Search costs and investor trading activity: evidences from limit order book

Lin, William and Tsai, Shih-Chuan and Sun, David

Kai Nan University

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William T. Lin
Tamkang University

Shih-Chuan Tsai[a]
National Taiwan Normal University

David S. Sun[b]
Kai Nan University

Abstract

We analyze in this study investor trading behavior based not on information related assumptions but on the search model of Vayanos and Wang (2007). Our study shows that search cost dictates trading polarization across investors, firm size and time of day. We find that individual investors prefer to trade at market open, while institutional investors trade more heavily near market close. Trading costs indicate that it is less costly for institutional investors to trade large cap stocks at market close than at open. Search cost is related significantly to order-based market liquidity measures depending on time of day, market capitalizations and investor type.

Keywords: Liquidity, search model, limit order book, market depth, execution cost
JEL codes: C14, D82, D83, G12, L11

[a] Address correspondences to: Shih-Chuan Tsai, National Taiwan Normal University, or e-mail: Tsai16888@gmail.com
[b] Address correspondences to: David Sun, Kai Nan University, Taoyuan, Taiwan, or davidsun0769@gmail.com

I. Introduction

Trading liquidity of investors has been studied more in literature as the popularity of order-driven trading mechanism rises. While a poorer liquidity measure, such as higher bid-ask spread, is considered a result of less active trading, Foucault, Moinas, and Theissen (2007) argued that limit order book provides information on future volatility in the market. A leading theory of liquidity is based on asymmetric information. Many studies, including Glosten and Milgrom (1985), suggest that wider bid-ask spread in a specialist market is often used to compensate against information disadvantage. Information argument, however, does not apply in many situations, such as in an emerging market, where individual investors are the majority, trading preference in timing and stock characteristics is closely related to investor type. Individual investors prefer to trade small cap stocks not because of its poor informational content or low transparency in corporate governance, but due to their lower price and hence smaller amount of funds needed to trade a given quantity. We show in this study that individual investors prefer to trade relatively small cap stocks right after market opens, while foreign institutional investor (FII) and domestic institutional investor (DII) tend to trade large cap stocks more heavily near market close, for reasons unrelated to information.

Vayanos and Wang (2007, VW) introduced a search-based model of asset trading, where search or trading cost differs and investors are constrained financially. In a search-based equilibrium of VW, liquidity in a specific market, measured by search costs, can be the result of investor characteristics, regulations and local custom, rather than information or diversification. In such an equilibrium, buyers anticipating to find a matching seller easily are willing to pay a higher price than in an otherwise situation. Sellers, while knowing this, would submit orders with more dispersed offer prices, as a form of economic rent, on the limit book. Order-based liquidity measure such as offer price dispersion, limit book depth and bid-offer difference can thus be considered as reflecting the economic rent.

We attempt to analyze in this study investor trading behavior in a stock market without relying on any information related presumptions. Specifically, we analyze in the study how different types of investor choose when to trade in any given trading day, and provide explanations to it based on a search model of trading according to VW. Our study shows that comparative advantage in search cost dictates a polarization of trading activity across investors, firm size and time of day. We find that, in the Taiwan stock market, individual investors prefer to trade right after market opens, but foreign and domestic institutional investors trade more heavily near market close. From the perspective of search equilibrium, search cost is related significantly to order-based market liquidity measures depending on time of day, market capitalizations and investor type. The results is a compromise between how easy it is to locate a counterparty and how much execution cost an investor is willing to accept given the distribution of order book at certain juncture.

We study intraday trading behavior involving search cots across individuals, foreign and domestic institutions. Our empirical results suggest that search cost is low during market opening period and goes down afterward. Individuals' search cost is low especially in trading small cap stocks at market open, while search cost for foreign and domestic institutions is relatively low in trading large cap stocks near market close. Yang and Zhang (2007) showed how marginal institutional investors engage in short-term trading due to cost factors compared to other institutional investor going after long-term values of stocks. The short horizon of a marginal FII may have induced them to concentrate in trading stocks with the said characteristics.

The main implication of our results would help, on the one hand, investors in general to locate at any given period the most cost-efficient market to trade, which lowers average trading cost and enhance market trading volume[1]. On the other hand, our analysis contributes to regulators as well as exchanges if certain extreme search environment entails ramification or any other actions. Unnecessary market alarms could be greatly reduced and market efficiency is thus improved. A brief literature review and discussion of how to measure search cost, as well as order-based liquidity, are given in Section II. Data and empirical results are laid out in Section III. Conclusion is given in Section IV.

II. How does search activity affect trading?

The competitive equilibrium of informed trading introduced by Back, Cao and Willard (2000) suggests that heavy trading occurs when informed traders compete in aggressive trading with correlated information when market opens, where more market depth is observed than the rest of the session. As market approaches its close, trading becomes heavy again as informed traders aggressively exploit their remaining private information. This model explains in part intraday trading patterns, as well as trading concentration. Hu (2006) suggests that an information-only argument is more applicable in quote-driven markets where trade initiation reflects nature of information. In an order-driven market, dynamic frictional costs, in the sense of Stoll (2000), have to be taken into account. Hu (2006) find that frictional costs are the smallest at market open, consistent with our findings on the polarization of trading activity.

In emerging financial markets, turnover and market volume are often generated by individual investors. Trading of individuals is worth studying in these markets as it interacts much with institutional investors, as suggested in Barber, Odean and Zhu (2009), and Dorn, Huberman and Sengmueller (2008). Ahmed, Rosser and Uppal (2010) also reported that there are excessive rapid price movements in emerging stock markets. Zhou, Geppert and Kong (2010) concluded that trading strategies contributed to profits in the China market. Ting (2009) indicated that, within a given period, foreign institutional in Taiwan tend to follow those with a higher turnover rate.

Diamond (1982) first studied search models first in labor economics. Duffie, Gˆarleanu, and Pedersen (2002) use a search-based model to study its impact on asset prices and securities lending Vayanos and Wang (2007) extended it into a risk-neutral framework. Duffie, Gˆarleanu, and Pedersen (2005) show that search frictions have different implications for bid-ask spreads than do information frictions. Vayanos and Weill (2008) presented a search model, extending the argument of VW we refer in this study, studying different prices for on-the-run and off-the-run US treasury securities.

