoretical models suggest that the proportion of informed traders will be positively related to spreads. This occurs because informed traders cause an adverse selection problem and other traders protect themselves by widening the spreads (Glosten and Milgrom (1985).

Foster and Viswanathan (1993a, 1994, 1996), Holden and Subrahmanyam (1992) and Wang (1998) propose that bid-ask spreads are positively related to volume. They suggest that informed traders are the cause of changes in volume, hence when volume is high; the proportion of informed traders will be higher causing an adverse selection problem.[1] To protect against this, traders will widen the spread. In contrast, Admati and Pfleiderer (1988), Back and Pedersen (1998) and Foster and Viswanathan (1990) propose that changes in volume are predominately caused by liquidity traders entering and leaving the market. This will cause spreads to be negatively related to volume.

The theoretical models suggest that volatility is caused by information being impounded into prices. Foster and Viswanathan (1990, 1993a, 1994, 1996), Holden and

[1] Foster and Viswanathan (1993a, 1994, 1996), Holden and Subrahmanyam (1992) and Wang (1998) models concentrate on informed traders behavior and assume liquidity traders' behavior is random, this could be a significant factor in causing this result.

Subrahmanyam (1992) and Wang (1998) propose that increased information flows are caused by a greater order flow from informed traders and reduced order flow from liquidity traders. This increase in the proportion of informed traders causes spreads to widen. Hence volatility and spreads are positively related. In contrast, Admati and Pfleiderer (1988) and Back and Pedersen (1998) propose that informed and liquidity traders trade in proportional amounts. Hence, even though more information is being impounded in prices this will not affect bid-ask spreads because there has been no change in the proportion of informed traders.

3 Institutional details

Trading on the Helsinki Stock Exchange (HEX)[2] occurs through an electronic limit order book. The complete limit order book, including identification number for the trading member, is displayed to all members during continuous trading. Orders entered into the limit order book may be market or limit orders. The tick size for all stocks is €0.01. During pre-trading and continuous trading, orders may not deviate more than +/-15% from the last traded price.

During the period studied the trading day is divided into five trading periods. These periods are: pre-trading 9:30-10:10, matching 10:10-10:30, continuous trading 10:30-17:30, after-market trading I 17:30-18:00 and after-market trading II 9:00-9:30 the following trading day.[3]

During pre-trading, orders may be entered, revised and deleted but no transactions will occur. During this period only orders entered by the trading member can be viewed.

[2] During the period of analysis HEX was an independent exchange, and today it is a part of OMX integrated markets of Stockholm, Helsinki, Tallinn, Riga and Vilnius.
[3] The official regulations are stated in Helsinki Stock Exchange (2002), Rules of the Stock Exchange.

Between 10:10 and 10:30 a closed call auction occurs and all overlapping orders are executed. The opening price is determined on the basis of the maximum quantity that can be executed in respect of all orders in the book and is disseminated to all members after execution. Unmatched orders from the call auction may be deleted from the limit order book before continuous trading commences. Unmatched orders that are not deleted form the basis of the limit order book for continuous trading. During continuous trading, trades are prioritized by price, then time and execute automatically when orders match. Pre-arranged (upstairs trades) can occur during continuous trading but must clear the order book up to the pre-determined price. HEX closes without an auction at 17:30. During after-market trading, only pre-arranged trades can be executed. These trades can execute at any price within the previous continuous trading session price range. Anecdotal evidence suggests that a large proportion of upstairs trades occur during after-market trading so the trade can be done at one price. This paper utilizes trades and orders posted during continuous trading. Examination of the after-market periods and the opening auction is left to future research.

HEX is divided into four trading lists: The Main List, the I-List, the New Market List and the Pre-List. The Main List contains companies with several years of operating history and a market capitalization of at least €35 million. The I-List contains mid-size companies with a market capitalization of at least €4 million. The New Market List is for growing innovative companies that are capital intensive with a market capitalization of at least €2 million. The Pre-List are companies that only require short-term listing or a preliminary listing before moving to one of the three other lists. This paper only utilizes stocks listed on the Main List. As at 1 June 2000 the Main list accounted for 99.5% of the total market capitalization.

4 Data

This paper uses data from Finnish Central Share Depository (FCSD), HEX, Datastream and Reuters from 12 April 1999 to 26 May 2000. The Reuters data is provided by the Securities Industry Research Centre of Asia-Pacific (SIRCA), while FCSD and other trading data are provided by HEX. The FCSD data is the official record of shareholdings in Finland and covers approximately 99% of all companies listed on HEX. FCSD registers changes in shareholdings for each investor registered. To trade on HEX, Finnish institutions, companies and individuals must register with FCSD and are given a unique account, even if they trade through multiple brokers. Foreign investors are partially exempt from registration. Foreign investors may choose to trade through a nominee account, which may have multiple foreign investors and are registered through financial institutions. The data also classifies each investor into one of over twenty-seven investor classes and ownership type (e.g. whether the account is a nominee or individual account) (Table 1). Grinblatt and Keloharju (2000) give a detailed description of the FCSD database.

[Insert Table 1]

The Reuters data provides details of the volume and price of each individual trade and changes in the best bid and ask time stamped to the nearest minute. FCSD data, HEX trading data and Reuter's quote and trading data are used to study intraday variations in spreads, trading activity and proportion of informed traders. Thirty stocks (representing 89% of the total market capitalization) which are continuously listed on HEX, for the period 12 April 1999 to 26 May 2000, are chosen. During this period all thirty stocks

spent at least six months in the HEX 25 Index. This index contains approximately the largest twenty-five stocks that trade on HEX.

The data provides major advantages over previous studies on intraday variations in that it contains information about all investors in the market and sufficient information to assign each trade to specific investors as well as to link these trades to others sources of data. This facilitates an analysis of the trading behavior of different types of investors through the day, enabling an analysis of their interaction during the trading day.

5 Method

5.1 Trader classification

To classify traders as either informed or liquidity, the performance of traders is analysed using an approach similar to Gompers and Metrick (2001). The FCSD data classifies all traders into twenty-seven investor classes. The FCSD data contains opening shareholdings, for each account, in thirty stocks listed on the Main List as at 12 April 1999, which is accumulated into twenty-seven distinct investor classes and two ownership types (either nominee or individual accounts).[4] Changes in shareholdings for the thirty stocks are calculated for each investor class for each day during the period 12 April 1999 to 26 May 2000.[5] The percentage change in shareholdings for each investor class is calculated by dividing the change in shareholding by the day's opening shareholding. Changes in shareholding which relate to the first purchase of stock by an

[4] To trade on HEX, Finnish institutions, companies and individuals must register with FCSD and are given a unique account. Foreign investors are partially exempt from registration as they may choose to trade through a nominee account, which may have multiple foreign investors and are registered through financial institutions.

[5] The robustness of the results is tested by an out of sample test which using the period 1995-1998. The results indicate that the investor class identified as informed during the period 1999-2000 also outperform out of sample.

investor are excluded from the sample. Subsequent stock performance is estimated by calculating returns over the next three months using closing prices.[6]

Gompers and Metrick (2001) suggest that other variables can affect stocks returns and ownership changes. To control for these other possibilities nine other variables are included in the model. These are market capitaltization, dividend yield, share price, turnover, momentum in stock returns, standard deviation of returns and beta.[7] These variables control for preference for larger stock (market capitalization, turnover and share price), liquidity (turnover), past performance (dividend yield and momentum) and risk (standard deviation of returns and beta). Each variable (except beta, and standard deviation of return) is calculated using the average value for the period 12 April 1999 to 26 May 2000. Since returns and changes in ownership are percentage values, the natural log of each variable is used in the regression model.