Search Model of Trading

VW proposed a model with two assets traded in two markets respectively. More trading could be generated by shorter horizons as it reduces search times and trading costs. Switching rates could correspond to buyers' characteristics, such as long horizon is more relevant to insurance companies, while shorter ones belong to hedge funds. A clientele equilibrium is where one market not only has more sellers, but also more buyers as well as a higher buyer-seller ratio than the other. Moreover, the price in the more active market is thus higher and buyers' search times are shorter. Investors with high switching rates, who have a stronger preference for short search times, prefer the more active market despite the higher prices. On the other hand, low-switching-rate investors, who are more patient, value more the lower prices in the less active market. So in essence, cost characteristics of investors determine concentration of trading and prices, rather than information about the assets. Individual investors trading for own accounts with unleveraged funds are supposed to have lower switching rates and prefers a less active market. However, when market moves fast, lack of knowledge could elevate their switching rates so they turn to the other market instead.

Although FII's hold about one third of the total values of Taiwanese stocks, their overall turnover rate is in general at around 10% monthly only. The positive relation between holdings and turnover within given periods presented by Ting (2009) suggest that marginal FII's are incurring risk-adjusted cost situation as discussed in Chan, Menkveld and Yang (2007). These marginal FII's are under shorter horizons due to liquidity reasons related to allocating funds across borders.

A measure of order dispersion

Two forms of liquidity measures will be used in this study. Both of them are based on order prices submitted to the market. Limit order book dispersion describes the *tightness* of the book by examining how far apart from each other (or from the mid-quote) the limit orders are placed in the book. Foucault, Kadam, and Kandel (2005) suggest that the limit order book dispersion is linked with the patience of limit order traders. We adopt the following measure by modifying the dispersion measure of Kang and Yeo (2008). The dispersion measure of stock *i* in a given day is defined as

$$OPD_i = \frac{1}{2 \times Tick_i} \left[\frac{\sum_{j=1}^{n} w_{ij}^{B} D_{ij}^{B}}{\sum_{j=1}^{n} w_{ij}^{B}} + \frac{\sum_{j=1}^{n} w_{ij}^{S} D_{ij}^{S}}{\sum_{j=1}^{n} w_{ij}^{s}} \right] \tag{1}$$

where $Tick_i$ is the tick size of the respective stock. D_j^b is the price interval between the *jth* best buy order price and its next better order price, and similarly D_j^s is that for the sell order price. The buy and sell price intervals, up to the fifth best limit orders are weighted by w_j^b and w_j^s, the size of the corresponding buy or sell limit orders. For the whole market, transaction prices are used to compute the first price interval, while for each type of investors, average of buy and sell order price at each priority level is used instead. This dispersion measure is designed to show how clustered or dispersed the limit orders are in the book. It measures how tightly orders are placed to each other or how closely they are to the mid-quote. The higher the dispersion is, the less tight the book is, and the lower amount of liquidity the limit order book provides.

In the Taiwan market, due to funding liquidity, individual investors tend to hold and trade stocks with lower prices, while institutional investors concentrate more on high price stocks. Therefore, D_j^b and D_j^s in (1) are computed using the raw price distance divided by tick size of the stock, so that only the relative price distance is used, allowing Dsp_i to be comparable across stocks and various types of investors.

A measure of order book depth

Bloomfield, O'Hara, and Saar (2005) argue that informed traders would submit more limit orders than market orders in an electronic market. McKenzie (2007) argued that in the emerging markets especially the ability to forecast future price movements is related to the depth of those markets. Therefore, beside the tightness measure, limit order book helps examining how well the book handles large volume of market orders. A deep limit order book can absorb a sudden surge in the demand of liquidity without inducing much price deviation. Without the interference of the specialist and before new limit orders can replenish the book, market buy (sell) orders will first be executed against the limit sell (buy) orders at the best offer (bid) quote. If the volume of the market order(s) is larger than the best offer (bid) size, the remainder of the unexecuted market orders will be executed against the limit orders queuing at the next best offer (bid) quote. In other words, large volume of market buy (sell) orders will walk up (down) the limit order book to get filled. The further away the market orders walk up or down the book, the larger the difference between the execution price and the mid-quote is, and therefore the more costly the trading process will be for the market order traders. Motivated by the mechanism described above, we design the cost-to-trade measure, which can be thought of as an enhanced depth measure for the limit order book.

$$CTT_i = \frac{\sum_{k=1}^{K} I_k^B (MQ_i - P_k^B) + \sum_{k=1}^{K} I_k^S (P_k^S - MQ_i)}{TNS_i \times MQ_i}, \tag{2}$$

where i=1,2,…,525. MQ_i is the midpoint of the nearest buy and sell quote prices, TNS_i is the total number of shares traded within the time interval of interest, P_k^B is the best bid price, P_k^S is the best offer price and,

$$I_k^B = \begin{cases} Q_j^B & if \quad TNS > \sum_{j=1}^{k} Q_j^B \\ (TNS - \sum_{j=1}^{k} Q_j^B) & if \quad TNS > \sum_{j=1}^{k-1} Q_j^B \quad and \quad TNS < \sum_{j=1}^{k} Q_j^B \\ 0 \quad otherwise & \end{cases}$$

$$I_k^S = \begin{cases} Q_j^S & if \quad TNS > \sum_{j=1}^{k} Q_j^S \\ (TNS - \sum_{j=1}^{k} Q_j^S) & if \quad TNS > \sum_{j=1}^{k-1} Q_j^S \quad and \quad TNS < \sum_{j=1}^{k} Q_j^S \\ 0 \quad otherwise & \end{cases}$$

III. Data and empirical results

This study employs intra-day order book data from the Taiwan Stock Exchange starting from March 1st, 2005 to December 31st, 2006, covering stocks of 525 firms over a period of 461 trading days. Excluded from the complete pool of stocks listed on the exchange are those with irregularities and unusual exchange sanctions. As of today, the order matching system in the Taiwan Stock Exchange does not allow market order, so the limit order book covers the entire body of orders submitted by all investors. Each data record includes date, exact time in hours, minutes and seconds, stock code, price and quantity of all orders, filled or not, submitted during the data period. Individual stock returns, market capitalizations, daily turnover and price-book ratios are obtained from the Taiwan Economic Journal (TEJ) database.

We divided each daily session, between 9:00 AM and 1:30 PM, into 9 intervals with 30 minutes in each interval. This is because trading volume varies much across the day. Gunduz and Hatemi-J (2005) also suggested that, price and volume relation is important in emerging markets. As our data contains flags identifying each investor as either an individual, an FII or a DII, we are able to extend our analysis according to investor type. Over the last ten years, percentage of trades accounted for by FIIl has apparently grown much faster than the DII. As a matter of fact, FII'S owns one third of the total market capitalization and account for one quarter of daily volume as of end of 2008 in Taiwan. Table I reports the distribution of number of investors in each investor category across a typical trading day. There are more individuals and DII's choosing to trade in the opening interval than in the rest of the day, while the closing interval is when the greatest number of FII's appears. Table I also gives total number of orders submitted by the three types of investors for stocks of 525 firms averaged over the entire data period of 495 days. As the number of individuals is overwhelming, their orders are almost 10 times those of FII'S. On average, more than 22% of the individual orders are submitted during the first half hour of a regular four and half hour daily trading session, while only around 13% of orders from the other two types are placed in this period. In the last half hour period, numbers of orders as daily percentage are about the same. Trading in other periods is usually slower than open and close. Based on the distribution of orders submitted, FII's appear more inclined to trade right before market close, while individuals and DII's prefer to trade at market open.

To further compare how investors choose a time to trade, we examine in Table II the average number of shares in each buy or sell order, for the entire session as well as the opening and the closing intervals. Although these two intervals are where we see the heaviest trading in any given day, the order size submitted by the market as a whole is larger right before market closes. Out of the three types of investors, FII is the only one submitting more heavily at market close, with order size averaging almost three times that in the opening period. However, the overwhelming number of individual investors placing orders in the opening interval generates 51% more individual's orders than in the closing interval, as seen in Table I.

In order to identify where the heavier orders are allocated, we show in Table III the transaction volume of FII and DII across market capitalizations, as well as percentages of their holdings in the respective category of shares. In the category of shares with the lowest market cap, the market as a whole trades on average 6.63 thousand shares in any given stock and any day. But for shares in the largest market cap category, the average market trading volume is more than 7 times as much. FII's, when they do trade, trade about 5.5 times that of market average in stocks with the smallest cap and 135 times as much in stocks of the largest firms. DII's also trade much more actively than market average, but not as much as FII's. This difference is consistent with results in Table II as well as institutional holdings of outstanding shares of stocks in each capitalization category. FII's trade extremely heavily on large cap stocks because they hold a substantial percentage of them. Despite the average order size is extremely large, the average trading volume for large cap stocks is still high, reflecting possible ease in finding counterparty.

The model of VW provides a framework where search costs dictate market equilibrium and how active trading takes place there. Investors with shorter investment horizon would more likely choose to trade when more buyers and sellers are around, which leads to shorter search time. Equilibrium price should be higher than otherwise as buyer-seller ratio is also high there. Table IV gives summary statistics of measures consistent with the VW model. We consider *BFT* and *SFT* as proxies for search time of buy and sell orders respectively. The former is the average number of seconds it takes to fill a certain buy order within the period of interest, while the latter is that to fill a sell order. The distribution of *BFT* and *SFT* across the day indicates that search time at market open is the shortest during among all intervals, while search time is the longest when market is about to close. The sharp increase in search time across the day is not proportional to the number of active investors in each intraday interval as reported in Table I. Although search time decreases when firm size goes up, across the firm size quintile, buy order search time for small cap stocks still enjoys the greatest edge of 1 to 15.8 at market open against market close. For the largest cap, the edge reduces to only 7.3.

Within the similar time-size block across time of day and firm size, *BOC* and *SOC*, the average numbers of buy and sell orders for any given stock submitted to the market, falls generally from market open to close. From the perspective of search equilibrium of VW, this suggests that search time is shorter at market open because there are more buyers and sellers at that time. However, the sharp rebound of *BOC* and *SOC* right before market closes only lowers *BFT* and *SFT* slightly. Buy order for the smallest cap concentrates disproportionally at market open with an average of 13 times that at market close. For the largest cap, buy and sell orders reach their maximums at market close, rebounding from the immediate preceding interval by 45% and 61% respectively. Although *BOC* is greater than *SOC*, as market regularity, their ratio, *BSR*, also falls from open to close, consistent with the intraday distribution of search time in the sense of search equilibrium.

BSD, defined as the difference between the best bid and offer price averaged across all incidences with a realized transaction price, over the intraday interval of interest. In a quote-driven market, this is equivalent to bid-ask spread quoted by a dealer. However, the intraday distribution of *BSD* is inconsistent with our natural expectation of bid-ask spread. In Table IV, *BSD* at market open, when trading is the heaviest, appears to be the highest than the rest of the day, and there is also a rebound right before market close. The correlation between *BSD* and market trading volume for the entire data period is, however, -0.24, conforming to common regularity. It is worth special attention that, for the smallest firms, the offer price difference is substantially higher than that for firms with large size in all intervals except in the opening one. Also, for the largest firms, *BSD* is significantly high at market open than in the rest of the day. Except for the two situations above, offer price difference generally falls from open to close and from low cap to high cap. *BSD* for the largest firms at market close enjoy nearly a global minimum across the time-size block, while only a local minimum is present for the smallest firms at market open. To the extent that *BSD* constitutes part of cost to order execution, its polarization within the time-size block in Table IV suggests that it is much less costly to trade stocks of the smallest firms at market open as well as stocks of the largest firms at market close.