Changes in shareholding, for each investor class, are matched with the stock's three month performance and the nine other variables. The following regression model is estimated using general method of moments (GMM) with autocorrelation and heteroscedasticity corrected for by using the Newey-West Correction.

$$R_{i,j} = \beta_1 + \beta_2 \Delta_{k,i,j-i} O + \beta_3 S_i + \beta_4 DY_i + \beta_5 P_i + \beta_6 Tur_i + \beta_7 M1_{i,-1,0} + \beta_8 M6_{i,-6,-1} + \beta_9 Open_{k,i,j} + \beta_{10} Std_i + \beta_{11} Beta_i + \varepsilon \quad (1)$$

$R_{i,j}$ = stock i performance from day j-1 to day j, $\Delta_{k,i,j-1}O$ = the proportional change in ownership by investor class k for stock i on day j-1, S_i = market capitalization of stock i, DY_i = dividend yield of stock i, P_i = price of stock i, Tur_i = volume traded in stock i, $M1_{i,-1,0}$ = return of stock i for previous month, $M6_{i,-6,-1}$ = return of stock i for month –6 to

[6] Sensitivity analysis is conducted using returns over one week, one month and two months. This analysis results in consistent classification of informed and liquidity traders.
[7] These variables are collected from Datastream.

month –1, $Open_{k,i,j}$ = Opening position for investor class k in stock i on day j, Std_i = standard deviation of returns for stock i, $Beta_i$ = beta of stock i,, β_i = parameter estimate and ε = error term.

This regression model tests for superior stock picking abilities. Investor classes that have a statistically significant positive relationship between subsequent stock performance and change in ownership demonstrate superior stock picking ability. These investor classes are classified as informed traders while all other investor classes are classified as liquidity traders.

5.2 Intraday patterns

To investigate intraday variation in bid-ask spreads, trading activity, volatility and the proportion of informed traders, an approach similar to Foster and Viswanathan (1993b) and Chan, Christie and Schultz (1995) is used. The trading day is split into fourteen half-hour trading intervals and for each half-hour period bid-ask spreads, trading activity, volatility, and the proportion of informed traders are calculated. There are no definitive measures for calculating these variables and because of this a number of commonly used techniques are utilized.[8] Similar results are found for each of these variables hence only relative spreads, volume of shares traded, number of trades and standard deviation of returns are reported.

The relative bid-ask spread is calculated using McInish and Wood's (1992) estimate of time-weighted spread. Trading activity is measured using volume of shares traded and the number of trades. Volume of shares traded is calculated by summing the number of shares traded for stock i during the half-hour time period t ($Vol_{i,t}$). The number of trades

[8] Measurements used are relative, effective and absolute spreads, number of trades, volume and value of shares traded and absolute returns and standard deviation returns.

is calculated by counting the number of trades in each half-hourly time period t for stock i ($NoTr_{i,t}$). Volatility is measured using the standard deviation of the best bid and ask prices. Midpoint prices are used for two reasons, first, it helps remove problems associated with infrequent trading. Second, it eliminates bid-ask bounce induced volatility. The standard deviation of prices is calculated for each half-hourly period.

5.3 Proportion of informed traders

In any trade there are two parties, a liquidity demander and a liquidity supplier. As this paper is concerned with investigating the timing of trading by informed and liquidity traders, only traders who demand liquidity (i.e. the party who initiated the trade) are included in the analysis. This is done because only the liquidity demander (the trade initiator) chooses the time to trade while the liquidity supplier, by waiting in the order book, do not determine their time of trading. To determine which trader initiated the trade we classify buy initiated trades as trades that occur above the midpoint price (and vice-versa for sell initiated trades). Trades executed at the midpoint price are excluded from the analysis.

The proportion of informed traders based on the number of trades is calculated by summing the number of trades initiated by informed traders for each half-hour period. The total number of trades initiated by informed traders is then divided by the total number of trades initiated by all traders.

$$PInfNt_{i,t} = \frac{NtInf_{i,t}}{NoTr_{i,t}} \qquad (2)$$

where $PInfNt_{i,t}$ = Proportion of informed traders in stock i during half-hour time period t, $NtInf_{i,t}$ = Number of trades initiated by informed traders in stock i during half hour time

period t and $NoTr_{i,t}$ = Number of trades initiated by all traders in stock i during half-hour time period t.

5.4 Regression Models

To facilitate comparisons of the variables between different stocks and time of the day the spreads, trading activity and volatility variables are standardized for the regression models, following Chung and Van Ness (2001).[9]

To test for the presence of intraday patterns for each variable, the null hypothesis is that the variable is uniform through the trading day. This gives the following general specification, which is estimated using GMM. As the study uses cross-sectional panel data it allows for arbitrary patterns of cross-correlations, autocorrelation and heteroscedasticity utilising the Newey-West correction.

$$W_t = w + \sum_{i=2}^{n} d_i \beta_i + \varepsilon \qquad (3)$$

Where W_t = the value of the variable being studied in time period t, w = the fixed effect, which will represent the variable base amount which throughout the study is 13:30-14:00. d_i = a dummy variable that reflects the time-of-day, which takes on the value of one if the time-of-day observation t is equal to i and zero otherwise. β_i = the estimated intraday coefficient for time periods other than the fixed effect time period and ε = an error term.

A second more general specification is used to test the effects of the time-of-day, trading activity, volatility and the proportion of informed traders on spreads. The following

[9] Each variable is calculated in each half-hourly interval and standardised by subtracting the mean (for the day) from the raw value and dividing by the standard deviation (for the day).

regression model estimated using GMM, with the Newey-West correction, allows a test of this hypothesis.

$$S_t = s + \sum_{i=2}^{n} d_i \beta_i + \sum_{t=1}^{n} W_t \gamma_i + \varepsilon \qquad (4)$$

Where S_t = the spread during time period t, d_i is a dummy variable that reflects the time of day, which takes on the value of one if the time-of-day observation t is equal to i and zero otherwise, s is a fixed effect, W_t other variables e.g. trading activity, volatility, and the proportion of informed traders, β_i = the estimated intraday coefficient for time periods other than the fixed effect time period γ_i = the parameter estimate for the other variables e.g. trading activity, volatility, and the proportion of informed traders and ε = an error term.

6 Results

6.1 Trader classifications

The stock picking ability for each of the twenty-seven classes of investors' are estimated for the period 12 April 1999 to 26 May 2000.[10] Table 2 reports the relationship between a percentage change in shareholding and control variables and the stocks' subsequent performance over the next three months.[11] Two investor classes, other financial institutions (nominee accounts) and residences in European Union member states, demonstrate significant positive relationships between changes in shareholdings and subsequent stock performance.

[Insert Table 2]

[10] The robustness of these results is tested by an out of sample test using the period 1995-1998 and using various period of stocks' subsequent performance, which included one week, two weeks, one month, two months. The results indicate that the investor class identified as informed during the period 1999 to 2000 also outperform out of sample and using various periods of stocks' subsequent performance.
[11] Only investor classes whose percentage of total trading is at least 0.02% are reported.

Previous research by Nofsinger and Sias (1999) and Sias and Starks (1997) find that financial institutions are more sophisticated investors, which typically outperform the market. Nofsinger and Sias (1999) argue that institutional investors buy and sell companies because of their informational advantage. The results, presented in Table 2, support this argument with other financial institutions exhibiting significant positive results. Grinblatt and Keloharju (2000) find that on HEX foreign investors outperform the market. Our results support this finding with European Union residences and nominee account[12] financial institutions exhibiting a positive relationship between changes in shareholdings and stock performance.

The results indicate that two investor classes, financial institutions, and European Union residences, have superior stock picking ability implying that after these investor classes purchase (sell) a stock, the stock exhibits positive (negative) out-performance. This superior stock picking ability leads us to classify these investor classes as informed traders and all other investor classes as liquidity traders.

6.2 Intraday patterns

6.2.1 Descriptive statistics

Descriptive statistics for the price, market capitalization, spread, volatility and trading activity are reported in Table 3.[13] The thirty stocks demonstrate wide variation in all variables. The sample has a price range of €2.10 to €239.22 with a median price of €15.10. Time-weighted relative spreads vary from 0 to 63.41 with a median of 0.73 percent. Price standard deviation ranges from 0 to 38.21 with a mean and median of

[12] Only foreign investors are allowed to have nominee accounts

[13] Nokia Plc represents approximately 65% of the total market capitalistion of HEX. Hence regressions are estimated also with Nokia Plc exluded. The results are substantially similar whether Nokia Plc is included or excluded and results presented include Nokia Plc.

0.054 and 0.019 respectively. The number of trades, volume of shares traded and market capitalization demonstrate that even though this paper focuses on the largest stocks on HEX, the trading activity and size is low. The median number of trades and volume of shares traded for each half-hourly period is 2 and 1000, mean of 9.95 and 12,621 and maximum of 1,222 and 3,229,023 respectively. The mean market capitalization is €7.78 billion and the median value is €779 million.[14] The market capitalization of stocks is relatively small.

[Insert Table 3]

6.2.2 Standardized results

Table 4 and Figure 1 report the standardized intraday variations in spread, volatility and trading activity. The results are consistent with previous studies on intraday patterns. The standardized spread, on average, is widest at the opening of trading and decreases during the trading day. On average, it reaches a daily minimum between 15:00 and 15:30. The spread, on average, widens as the close approaches. Figure 1 demonstrates that spreads exhibit a reverse J-shape pattern.

The standardized price standard deviation of returns follows a similar, though more pronounced, reverse J-shape pattern. Table 4 demonstrates that standard deviation of returns is highest in the opening half-hour of trading and declines for the next three hours. From 14:30 to 16:30 there is little change in volatility but it increases significantly during the last hour of trading. These results are consistent with previous empirical studies (Ahn and Cheung (1999), Andersen, Bollerslev and Cai (2000), Brockman and Chung (1998 & 1999), Chung, Van Ness and Van Ness (1999) Ding and

[14] Nokia Plc significantly affects these numbers. When Nokia Plc is excluded the mean and median value falls to €2.2 billion and €714 million.

Lau (2001), Foster and Viswanathan (1993b), Ke, Jiang and Huang (2004) and Madhavan, Richardson and Roomans (1997)).

[Insert Table 4 and Figure 1]

Trading activity measured with number of trades and volume, exhibit two distinct patterns. Figure 1 demonstrates that the volume of shares traded exhibits a J-shape pattern, while the number of trades exhibits a reverse J-shape pattern. Previous empirical research generally finds a U shape or reverse J-shape pattern (Ding and Lau (2001), Foster and Viswanathan (1993b), and Ke, Jiang and Huang (2004)), though Werner and Kleidon (1996) found evidence that trading in stocks cross-listed on the London Stock Exchange (LSE) and North American markets exhibit significantly higher trading volume after the North American markets open. As at 1 June 2000 foreigners owned approximately 69.9% of the market capitalization on HEX (Karhunen and Keloharju (2001)). These investors may prefer to trade during their local trading hours. If a large proportion of foreign investors come from North America this may compound the preference to trade during simultaneous trading sessions, causing the increase in trading volume as the close approaches. Further investigation would require analyses of where foreign residents reside and when they predominantly trade: however this is left for future research. A second possibility for the J-shaped pattern in volume is that the opening auction is excluded from the analyses, lowering the amount traded in the first half-hour.

6.3 Proportion of informed traders

Table 5 and Figure 2 report intraday variations in the proportion of informed traders. The results indicate that the proportion of informed traders is lower during the first half

hour of trading, variable through the day and then increases in the last hour and half of trading. The results demonstrate that during the 10:30 to 11:00 trading period, the proportion of informed traders is, on average, 20.9%. This result could be influenced by the exclusion of the opening auction. The proportion of informed traders increases in the next half-hour (11:00 to 11:30) to 24.1% (on average) and then varies between 22.6% and 25.3% (on average) for the next five hours. In the last hour and a half of trade the proportion of informed traders increases to reach a maximum of 30.6%, on average, in the last half-hour (17:00 to 17:30). Generally the results indicate that informed and liquidity traders trade at the same time, causing small changes in the proportion of informed traders throughout the trading day. This is consistent with the argument that informed traders try to disguise their trading activity by trading with liquidity traders particularly at the start of the trading day (Admati and Pfleiderer (1988)). As the trading day progresses informed traders become less concerned about hiding their identity and more concerned that they trade before their information becomes useless (Foster and Viswanathan (1996) and Wang (1998)). Hence the proportion of informed traders increases during the trading day.

[Insert Table 5 and Figure 2]

To obtain a more detailed understanding of the trading behavior of informed and liquidity traders we examine the behavior of both traders separately. First, variations in the proportion of trading by informed or liquidity traders through the day are analysed. For informed and liquidity traders, the total number of trades for informed (liquidity) traders is calculated for each half-hour period.[15] The number of trades for each half hour period for informed (liquidity) is divided by the total number of trades by informed (liquidity)

[15] Only trades initiated by an informed or liquidity trader are considered.

traders for the day. Table 6 and Figure 3 panel A reports that the proportion of trading by informed and liquidity traders differs through the trading day. The result indicates that both traders concentrate trading in the first and last half-hour of trading, with a relatively constant proportion of trading through the middle of the day. This suggests both traders trade strategically through the day. The percentage of trades in the first half hour is 13.1% and 15.1% (on average) for informed and liquidity traders respectively, while in the last half hour the percentage of trades is 15.1% and 10.9% (on average) for informed and liquidity traders respectively. This result again highlights that informed and liquidity traders trade a similar percentage of their total trading activity at the same time during the trading day.

Second, variations in trade size for informed and liquidity traders are analysed. The average trade size by informed (liquidity) traders is calculated for each half hour and then standardized by dividing it by the average trade size for informed (liquidity) traders for the day. Changes in standardized trade size through the trading day are reported in Table 6 and Figure 3 panel B. Consistent with Biais, Hillion and Spatt (1995) the results indicate that both informed and liquidity traders increase their trade size through the day.

[Insert Table 6 and Figure 3]

These results are consistent with two explanations. First, liquidity traders have liquidity shocks during non-trading periods, forcing them to trade near the open and close of trading which is consistent with Admati and Pfleiderer (1988) and Foster and Viswanathan (1990). This increase in liquidity traders provides an opportunity for informed traders to hide their trading activity, causing a proportional increase in their trading activity. Alternatively, increased trading by informed traders at the open and the

close is caused by competition and divergent beliefs about the value of the asset. Foster and Viswanathan (1994, 1996) and Wang (1998) propose that trading by informed traders at the opening of trading is caused by competition between informed traders with similar information. To exploit their information, informed traders enter the market at the open and the price will change to reflect this information. They suggest that informed traders trade near the close of trading because of divergent beliefs in the value of the asset (Foster and Viswanathan (1994, 1996)) or divergent beliefs on the distribution of the value of the asset (Wang (1998)). The difference in opinion causes the informed traders to trade at the close because they believe the market has not priced their information correctly. Foster and Viswanathan (1994, 1996) and Wang (1998) do not analyse the trading behavior of liquidity traders (they assume it is random). The results presented in this paper suggest that both informed and liquidity traders behave strategically. This would indicate that models that focus solely on one type of trader are missing an important segment of the market.

The theoretical models suggest that the timing of informed and liquidity traders trades causes changes in spreads, trading activity and volatility. The results presented indicate that informed and liquidity traders concentrate at the open and close of the trading day. During these periods spreads are widest, while trading activity and volatility is higher. These results are consistent with Foster and Viswanathan (1996) and Wang (1998).