The unique polarized pattern of trades, at the upper left and lower right corners of the time-size block, in Table IV can be further clarified if we examine the block across major investor groups using more sophisticated measures constructed from the limit order book for the data period of the study. Table V reports the distribution of composite order price dispersion measure, *OPD*, using the same time-size blocks as in Table IV. As the computed value of measure is affected in practice by the arrival rate of orders within a given time, figures in the table is modified to reflect the percentage each cell in the block is above or below corresponding daily averages. Order price dispersion reported here follows a pattern opposite to that of search time in Table IV. *OPD* generally falls from open to close, but the difference between open and close decreases with firm size, similar to the case of search time. Taking investor type into consideration, we are able to see more prominent northwest-southeast block polarization, with *OPD* being polarized the most for individuals and the least for FII's. In fact, order price dispersion goes up with firm size on orders submitted by FII's and DII's, contrary to the direction for individuals. Based on the summary statistics about trading activity given in Table I, the block distribution by investor type in Table IV suggests that, across time of day, order price dispersion benefits trading. But in the category of individuals, it benefits more when trading stocks of the smaller firms, while for institutional investors higher dispersion benefits trading stocks of larger firms. This kind of clientele distribution of trading activity is not compatible with information-based explanation, especially why order price dispersion is higher, at market open, when trading is extremely heavy. However, if *OPD* is just a form of economic rent imposed by limit order traders to reflect the benefits each trader can enjoy through shorter search time, then the VW search equilibrium justifies why *OPD* should be negatively, rather than positively, related to search time. From this perspective, *OPD* has different implications from *BSD*, with the former serving as a *necessary* rather than *sufficient* condition for search-based trading concentration.

Trading behavior of individuals has often been considered as different from that of institutional investors. Considered alternatively in a search-cost driven market, the divergence of trading behavior may still exist. In the view of VW, search cost is important because investors are constrained in choosing assets to hold or trade. In many of the emerging markets, individuals with limited funds tend to trade infrequently on small cap stocks whose low liquidity, to go after potentially higher returns. Institutional, especially foreign and western, investors possess ample funds, so they are also constrained to trade or hold large cap stocks for depth and the likelihood of finding counterparty. Unlike FII's and DII's, *OPD* for individuals in Table V indicate that their search time is actually *longer* when *OPD* is high. This implies placing limit orders on large cap stocks is very risky. The substantial low ratios between *OPD* at open and at close in low cap stocks for FII's and DII's, as compared with individuals, also suggest institutional investors tend to avoid submitting limit orders there[2]. Individuals facing funding constraints are always better of submitting limit orders. The clientele search equilibrium of VW justifies the existence of diagonal polarization of trading choices within a time-size block. Search costs cause different comparative advantage for individual as institutional investors. Individuals' advantage is in small cap stocks at market open, while FII's and DII's in large cap stock near market close.

According to Table VI, the distribution of the second order-price-based measure, though created to gauge depth of a limit order book, is also compatible with our findings in previous tables. *CTT* falls in general with both time of day and firm size, uniformly across all types of investors. Although stocks of larger firms possess better depth, orders from individuals have on average more depth than those from institutional investors. At market open, this edge is about 2.4 times, and increases to 3.9 times at market close. Along the direction of firm size, individuals' edge in order book depth at market open is 2.1 times on small cap and 2.3 times on large cap, but is 3.7 times and 2.7 times respectively at market close. So the results on order book depth measure in Table VI implies that it is in the interest of FII's and DII's to trade large cap stocks, especially at market close.

For individuals, order book depth indicated they should make the similar trading decision as the institutional investors to avoid higher execution cost in trading small cap stocks at market open. However, the search cost advantage dominates the execution cost. Apparently, for individuals finding a counterparty to complete an intended trade is more important than walking up a few ticks on the limit order book and paying for a slightly higher transacted price. After all, not being able to submit a market order in the Taiwan market is itself a strong protection against shallow limit order book. Besides, there is also a 7% price limit on either direction. Actual trading intensity may depend in part on the relative strength of search and execution costs.

Based on a framework of time-size block, we have used search cost argument to support the observed diagonal polarization of trading activity among individual and institutional investors in the market. Comparative advantage causes investors to trade in a more beneficial environment than otherwise by weighing between search and execution costs. The relation is, however, on the level of broad categories. To determine on average what dictates search equilibrium at every incidence, we need to conduct further point estimation on search time and its driving factors. We use the following model to find out how order price dispersion affects actual time it takes to fill a buy order. A fixed effect panel regression based on

$$BFT_{k,t} = \alpha + \beta_1 OPD_{k,t} + \beta_2 BSD_{k,t} + \varepsilon_{k,t} \qquad (3)$$

is conducted, where *BFT* and *BSD* are the same as those defined for Table IV , and *OPD* is the same as that defined in (2). In (3), *BSD* is included as a control variable. Although the results in Table IV show that the pattern of *BSD* within the time-size block is contrary to that of *BFT*, Glosten and Milgrom (1985) imply that *BSD* should be positively related to *BSD*. Table VII indicate that overall and for all major types of investors, *BSD* does affect *BFT* positively, with an exception in the opening interval. The explanation is related to the fact that, in Table IV, *BSD* happens to have a local minimum at the upper left hand corner of the time-size block. Within that cell, search factor is so strong that it drives up expectation for future offer price, hence current bid offer price difference. In Table VII, the coefficient for OPD is negative within the first two hours of trading for individuals. Larger order price dispersion, arising from the expectation of lower search cost, causes shorter execution time to fulfill that expectation in those periods. Later on as that expectation weakens, execution time is lengthened due to dispersed ordered prices which are hard to fill. Note that in Table VII the expectation effect from search factor can last till mid-session for individuals, indicating that it is more difficult to interpret a large limit order book.

Similar analysis is conducted for *SFT*, the execution time for sell orders, according to the following fixed effect panel regression model,

$$SFT_{k,t} = \alpha + \beta_1 OPD_{k,t} + \beta_2 BSD_{k,t} + \varepsilon_{k,t} \quad (4).$$

The results for the model above are reported in Table VIII, which are somewhat different from those for *BFT* as seen in VII. The coefficients for *BSD* in the case of both FII's and DII's are uniformly negative across the entire day. This suggests that their best offer price tend to increase faster than the best bid price, so sell orders can be filled faster even when *BSD* rises. Similar reason applies for the coefficients of *OPD*. Greater order price dispersion always makes it easier to execute an sell order, whether there are more or fewer institutional investors selling in the market.