6.4 Influence of variables on spreads

Table 7 reports the extent to which time of day, volume, standard deviation of returns and the proportion of informed traders influence spreads. The results indicate that all variables (volume, standard deviation of returns and the proportion of informed traders) have a statistically significant effect on relative spreads, though time-of-day dummy

variables still explain a large proportion of the intraday variation in spreads. *Ceteris paribus*, the 14 half-hour periods indicate that standardized relative spreads exhibit a reverse J shape. The results demonstrate that standardized volume has a statistically significant negative effect on relative spread. The results indicate that a one unit increase in standardized volume traded, on average, decreases the standardized relative spread by 0.052 units, *ceteris paribus*. In contrast, standardized price standard deviation and the proportion of informed traders exhibit a statistically significant positive influence on relative spreads. Table 7 indicates that a one unit increase in standardized price standard deviation, on average, widens the standardized relative spread by 0.310 units, *ceteris paribus*. Similarly, a one percent increase in the proportion of informed traders, on average, widens the standardized relative spread by 0.044 units, *ceteris paribus*.

[Insert Table 7]

Admati and Pfleiderer (1988), Back and Pedersen (1998) and Foster and Viswanathan (1990) models focus on both liquidity and informed traders' behavior. They propose that volume will be inversely related to spreads because changes in liquidity traders' volume are the major cause of changes in volume. Hence, when volume increases spreads decline. In contrast, Foster and Viswanathan (1993a, 1994, 1996), Holden and Subrahmanyam (1992) and Wang (1998) models focus solely on informed traders and assume liquidity trading is random. These models argue that informed traders' are the cause of changes in volume, causing spreads to widen. Our results indicate that volume and spreads are inversely related with a one unit increase, on average, decreases the spreads by 0.052 units, *ceteris paribus*, suggesting that liquidity traders are the major cause of changes in volume.

Strategic behavior models suggest that volatility is caused by information being impounded in prices. Foster and Viswanathan (1990, 1993a, 1994, 1996), Holden and Subrahmanyam (1992) and Wang (1998) propose that when volatility is high new information is rapidly appearing in the market. This will cause spreads to widen. The results presented in this paper support this theory.

Strategic behavior models suggest that the proportion of informed traders will be positively related to spreads (Admati and Pfleiderer (1988), Back and Pedersen (1998), Foster and Viswanathan (1990, 1993a, 1994, 1996), Holden and Subrahmanyam (1992), and Wang (1998)). As the proportion of informed traders increases there is a greater chance of trading against an informed trader causing an adverse selection problem leading to a widening of the bid-ask spread. Again the results are consistent with this argument.

The results indicate that time of day explains a significant proportion of the intraday pattern in spread. This suggests that the time-of-day dummy variables are proxies for other variables. These other variables could include other motives for trade. The burgeoning research in behavioral finance indicates that not all traders follow rational economic behavior (Barber and Odean (2000), Odean (1998), Hirshleifer (2001)), which may affect trading patterns in the stock market. If these traders trade in a systematic manner (e.g. the disposition effect, momentum trading and contrarian trading), time-of-day variables could constitute a proxy for this behavior.

Theoretical models focus either on informed traders (Foster and Viswanathan (1993a, 1994, 1996), Holden and Subrahmanyam (1992) and Wang (1998)) or both liquidity and informed traders (Admati and Pfleiderer (1988), Back and Pedersen (1998) and Foster

and Viswanathan (1990)). The results presented demonstrate that both informed and liquidity traders trade strategically through the trading day. This is illustrated by the fact that both traders concentrate activity at the open and close of the trading day. The results are consistent with Foster and Viswanathan (1996) and Wang (1998), with the influence of volume on spreads being the exception, even though they focus on informed traders.

7 Conclusion

This paper analyses intraday variations in spreads, trading activity, volatility and the proportion of informed traders on HEX for thirty stocks during the period 12 April 1999 to 26 May 2000. The paper details the influence of trading activity, volatility and the proportion of informed traders on spreads. This provides a direct test of the theoretical models based on the strategic behavior of two types of traders, informed and liquidity. Theoretical models suggest that the strategic timing of trading by informed and liquidity traders is an important determinant of intraday patterns. Previous empirical research on intraday patterns has focused on spreads, trading activity and volatility. This paper is the first study to use trading activity of informed and liquidity traders to explain intraday patterns.

Consistent with previous research (Grinblatt and Keloharju (2000), Nofsinger and Sias (1999) and Sias and Starks (1997)) two classes of investors out of twenty-seven in the FCSD data exhibit superior stock picking ability and are classified as informed traders, while all other classes of investors are classified as liquidity traders.

Spreads, trading activity, volatility and the proportion of informed traders all exhibit statistically significant intraday variations. Consistent with previous studies relative

spreads and standard deviation of returns both exhibit a reverse J-shape pattern. In contrast, trading activity (volume and number of trades) has two distinct patterns, volume of shares traded exhibit a J-shape pattern while the number of trades exhibits a reverse J-shape pattern. It is argued that this large increase in volume of shares occurs because of the simultaneous afternoon trading on North American markets and because the opening auction is excluded from the analysis.

The results demonstrate that the proportion of informed traders exhibits a small increase across the trading day. Closer analysis demonstrates that both informed and liquidity traders enter the market at the same time, with a concentration of activity at the open and close. This result is consistent with two explanations proposed by the theoretical literature. First, liquidity traders suffer liquidity shocks during non-trading periods, causing liquidity traders to trade at open and close of the trading periods. Informed traders enter the market during these periods to attempt to hide their trading activity (Admati and Pfleiderer (1988) and Foster and Viswanathan (1990)). Second, competition and divergent beliefs lead informed traders to trade at the open and close of trading periods (Foster and Viswanathan (1994, 1996) and Wang (1998)).

Trading activity, volatility, the time of day and the proportion of informed traders have statistically significant effects on spreads. The results indicate that trading activity negatively affects spreads, while volatility and the proportion of informed traders positively affect spreads. These results are consistent with three explanations. First, liquidity traders drive changes in volume causing volume to be inversely related to spread (Admati and Pfleiderer (1988), Back and Pedersen (1998) and Foster and Viswanathan (1990)). Second, volatility is driven by information being impounded in prices causing volatility to be positively related to spreads (Foster and Viswanathan

(1990, 1993a, 1994, 1996), Holden and Subrahmanyam (1992) and Wang (1998)). Third, as the proportion of informed traders increases, it creates an adverse selection problem, causing the proportion of informed traders to be positively related to spreads. Overall the results give substantial support to the models proposed by Foster and Viswanathan (1996) and Wang (1998) in explaining observed intraday patterns in bid-ask spreads, trading activity and volatility.

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Table 1

Descriptions of investor classes

Table 1 presents details of the twenty-seven different investor classes included in the Finnish Central Securities Depository (FCSD) database. The description for each investor class and the percentage of total trading carried out is reported for the period 12 April 1999 to 26 May 2000. The table presents the percentage of trading activity in each category by individual and nominee accounts. To trade on HEX, Finnish institutions, companies and individuals must register with FCSD and are given a unique account. Foreign investors are partially exempt from registration as they may choose to trade through a nominee account, which may have multiple foreign investors and are registered through financial institutions.