Model (3) is then modified for analysis, regardless of investor type, across firm size according to (5),

$$BFT_{k,t} = \alpha + \beta_1 OPD_{k,t} + \beta_2 CTT_{k,t} + \beta_3 BSD_{k,t} + \varepsilon_{k,t} \quad (5).$$

Table IX gives the results of (5), where coefficients for *BSD* and *OPD* are quite similar to those in Table VII. However, the effect of *OPD* in large caps last longer into the day. As institutional investors often place no more than two order prices, which vary rapidly, on either the bid or offer side, higher *OPD* on large cap orders could always suggest more active trading and hence shorter execution time. For the small cap stocks, higher *OPD* later on in the day is caused by more order price farther away from mid-quote, therefore it cannot help expediting execution when there are not enough individual investors. The coefficients for *CTT* reflect that for large caps near market close better order book depth intensifies the search cost advantage over the execution cost disadvantage, further affirming the polarized trading activity implied by Table IV. For the small caps, although search cost advantage also dominates the execution cost disadvantage in all but the first intraday intervals, weaker search effect would only generate less trading activity. It is worth noting that for medium cap stocks, *CTT* reflects only the search cost is present. Analysis on the effect of *CTT* on *BFT* in Table IX reveals that there is strong search cost effect only in the smallest cap at market open, and that there is ultra strong search effect which dominates execution effect in the largest cap near market close. The results in Table IX validate findings in Table VI.

Model (4) is analyzed also again across firm size. Adding *CTT* to model (4) we have

$$SFT_{k,t} = \alpha + \beta_1 OPD_{k,t} + \beta_2 CTT_{k,t} + \beta_3 BSD_{k,t} + \varepsilon_{k,t} \quad (6).$$

Table X gives the results of (6), which are somewhat different from those in Table IX. The effect of *OPD* on *SFT* in large caps is about the same. However, for the small caps, higher *OPD* help expediting execution, possibly due to offer price submitted closer to mid-quote. For large caps, the negative coefficients of *CTT* across all firm size suggest the dominance of search cost advantage over the execution cost disadvantage is uniform on sell orders. Execution costs of sell orders are largely unimportant as sell orders placed not far away from mid-quote, further clarifying the results in Table VIII.

V. Conclusion

This study presents a set of intra-day order book data to study trading behavior in the securities market. We adopted a search model specifically ideal for exploring our detailed order data. We attempt to analyze in this study investor trading behavior in a stock market without relying on any information related presumptions. Our study shows that comparative advantage in search cost dictates a polarization of trading activity across investors, firm size and time of day. We find that, in the Taiwan stock market, individual investors prefer to trade right after market opens, while foreign and domestic institutional investors trade more heavily near market close. Our analysis suggests that low search cost at market open induces individuals to trade at that time. High search cost near market close drives institutional investors to trade more before market closes. Trading costs implied by limit order book indicate that it is less costly for institutional investors to trade large cap stocks at market close than at open. From the perspective of search equilibrium, search cost is related significantly to order-based market liquidity measures depending on time of day, market capitalizations and investor type. In a typical trading day, order prices are more disperse as search time is low in earlier part of the session, later on the dispersion falls as search time rises. Individuals, who are constrained in choices, tend to take this advantage at market open more than the institutional, especially in buy orders for low cap stocks. The results is a compromise between how easy it is to locate a counterparty and how much execution cost an investor is willing to accept given the distribution of order book at certain juncture.

Although we have presented valid arguments regarding the central issue of this study, there are areas we do have to work on to enrich our study with. We have yet to investigate further order submission detail in individual stocks to support the search cost model. Other analysis, such as trading motives of investors, evidence on sequence or development of trading concentration and the dynamics of search equilibrium could be added to an extension as well.

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Footnotes

1. This is indeed consistent with Hu (2006) where it was shown that the participation of individual investor helps reducing frictional costs.

2. While constructing the measure of *OPD*, we examined in detail the limit order book and find that FII's and DII's rarely submit more than two bid or offer prices at any transaction even in the case of large cap stocks. There are no limit order prices at all for stocks not with the largest firm size. These are all indications of market order submission.

Table I Number of Investors in and Orders Submitted to the Taiwan Stock Market

Averaged over 461 trading days, by type of investors and time of day

Investor Type	All day	9:00~ 9:30	9:30~ 10:00	10:00~ 10:30	10:30~ 11:00	11:00~ 11:30	11:30~ 12:00	12:00~ 12:30	12:30~ 13:00	13:00~ 13:30
					Number of Investors					
Individuals		253,996	245,869	240,691	236,557	232,882	229,559	228,973	234,169	249,891
FII's		74,956	70,717	68,085	67,953	66,552	67,191	67,308	69,626	77,828
DII's		69,744	51,066	41,556	37,051	35,713	34,596	32,481	34,370	51,786
					Number of Orders					
Individuals	790,275	176,874	111,960	83,988	70,032	61,049	56,174	54,046	64,065	112,088
FII's	84,086	11,273	8,883	8,174	8,166	8,146	8,455	8,876	10,201	11,912
DII's	15,375	2,752	1,902	1,566	1,416	1,379	1,357	1,325	1,449	2,229

Table II Daily and Intra-day Buy and Sell Orders By Investor Type

Averaged across 525 stocks and 461 days, in lots of thousand shares

	All Day		**9:00~9:30**		**13:00~13:30**	
			Average size per order			
Investor Type	*Buy*	*Sell*	*Buy*	*Sell*	*Buy*	*Sell*
All	8.50	8.45	14.19	14.24	19.92	18.07
Individual	7.29	7.36	10.54	11.12	9.76	10.18
FII	17.10	17.34	27.12	26.18	69.19	59.72
DII	26.23	24.59	37.64	28.77	29.26	26.87

Table III Trading Volume and Holding Percentages By Market Cap and Investor Type

Averaged across 525 stocks and 461 days, volume in lots of thousand shares

	All	***FII's***		***DII's***	
Market Caps		Volume	Holdings	Volume	Holdings
1 (smallest)	6.63	36.62	3.50%	11.19	.28%
2	6.63	36.62	4.44%	11.19	1.23%
3	12.09	153.23	7.71%	63.41	2.33%
4	18.81	568.70	13.40%	200.25	2.82%
5 (largest)	48.76	6598.87	25.60%	498.83	2.68%

Table IV Summary Statistics of Intraday Indicators for VW Search Equilibrium

Sample means across 525 firms over 461 trading days

Indicators used in this study to explore the search equilibrium in VW include search time, number of buy and sell orders and buyer/seller ratio. The search times of buy and sell orders are proxied by, *BFT* and *SFT* respectively. The former is the average number of seconds it takes to fill a buy order within the period of interest, while the latter is that to fill a sell order. Average numbers of buy and sell orders submitted to the market are denoted by *BOC* and *SOC*. *BSR* is the ratio between total buy and sell orders for a given stock on a given day, and is used to proxy the buyer to seller ratio in VW. *BSD* is the difference between the best bid and offer price in the market, averaged over the time period of interest.

Market Caps[1]	9:00~ 9:30	9:30~ 10:00	10:00~ 10:30	10:30~ 11:00	11:00~ 11:30	11:30~ 12:00	12:00~ 12:30	12:30~ 13:00	13:00~ 13:30
				BFT					
All	125	348	575	783	942	1,072	1,271	1,451	1,440
1	125	445	741	1,017	1,249	1,439	1,705	1,958	1,970
2	127	397	657	897	1,088	1,238	1,478	1,706	1,698
3	125	340	565	776	930	1,058	1,271	1,446	1,440
4	124	316	518	703	841	959	1,140	1,286	1,250
5	123	260	420	564	663	738	847	940	906
				SFT					
All	101	252	371	468	574	687	722	725	736
1	103	310	454	575	708	845	914	923	1,043
2	102	267	392	491	596	722	756	758	793
3	99	244	356	442	548	649	670	667	651
4	102	233	342	435	526	634	656	662	640
5	100	218	327	415	512	614	650	646	588
				BOC					
All	145	73	56	48	42	40	38	44	67
1	143	13	10	8	7	7	6	7	11
2	140	30	23	19	17	15	14	16	25
3	150	59	44	37	36	30	27	21	50
4	148	83	62	52	45	42	39	46	70
5	143	181	140	122	109	105	104	121	176
				SOC					
All	141	69	53	45	40	37	37	43	73
1	139	13	10	8	7	6	6	7	12
2	135	29	22	18	16	14	13	16	28
3	143	55	41	34	30	27	26	31	54
4	142	78	58	48	43	39	38	44	77
5	144	170	134	117	105	99	102	119	192
				BSR					
All	1.3691	1.2834	1.2708	1.2631	1.2741	1.3124	1.2175	1.1515	0.9577
1	1.3746	1.2500	1.2046	1.1797	1.1771	1.1933	1.1215	1.0483	0.9650
2	1.3987	1.2668	1.2574	1.2420	1.2535	1.2997	1.2034	1.1200	0.9290
3	1.3882	1.2743	1.2560	1.2689	1.2846	1.3304	1.2173	1.1500	0.9374
4	1.3735	1.3175	1.3217	1.3186	1.3322	1.3749	1.2685	1.2082	0.9658
5	1.3108	1.3038	1.3044	1.2926	1.3060	1.3418	1.2586	1.2138	0.9907
				BSD[2]					
All	1.9708	1.7049	1.6313	1.5959	1.5732	1.5598	1.5546	1.5661	1.5996
1	1.9581	2.6617	2.4975	2.4158	2.3587	2.3208	2.3058	2.3163	2.3711
2	1.9620	1.8960	1.8045	1.7597	1.7353	1.7182	1.7099	1.7209	1.7560
3	1.9398	1.5210	1.4656	1.4425	1.4290	1.4255	1.4193	1.4245	1.4464
4	1.9754	1.4140	1.3745	1.3581	1.3472	1.3455	1.3438	1.3481	1.3681
5	2.0185	1.1581	1.1404	1.1339	1.1298	1.1293	1.1294	1.1305	1.1415

1. Firms with the lowest market capitalization is assigned with 1, while the largest firms are assigned with 5.
2. Measured in number of ticks.

Table V Summary Statistics of Intraday Order Dispersion Relative to Daily Average

Across 525 firms over 461 trading days

$$OPD_i = \frac{1}{2 \times Tick_i} \left[\frac{\sum_{j=1}^{n} w_{ij}^B D_{ij}^B}{\sum_{j=1}^{n} w_{ij}^B} + \frac{\sum_{j=1}^{n} w_{ij}^S D_{ij}^S}{\sum_{j=1}^{n} w_{ij}^s} \right]$$

where i=1,2,⋯,525 and $Tick_i$ is the tick size of the respective stock. $D_{ij}^B = (Bid_{i,j-1} - Bid_{ij})$, which is the price interval between the jth best bid order price and the next better quote, whereas $D_{ij}^S = (Offer_{i,j-1} - Offer_{ij})$, which is the price interval between the jth best offer order price and the next better quote, with. w_{ij} being the size of the corresponding bid or offer order. As the computed value of measure is affected in practice by the arrival rate of orders within a given time, figures in the table is modified to reflect the percentage each cell in the block is above or below corresponding daily averages.