Investor Class	Description	Individual Accounts	Nominee Accounts	All Accounts
		% of Total Trading Activity	% of Total Trading Activity	% of Total Trading Activity
0	Others	0.95	0.00	0.95
100	Companies	0.10	0.00	0.10
110	Public Sector Companies	0.00	0.00	0.00
111	Government Owned Companies	0.03	0.00	0.03
120	Domestic Companies	0.02	0.00	0.02
121	Foreign Companies	7.00	0.00	7.00
122	Foreign Majority Owned Companies	0.01	0.00	0.01
200	Financial and Insurance Institutions	0.01	0.00	0.01
221	Domestic Deposit Taking Banks	0.14	10.24	10.38
222	Foreign Owned Deposit Taking Banks	0.00	9.85	9.85
230	Other Credit Institutions	0.01	0.00	0.01
240	Insurance Institutions	0.21	0.07	0.28
250	Finance and Brokerage Service Institutions	0.66	0.42	1.08
260	Other Financial Institutions	3.67	33.26	36.93
300	Public Sector Authorities	0.00	0.00	0.00
310	The State of Finland	0.00	0.00	0.00
320	Municipalities	0.04	0.00	0.04
340	A Provincial Government	0.02	0.00	0.02
352	Pension and Social Security Funds	0.44	0.00	0.44
410	Strata Companies	0.03	0.00	0.03
420	State Churches	0.02	0.00	0.02
430	Other Non-profit Institutions	0.44	0.00	0.44
511	Farming Households	0.51	0.00	0.51
512	Entrepreneur Households	1.17	0.00	1.17
520	Salary Earning Households	27.96	0.00	27.96
530	Other Households	2.45	0.00	2.45
600	Foreign Residence	0.02	0.00	0.02
610	Resident in European Union	0.05	0.00	0.05
611	Resident in European Union Member State	0.19	0.00	0.19
621	Resident in Other Countries	0.01	0.00	0.01

Table 2

Changes in share holdings and stocks subsequent performance

Table 2 reports the stock picking ability for each of the investor classes in thirty stocks, continuously listed on the Helsinki Stock Exchange, during the period 12 April 1999 to 26 May 2000. The relationship between a percentage change in shareholding and control variables and the stocks' subsequent performance over the next three months is estimated using the following equation utilising GMM procedure

$$R_{i,j} = \beta_1 + \beta_2 \Delta_{k,i,j-i} O + \beta_3 S_i + \beta_4 DY_i + \beta_5 P_i + \beta_6 Tur_i + \beta_7 M1_{i,-1,0} + \beta_8 M6_{i,-6,-1} + \beta_9 Open_{k,i,j} + \beta_{10} Std_i + \beta_{11} Beta_i + \varepsilon$$

Where $R_{i,j}$ = stock *i* performance from day *j-1* to day *j*, $\Delta_{k,i,j-1}O$ = the proportional change in ownership by investor class *k* for stock *i* on day *j-1*, S_i = market capitalization of stock *i*, DY_i = dividend yield of stock *i*,, P_i = price of stock *i*, Tur_i = volume traded in stock *i*, $M1_{i,-1,0}$ = return of stock i for previous month, $M6_{i,-6,-1}$ = return of stock i for month –6 to month –1, $Open_{k,i,j}$ = Opening position for investor class *k* in stock *i* on day *j*, Std_i = standard deviation of returns for stock *i*, $Beta_i$ = beta of stock *i*,, β_i = parameter estimate and ε = error term.

Investor Class	Nominee account	*Intercept*	*ΔO*	*S*	*DY*	*P*	*Tur*	*M1*	*M6*	*Open*	*Std*	*Beta*	R-Square	N
100	0	0.37398	2.97E-06	-0.02102	-0.01673	0.033720	0.00294	-0.10535	0.26913	-0.07307	-0.06765	0.36449	0.1751	1,146
		0.56	1.07	-0.82	-0.68	0.83	0.07	-1.21	2.28 **	-1.27	-0.65	2.41 **		
121	0	0.46846	-0.00001	-0.03191	-0.04541	0.055480	-0.01704	-0.10222	0.15432	-0.00017	-0.03647	0.25975	0.1214	8,162
		2.05 **	-2.02 **	-3.30 ***	-3.82 ***	3.41 ***	-1.26	-1.75 *	3.91 ***	-0.54	-0.80	4.92 ***		
221	0	0.91703	-0.00007	-0.04560	-0.09850	0.069461	-0.00289	-0.15639	0.15438	0.00263	-0.14409	0.25627	0.1716	1,819
		1.76 *	-1.13	-2.71 ***	-3.60 ***	2.12 **	-0.07	-1.83 *	2.29 **	1.57	-1.60	2.31 **		
221	1	0.08843	-0.00802	-0.01244	-0.06441	0.085686	-0.01817	-0.06289	0.13962	0.00057	-0.15401	0.17707	0.1371	5,622
		0.34	-1.23	-1.30	-5.68 ***	4.69 ***	-1.09	-1.06	4.06 ***	2.02 **	-3.18 ***	3.40 ***		
222	1	0.51351	-9.54E-07	-0.03347	-0.04942	0.071931	-0.01187	-0.10309	0.17443	0.00448	-0.07782	0.26879	0.1384	6,079
		1.76 *	-0.12	-2.90 ***	-3.98 ***	3.88 ***	-0.72	-1.64	4.20 ***	0.77	-1.56	3.56 ***		
240	0	0.52232	-0.00755	-0.03365	-0.06032	0.074102	-0.01495	-0.01274	0.26555	0.00357	-0.12474	0.32040	0.1717	2,802
		1.30	-2.22 **	-2.16 **	-2.57 **	3.15 ***	-0.62	-0.14	3.22 ***	3.42 ***	-1.60	3.15 ***		
250	0	0.44616	-7.33E-06	-0.03337	-0.04327	0.087426	-0.01945	-0.07766	0.18860	0.04514	-0.10141	0.31998	0.1652	2,736
		0.97	-0.6	-1.85 *	-1.59	2.71 ***	-0.68	-0.95	2.99 ***	2.43 **	-1.16	2.77 ***		
250	1	0.53789	-2.15E-07	-0.05053	-0.03743	0.063958	-0.04880	0.01073	0.28062	0.02236	0.00145	0.41951	0.1763	2,316
		1.21	-1.00	-3.39 ***	-1.42	2.12 **	-1.45	0.11	3.18 ***	1.18	0.02	4.17 ***		
260	0	0.12483	-6.57E-06	-0.02042	-0.03742	0.071923	-0.02766	-0.06331	0.14300	0.00341	-0.06223	0.24519	0.1342	5,835
		0.40	-0.22	-1.77 **	-2.74 ***	4.04 ***	-1.36	-0.95	3.62 ***	3.14 ***	-1.13	3.75 ***		
260	1	0.39058	1.11E-06	-0.02676	-0.04199	0.053706	-0.01028	-0.07603	0.19745	0.00797	-0.01022	0.22890	0.1225	7,602
		1.69 *	5.18 ***	-2.81 ***	-3.67 ***	3.43 ***	-0.73	-1.28	4.97 ***	2.68 ***	-0.21	4.39 ***		