Market Caps*	9:00~ 9:30	9:30~ 10:00	10:00~ 10:30	10:30~ 11:00	11:00~ 11:30	11:30~ 12:00	12:00~ 12:30	12:30~ 13:00	13:00~ 13:30
				All Investors					
All	20.50%	5.63%	0.72%	-1.74%	-3.46%	-4.51%	-5.33%	-5.78%	-6.03%
1	30.57%	10.19%	2.16%	-2.22%	-5.19%	-`7.18%	-8.59%	-9.56%	-10.18%
2	25.19%	7.16%	0.98%	-2.15%	-4.45%	-5.66%	-6.63%	-7.16%	-7.38%
3	20.35%	5.04%	0.40%	-1.80%	-3.36%	-4.35%	-5.15%	-5.47%	-5.66%
4	17.03%	4.04%	0.18%	-1.59%	-2.86%	-3.55%	-4.18%	-4.45%	-4.62%
5	9.36%	1.71%	-0.13%	-0.95%	-1.52%	-1.81%	-2.11%	-2.25%	-2.30%
				Individuals					
All	20.20%	5.79%	0.85%	-1.64%	-3.39%	-4.43%	-5.28%	-5.83%	-6.26%
1	30.40%	10.18%	2.21%	-2.19%	-5.16%	-`7.15%	-8.59%	-9.59%	-10.11%
2	24.95%	7.21%	1.06%	-2.08%	-4.28%	-5.60%	-6.64%	-7.23%	-7.41%
3	19.87%	5.12%	0.52%	-1.67%	-3.26%	-4.23%	-5.04%	-5.49%	-5.81%
4	16.16%	4.17%	0.38%	-1.37%	-2.70%	-3.35%	-3.99%	-4.41%	-4.88%
5	9.62%	2.27%	0.09%	-0.88%	-1.57%	-1.82%	-2.17%	-2.46%	-3.08%
				FII's					
All	8.97%	3.38%	0.82%	-0.66%	-1.78%	-2.53%	-3.08%	-3.03%	-2.09%
1	0.22%	0.09%	-0.00%	-0.04%	-0.05%	-0.08%	-0.10%	-0.08%	0.04%
2	0.90%	0.46%	0.16%	-0.01%	-0.19%	-0.31%	-0.39%	-0.39%	-0.24%
3	3.00%	1.38%	0.49%	-0.09%	-0.60%	-0.97%	-1.24%	-1.20%	-0.77%
4	7.73%	3.36%	1.12%	-3.63%	-1.52%	-2.39%	-2.97%	-2.99%	-1.20%
5	32.97%	11.62%	2.31%	-2.80%	-6.53%	-8.90%	-10.69%	-10.52%	-7.47%
				DII's					
All	11.41%	3.72%	0.46%	-1.22%	-2.46%	-3.18%	-3.40%	-2.81%	-2.53%
1	1.17%	0.52%	0.15%	-0.06%	-0.18%	-`0.29%	-0.29%	-0.23%	-0.80%
2	3.25%	1.37%	0.33%	-0.25%	-0.78%	-1.04%	-1.04%	-0.76%	-1.09%
3	7.54%	2.73%	0.41%	-0.83%	-1.76%	-2.26%	-2.45%	-1.80%	-1.57%
4	15.09%	5.47%	0.97%	-1.42%	-3.25%	-4.37%	-4.79%	-4.11%	-3.59%
5	30.02%	8.55%	0.46%	-3.57%	-6.33%	-7.95%	-8.43%	-7.16%	-5.60%

* Firms with the lowest market capitalization is assigned with 1, while the largest firms are assigned with 5.

Table VI Summary Statistics of Intraday Cost-To-Trade Relative to Daily Average

Across 525 firms over 461 trading days

$$CTT_i = \frac{\sum_{k=1}^{K} I_k^B (MQ_i - P_k^B) + \sum_{k=1}^{K} I_k^S (P_k^S - MQ_i)}{TNS_i \times MQ_i},$$

where i=1,2,⋯,525. MQ_i is the midpoint of the nearest buy and sell quote prices, TNS_i is the total number of shares traded within the time interval of interest, P_k^B is the best bid price, P_k^S is the best offer price and,

$$I_k^B = \begin{Bmatrix} Q_j^B & if & TNS > \sum_{j=1}^{k} Q_j^B \\ (TNS - \sum_{j=1}^{k} Q_j^B) & if & TNS > \sum_{j=1}^{k-1} Q_j^B \ \ and \ \ TNS < \sum_{j=1}^{k} Q_j^B \\ 0 & otherwise & \end{Bmatrix} \quad I_k^S = \begin{Bmatrix} Q_j^S & if & TNS > \sum_{j=1}^{k} Q_j^S \\ (TNS - \sum_{j=1}^{k} Q_j^S) & if & TNS > \sum_{j=1}^{k-1} Q_j^S \ \ and \ \ TNS < \sum_{j=1}^{k} Q_j^S \\ 0 & otherwise & \end{Bmatrix}$$

Market Caps*	9:00~ 9:30	9:30~ 10:00	10:00~ 10:30	10:30~ 11:00	11:00~ 11:30	11:30~ 12:00	12:00~ 12:30	12:30~ 13:00	13:00~ 13:30
				All Investors (x1000)					
All	13.0079	9.8449	8.6888	8.1036	7.6669	7.3865	7.1746	7.0736	6.9958
1	17.8589	14.1373	12.5737	11.7438	11.1532	10.7470	10.4468	10.1948	9.9790
2	14.1931	10.6952	9.4177	8.7636	8.2676	7.9675	7.7290	7.6085	7.5207
3	12.3820	9.2101	8.0962	7.5566	7.1474	6.8688	6.6576	6.5776	6.5194
4	11.4488	8.4558	7.4450	6.9397	6.5596	6.3176	6.1297	6.0875	6.0521
5	9.1591	6.7281	5.9134	5.5160	5.2082	5.0333	4.9114	4.9011	4.9092
				Individuals (x1000)					
All	13.3955	10.4136	9.2868	8.7193	8.2999	8.0390	7.8118	7.6603	7.5285
1	18.0690	14.3891	12.8305	11.9916	11.3952	10.9884	10.6776	10.4073	10.2155
2	14.2668	10.8553	9.5973	8.9522	8.4784	8.1937	7.9314	7.7879	7.7046
3	12.6287	9.5807	8.4841	7.9552	7.5623	7.2972	7.0700	6.9430	6.8464
4	11.9329	9.2087	8.2513	7.7756	7.4143	7.2065	7.0072	6.9023	6.7844
5	10.0826	8.0364	7.2727	6.9234	6.6509	6.5103	6.3740	6.2626	6.0931
				FII's (x1000)					
All	31.6742	30.7326	30.2594	29.9569	29.6639	29.4932	29.3019	29.3110	29.4198
1	38.2287	38.1884	38.1322	38.0976	38.0382	38.0152	38.0066	38.0051	38.0210
2	38.4410	38.2997	38.2193	38.1541	38.0731	38.0783	37.9811	37.9710	38.0837
3	30.5419	30.2111	30.0790	30.0179	29.8711	29.7989	29.7067	29.7387	29.9595
4	25.5691	25.8143	25.3715	25.1059	24.8172	24.6598	24.4530	24.4801	24.8677
5	24.5935	21.1536	19.4991	18.4132	17.5244	16.9181	16.3665	16.3646	16.1717
				DII's (x1000)					
All	35.3645	32.8618	31.9597	31.4973	31.0950	30.8792	30.8544	31.1076	30.5155
1	49.1130	48.7376	48.5554	48.3584	48.2354	48.1506	48.1809	48.2515	47.0022
2	38.9963	38.0760	37.6922	37.4903	37.2298	37.1191	37.1422	37.3311	36.4473
3	33.0821	31.3160	30.5527	30.2103	29.8196	29.6622	29.6451	29.9616	29.5253
4	30.7961	27.2124	25.8983	25.2023	24.6050	24.2437	24.0973	24.4305	24.1344
5	24.8420	18.9749	17.1083	16.2339	15.5939	15.2289	15.2152	15.5719	15.4765

* Firms with the lowest market capitalization is assigned with 1, while the largest firms are assigned with 5.