Table 2 continued

Investor Class	Nominee account	*Intercept*	*ΔO*	*S*	*DY*	*P*	*Tur*	*M1*	*M6*	*Open*	*Std*	*Beta*	R-Square	N
320	0	-0.10620	0.00004	-0.02071	-0.06343	0.083918	-0.05272	-0.14290	0.17715	0.06245	0.03049	0.19872	0.1831	677
		-0.14	0.15	-0.89	-1.73 *	1.39	-0.84	-1.09	1.63	0.43	0.22	1.28		
340	0	0.04422	-0.00023	-0.00941	-0.08781	0.082126	-0.00964	-0.08924	0.36276	0.28003	-0.05174	0.13599	0.1885	494
		0.04	-1.38	-0.40	-2.39 **	1.39	-0.08	-0.50	1.93 *	1.79 *	-0.23	0.77		
352	0	0.09760	0.00024	-0.02708	-0.04676	0.056722	-0.04732	-0.10882	0.21719	0.00225	0.03033	0.24480	0.1574	3,353
		0.26	1.12	-2.20 **	-2.46 **	2.33 **	-1.61	-1.22	3.24 ***	1.96 *	0.37	3.41 ***		
430	0	0.33825	0.00101	-0.02590	-0.04553	0.064254	-0.01530	-0.09996	0.16802	0.00588	-0.08112	0.26896	0.1459	3,851
		0.94	0.44	-2.03 **	-2.60 ***	2.98 ***	-0.63	-1.43	3.30 ***	1.88	-1.23	3.60 ***		
511	0	0.77798	0.00037	-0.04032	-0.06657	0.083347	-0.00137	-0.13315	0.15644	0.01580	-0.22057	0.35139	0.1598	3,131
		1.77 *	1.67 *	-2.78 ***	-2.60 ***	2.56 **	-0.04	-1.90 *	3.36 ***	0.39	-2.34 **	3.53 ***		
512	0	0.53615	0.00898	-0.03188	-0.05139	0.066753	-0.00938	-0.13584	0.15685	0.00111	-0.12579	0.29305	0.1376	5,355
		1.76 *	1.49	-2.95 ***	-2.99 ***	3.07 ***	-0.46	-2.23 **	3.70 ***	0.09	-2.06 **	4.19 ***		
520	0	0.29101	-0.01867	-0.02386	-0.03578	0.056242	-0.01657	-0.08391	0.15234	0.00062	-0.03953	0.24988	0.1290	8,586
		1.31	-1.71 *	-2.42 **	-3.06 ***	3.96 ***	-1.29	-1.44	4.03 ***	2.23 **	-0.90	4.81 ***		
530	0	0.55274	0.00252	-0.03240	-0.04606	0.065367	-0.00517	-0.10689	0.15886	0.01031	-0.11308	0.30941	0.1400	7,360
		2.35 **	0.12	-3.33 ***	-3.42 ***	4.11 ***	-0.36	-1.81 *	4.11 ***	2.48 **	-2.49 **	5.28 ***		
610	0	-0.27246	-0.00003	-0.02634	0.02667	0.057951	-0.08016	-0.14789	0.26817	0.43340	0.05981	0.39664	0.1171	527
		-0.33	-0.38	-0.99	0.43	1.15	-1.22	-1.08	2.40 **	0.57	0.35	1.84 *		
611	0	0.59505	0.00080	-0.03795	-0.04111	0.090294	-0.00721	-0.22324	0.16576	0.00383	-0.12386	0.33227	0.1496	2,440
		1.08	2.06 **	-2.13 **	-1.48	2.94 ***	-0.17	-2.75 ***	3.33 ***	0.99	-1.12	2.81 ***		

* significant at the 10% level
** significant at the 5% level
*** significant at the 1% level

Table 3

Descriptive Statistics

Table 3 reports descriptive statistics for the thirty companies analysed over the period 12 April 1999 to 26 May 2000. The descriptive statistics reports non-standardized values of the 14 half-hour time intervals during the trading day (except price).

Variable	Mean	Median	Std Dev	Minimum	Maximum
Price (€)	26.28	15.10	29.19	2.10	239.22
Market Capitalization (€ millions)	7,780	779	31,786	39	303,787
Relative Spread %	1.08	0.73	1.18	0	63.41
Volume	12,621	1000	44,455	0	3,229,023
Number of Trades	9.95	2.00	27.68	0	1,222
Price Standard Deviation	0.0584	0.0191	0.1970	0	38.2063

Table 4

Intraday variations in relative spreads, volatility and trading activity

Table 4 reports variations of standardized relative spreads, standard deviation of returns, volume and number of trades for 30 companies listed on HEX over the period 12 April 1999 to 26 May 2000. The trading day is divided into 14 half-hour time periods. Each variable is calculated in each half-hourly interval and standardized by subtracting the mean (for the day) from the raw value and dividing by the standard deviation (for the day). The standardized variable is regressed against time-of-day dummy variables, with time period 13:30-14:00 being the reference period. The following equation is estimated using GMM.

$$W_t = w + \sum_{i=2}^{n} d_i \beta_i + \varepsilon$$

Where W_t = the value of the variable being studied in time period t, w = the fixed effect, which will represent the variable base amount which is the 13:30-14:00 half hour period. d_i = a dummy variable that reflects the time-of-day, which takes on the value of one if the time-of-day observation t is equal to i and zero otherwise. β_i = the estimated intraday coefficient for time periods other than the fixed effect time period and ε = an error term.

	Relative Spread		Price Standard Deviation		Volume		Number of Trades	
Parameter	Estimate	t-Statistic	Estimate	t-Statistic	Estimate	t-Statistic	Estimate	t-Statistic
10.30-11.00	1.16413	62.10***	1.14277	62.05***	0.25658	15.14***	0.82298	43.02***
11.00-11.30	0.56788	34.05***	0.44052	26.12***	0.06917	4.39***	0.16637	10.40***
11.30-12.00	0.31433	20.07***	0.20689	13.02***	0.01188	0.77	0.07283	4.70***
12.00-12.30	0.15409	10.22***	0.11534	7.51***	-0.00755	-0.49	0.00621	0.41
12.30-13.00	0.08035	5.74***	0.03888	2.63***	-0.02361	-1.56	-0.00726	-0.48
13.00-13.30	0.04086	3.48***	-0.00054	-0.04	-0.00893	-0.59	-0.02761	-1.87*
13:30-14:00 (Intercept)	-0.15004	-15.21***	-0.17333	-17.04***	-0.11414	-10.70***	-0.14872	-14.12***
14.00-14.30	-0.01256	-1.06	-0.03504	-2.50***	0.02626	1.71*	0.01187	0.79
14.30-15.00	-0.03070	-2.20***	-0.02587	-1.81*	0.03436	2.19***	0.01641	1.08
15.00-15.30	-0.07860	-5.47***	-0.04869	-3.41***	0.02424	1.55	-0.01854	-1.23
15.30-16.00	-0.03812	-2.54***	0.01040	0.70	0.12450	7.61***	0.09730	6.23***
16.00-16.30	-0.07298	-4.83***	0.00985	0.67	0.13054	7.97***	0.08708	5.63***
16.30-17.00	-0.00558	-0.35	0.17684	11.26***	0.29207	16.74***	0.22641	13.73***
17.00-17.30	-0.00158	-0.10	0.36279	22.40***	0.64093	33.83***	0.59055	32.74***
R-Square	0.120		0.104		0.034		0.066	
N	95,828		95,732		94,405		94,405	

* significant at the 10% level
** significant at the 5% level
*** significant at the 1% level

Table 5

Intraday variations in the proportion of informed traders

Table 5 reports the intraday variations in the proportion of informed traders. The trading day, during the period 12 April 1999 to 26 May 2000, is divided into 14 half-hour trading intervals. The proportion of informed traders is calculated by summing the number of trades initiated by informed traders for each half-hour period and then dividing by the total number of trades initiated by all traders. The proportion of informed traders is regressed against time-of-day dummy variables, with time period 13:30-14:00 being the reference period. The following equation is estimated using GMM.

$$W_t = w + \sum_{i=2}^{n} d_i \beta_i + \varepsilon$$

Where W_t = the proportion of informed traders in time period t, w = the fixed effect, which will represent the proportion of informed traders base amount which is the 13:30-14:00 half hour time period, d_i = a dummy variable that reflects the time-of-day, which takes on the value of one if the time-of-day observation t is equal to i and zero otherwise. β_i = the estimated intraday coefficient for time periods other than the fixed effect time period and ε = an error term.

Parameter	Estimate	t-statistic
10.30-11.00	-0.03170	-5.91***
11.00-11.30	-0.00824	-1.46
11.30-12.00	-0.00732	-1.31
12.00-12.30	0.01332	2.35**
12.30-13.00	0.00615	1.11
13.00-13.30	0.01243	2.27**
13:30-14:00 (Intercept)	0.24100	48.57***
14.00-14.30	-0.01470	-2.85***
14.30-15.00	-0.00316	-0.58
15.00-15.30	0.01249	2.17**
15.30-16.00	0.00704	1.26
16.00-16.30	0.02486	4.28***
16.30-17.00	0.03348	5.72***
17.00-17.30	0.06553	11.37***
R-Square	0.0049	
N	72,047	

* significant at the 10% level
** significant at the 5% level
*** significant at the 1% level

Table 6

Intraday variations in the proportion of trading and trade size by informed and liquidity traders

Table 6 reports intraday variations in the proportion of trading and trade size by informed and liquidity traders. The trading day, during the period 12 April 1999 to 26 May 2000, is divided into 14 half-hour trading intervals. Panel A reports variations in the proportion of trading by informed or liquidity traders through the day. The total number of trades for informed (liquidity) traders is calculated for each half-hour period in stock *i*. The number of trades for each half hour period for informed (liquidity) is divided by the total number of trades by informed (liquidity) traders for the day in stock *i*. Each variable is regressed against time-of-day dummy variables, with time period 13:30-14:00 being the reference period. Panel B reports variations in trade size. The average trade size for informed (liquidity) traders is calculated for each half hour in stock *i*. The trade size is standardized by dividing trade size for informed (liquidity) traders by the average trade size for informed (liquidity) traders for the day in stock *i*. The following equation is estimated using GMM

$$W_t = w + \sum_{i=2}^{n} d_i \beta_i + \varepsilon$$

Where W_t = the variable being studied in time period *t*, w = the fixed effect, which will represent the variable base amount which is the 13:30-14:00 half-hour time period. d_i = a dummy variable that reflects the time-of-day, which takes on the value of one if the time-of-day observation *t* is equal to *i* and zero otherwise. β_i = the estimated intraday coefficient for time periods other than the fixed effect time period and ε = an error term.

	Panel A					
	Informed Traders			Liquidity Traders		
Parameter	Estimate	t-statistic		Estimate	t-statistic	
10.30-11.00	0.06521	17.66	***	0.07416	30.04	***
11.00-11.30	0.01600	5.12	***	0.01008	5.06	***
11.30-12.00	0.00880	2.93	**	0.00122	0.64	
12.00-12.30	0.00661	2.26	**	-0.00328	-1.70	*
12.30-13.00	0.00390	1.35		-0.00291	-1.48	
13.00-13.30	0.00440	1.49		-0.00550	-2.90	***
13:30-14:00 (Intercept)	0.06532	33.31	***	0.07695	56.26	***
14.00-14.30	0.00030	0.10		0.00336	1.68	*
14.30-15.00	0.00290	1.02		0.00270	1.32	
15.00-15.30	0.00332	1.16		-0.00311	-1.59	
15.30-16.00	0.01146	3.85	***	0.00674	3.26	***
16.00-16.30	0.01813	5.84	***	0.00281	1.43	
16.30-17.00	0.02832	9.24	***	0.00972	4.84	***
17.00-17.30	0.08606	23.35	***	0.03218	14.93	***
R-Square	0.0229			0.0288		
N	72,248			93,872		

	Panel B					
	Informed Traders			Liquidity Traders		
Parameter	Estimate	t-statistic		Estimate	t-statistic	
10.30-11.00	-0.11102	-9.34	***	-0.13527	-11.99	***
11.00-11.30	-0.04249	-3.26	***	-0.00930	-0.73	
11.30-12.00	-0.03600	-2.74	***	-0.01317	-1.03	
12.00-12.30	-0.00205	-0.15		-0.01602	-1.26	
12.30-13.00	-0.00181	-0.13		-0.00376	-0.29	
13.00-13.30	0.00425	0.31		0.01465	1.13	
13:30-14:00 (Intercept)	-0.01036	-1.11		0.00255	0.28	
14.00-14.30	-0.02345	-1.84	*	0.02727	2.17	**
14.30-15.00	-0.00961	-0.73		0.03902	2.93	***
15.00-15.30	0.02164	1.61		0.02946	2.22	**
15.30-16.00	0.02248	1.64		0.04223	3.18	***
16.00-16.30	0.04760	3.40	***	0.04688	3.45	***
16.30-17.00	0.07204	5.24	***	0.07539	5.60	***
17.00-17.30	0.13898	10.08	***	0.07485	5.79	***
R-Square	0.0087			0.0064		
N	61,256			72,189		

* significant at the 10% level
** significant at the 5% level
*** significant at the 1% level

Table 7

Extent to which time of day, volume, standard deviation of returns and the proportion of informed traders influence spreads

Table 7 reports the extent to which time of day, volume, standard deviation of returns and the proportion of informed traders influence spreads. The trading day, during the period 12 April 1999 to 26 May 2000, is divided into 14 half-hour trading intervals. Relative spread, volume of shares traded, standard deviation of returns and the proportion of informed traders are calculated for each half-hour interval. Relative spread, volume of shares traded, standard deviation of returns is standardized by subtracting the mean (for the day) from the raw values and dividing by the standard deviation (for the day). The standardized relative spread is regressed against time-of-day volume, standard deviation of returns and the proportion of informed traders, with 13:30-14:00 being the reference period. The following equation is estimated using GMM.

$$S_t = s + \sum_{i=2}^{n} d_i \beta_i + \sum_{t=1}^{n} W_t \gamma_i + \varepsilon$$

Where S_t = the spread during time period t, d_i is a dummy variable that reflects the time of day, which takes on the value of one if the time-of-day observation t is equal to i and zero otherwise, s is a fixed effect, W_t other variables e.g. trading activity, volatility, and the proportion of informed traders, β_i = the estimated intraday coefficient for time periods other than the fixed effect time period γ_i = the parameter estimate for other variables and ε = an error term.

Parameter	Estimate	t-statistic
10.30-11.00	0.80825	40.84***
11.00-11.30	0.40203	22.16***
11.30-12.00	0.22414	13.07***
12.00-12.30	0.09997	5.93***
12.30-13.00	0.05844	3.63***
13.00-13.30	0.03738	2.58***
13:30-14:00 (Constant)	-0.16842	-15.11***
14.00-14.30	0.01334	0.92
14.30-15.00	-0.01031	-0.64
15.00-15.30	-0.06415	-3.99***
15.30-16.00	-0.00361	-0.22
16.00-16.30	-0.04004	-2.44**
16.30-17.00	0.00336	0.20
17.00-17.30	-0.05734	-3.40***
Volume	-0.05161	-14.66***
Price Standard Deviation	0.30957	67.81***
Proportion of informed (Number of Trades)	0.04435	4.82***
R-Square	0.2056	
N	72,018	

* significant at the 10% level
** significant at the 5% level
*** significant at the 1% level

Figure 1

Intraday variations in relative spreads, volatility and trading activity

Figure 1 reports intraday variations in standardized relative spreads, volatility and trading activity. The trading day is divided into 14 half-hourly intervals and the variables are calculated for each half-hourly interval between 12 April 1999 and 26 May 2000. Each variable is standardized by subtracting the mean (for the day) from the raw value and dividing by the standard deviation (for the day). The standardized variable is regressed against time-of-day dummy variables, with time period 13:30-14:00 being the reference period. The values plotted are calculated by adding the co-efficient estimated for each time period to the reference period i.e. 13:30-14:00.

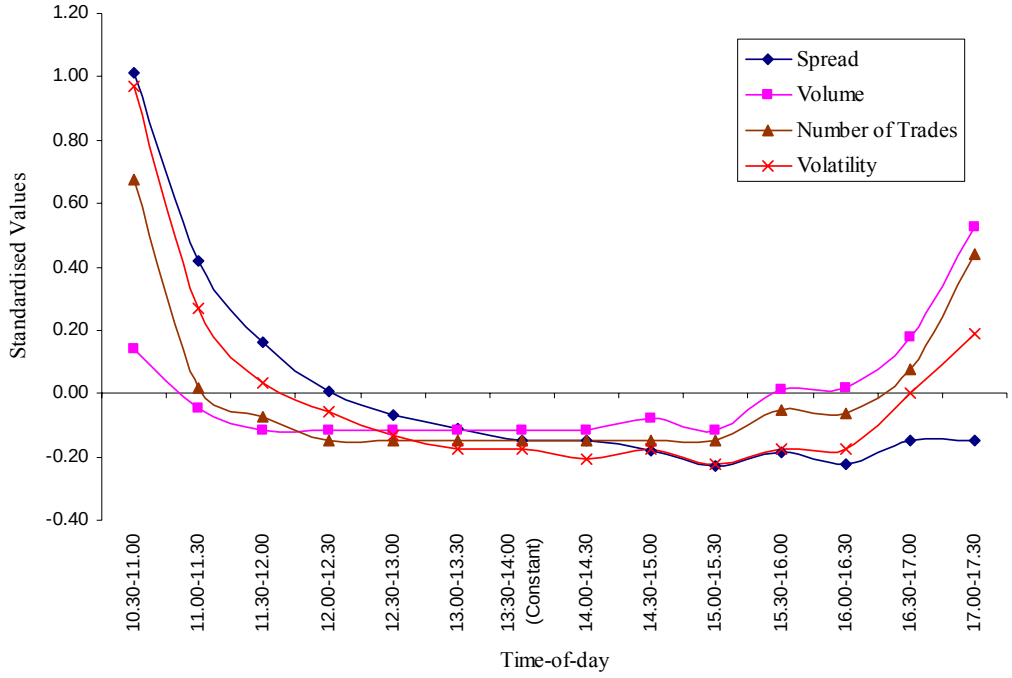


Figure 2

Intraday variations in the proportion of informed traders

Figure 2 reports the intraday variations in the proportion of informed traders. The trading day, during 12 April 1999 to 26 May 2000, is divided into 14 half-hour intervals. The proportion of informed traders is calculated by summing the number of trades initiated by informed traders for each half-hour period and then dividing by the total number of trades initiated by all traders. The proportion of informed traders is regressed against time-of-day dummy variables, with time period 13:30-14:00 being the reference period. The values plotted are calculated by adding the co-efficient estimated for each time period to the reference period i.e. 13:30-14:00.

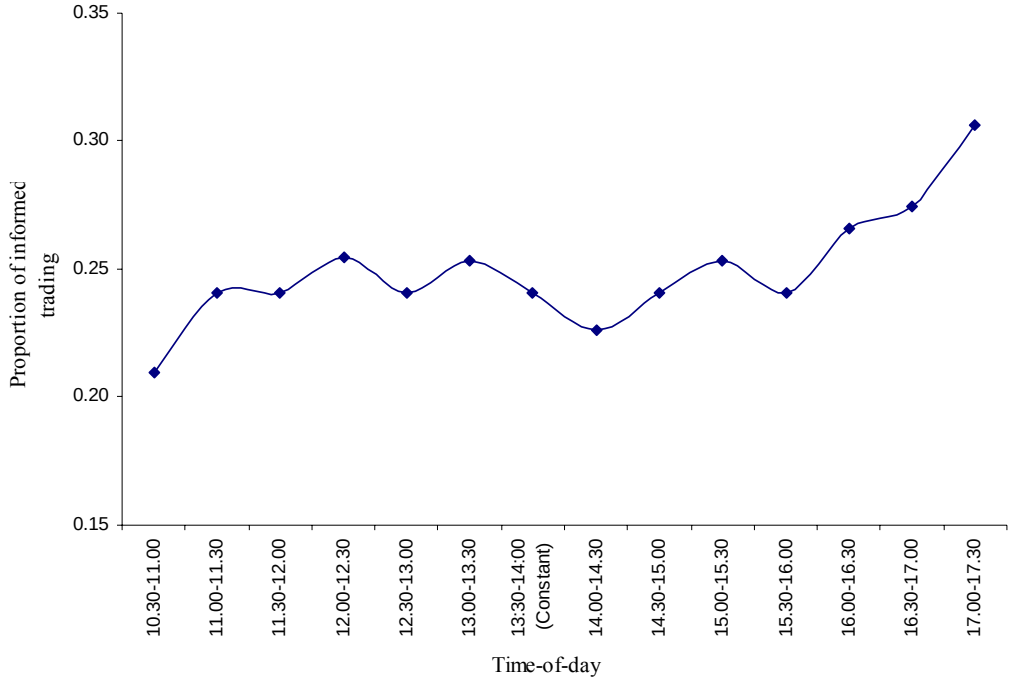
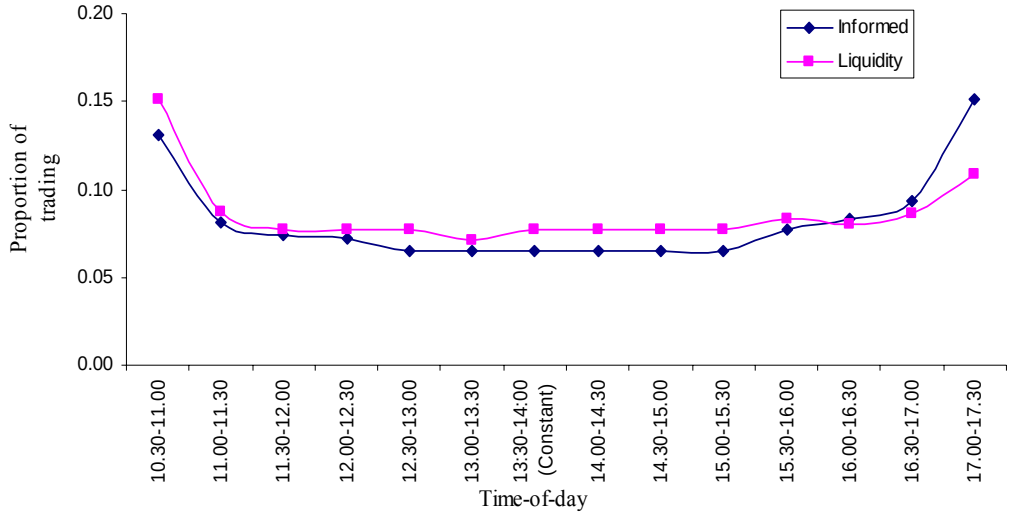


Figure 3

Intraday variations in the proportion of trading and trade size by informed and liquidity traders

Figure 3 reports the intraday variations in the proportion of trading and trade size by informed an liquidity traders. The trading day, during the period 12 April 1999 to 26 May 2000, is divided into 14 half-hour trading intervals. Panel A plots variations in the proportion of trading by informed or liquidity traders through the day. The total number of trades for informed (liquidity) traders is calculated for each half-hour period in stock *i*. The number of trades for each half hour period for informed (liquidity) is divided by the total number of trades by informed (liquidity) traders for the day in stock *i*. Each variable is regressed against time-of-day dummy variables, with time period 13:30-14:00 being the reference period. Panel B reports variations in trade size. The average trade size for informed (liquidity) traders is calculated for each half hour in stock *i*. The trade size is standardized by dividing trade size for informed (liquidity) traders by the average trade size for informed (liquidity) traders for the day in stock *i*. Each variable is regressed against time-of-day dummy variables, with time period 13:30-14:00 being the reference period. The values plotted are calculated by adding the co-efficient estimated for each time period to the reference period i.e. 13:30-14:00.

Panel A: Timing of trading of informed and liquidity traders



Panel B: Trade size for informed and liquidity traders