Table VII Intraday Search Time Effects on Buy Order by Investor Type

Fixed-effect panel estimation, all investor types

A search equilibrium is characterized by shorter search time is accompanied by better liquidity and higher prices in the market. To further explore this relation across different intraday intervals and firm size, we performed a panel regression with fixed effect based on

$$BFT_{k,t} = \alpha + \beta_1 OPD_{k,t} + \beta_2 BSD_{k,t} + \varepsilon_{k,t},$$

where t=1,…,461 and k=1,…,525. *BFT* and *BSD* are the same as those defined for Table IV, and *OPD* is the same as that defined in Table V.

	9:00~ 9:30	9:30~ 10:00	10:00~ 10:30	10:30~ 11:00	11:00~ 11:30	11:30~ 12:00	12:00~ 12:30	12:30~ 13:00	13:00~ 13:30
					Whole Market				
β_1	-0.0190*	-0.4043**	-0.5120**	-0.3004**	-0.2686**	-0.0795*	0.0995**	0.3939**	0.6434**
	(0.0095)	(0.0199)	(0.0279)	(0.0330)	(0.0365)	(0.0377)	(0.0367)	(0.0334)	(0.0297)
β_2	-0.0367**	0.0553**	0.0999*	0.1203**	0.1165*	0.1393**	0.1368**	0.1118**	0.0704**
	(0.0019)	(0.0042)	(0.0050)	(0.0055)	(0.0059)	(0.0063)	(0.0064)	(0.0063)	(0.0061)
Obs	228,928	229,305	228,706	227,489	226,341	225,279	225,149	227,619	229,975
					Individuals				
β_1	-0.0209*	-0.4005**	-0.4699**	-0.2968**	-0.2477**	0.0682	0.1054**	0.3730**	0.5732**
	(0.0095)	(0.0192)	(0.0267)	(0.0316)	(0.0350)	(0.0361)	(0.0351)	(0.0320)	(0.0285)
β_2	-0.0367**	-0.0528**	0.0963	0.1193**	0.0115*	0.1387**	0.1366**	0.1131**	0.0736**
	(0.0019)	(0.0041)	(0.0049)	(0.0055)	(0.0059)	(0.0063)	(0.0064)	(0.0063)	(0.0061)
Obs	228,954	229,305	228,706	227,489	226,341	225,279	225,149	227,619	229,975
					FII's				
β_1	0.0086	-0.1280**	-0.1223**	-0.0213	-0.0145	0.0701*	0.1037**	0.1528**	0.0118**
	(0.0085)	(0.0155)	(0.0222)	(0.0270)	(0.0296)	(0.0302)	(0.0285)	(0.0257)	(0.0219)
β_2	-0.0367**	0.0319**	0.0761**	0.1072**	0.1053**	0.1356**	0.1407**	0.1295**	0.1016**
	(0.0019)	(0.0040)	(0.0048)	(0.0053)	(0.0057)	(0.0061)	(0.0062)	(0.0061)	(0.0059)
Obs	228,954	229,305	228,706	227,489	226,341	225,279	225,149	227,619	229,975
					DII's				
β_1	-0.0080	-0.1103**	-0.1283**	-0.0454	0.0432	0.0224	-0.0400	-0.0017	0.0191
	(0.0077)	(0.0138)	(0.0202)	(0.0245)	(0.0271)	(0.0277)	(0.0261)	(0.0236)	(0.0203)
β_2	0.0570	0.0319**	0.0762**	0.1073**	0.1056**	0.1357**	0.1415**	0.1302**	0.0059**
	(0.1187)	(0.0040)	(0.0048)	(0.0053)	(0.0057)	(0.0061)	(0.0062)	(0.0061)	(0.0059)
Obs	229,155	229,305	228,706	227,489	226,341	225,279	225,149	227,619	229,975

Standard deviations are in the parentheses; ** denotes significant at 1% and * denotes significant at 5%.

Table VIII Intraday Search Time Effects on Sell Order by Investor Type

Fixed-effect panel estimation, all investor types

A search equilibrium is characterized by shorter search time is accompanied by better liquidity and higher prices in the market. To further explore this relation across different intraday intervals and firm size, we performed a panel regression with fixed effect based on

$$SFT_{k,t} = \alpha + \beta_1 OPD_{k,t} + \beta_2 BSD_{k,t} + \varepsilon_{k,t},$$

where t=1,…,461 and k=1,…,525. *SFT* and *BSD* are the same as those defined for Table IV, and *OPD* is the same as that defined in Table V.

	9:00~ 9:30	9:30~ 10:00	10:00~ 10:30	10:30~ 11:00	11:00~ 11:30	11:30~ 12:00	12:00~ 12:30	12:30~ 13:00	13:00~ 13:30
					Whole Market				
β_1	-0.0008	-0.2014**	-0.1973**	-0.3455**	-0.1108**	-0.0991*	-0.1859**	-0.4977**	-0.7404**
	(0.0091)	(0.0203)	(0.0292)	(0.0345)	(0.0382)	(0.0394)	(0.0392)	(0.0351)	(0.0309)
β_2	-0.0724**	-0.1132**	-0.1253**	-0.1411**	-0.1240**	-0.1467**	-0.1356**	-0.0720**	0.0461**
	(0.0019)	(0.0043)	(0.0052)	(0.0058)	(0.0062)	(0.0066)	(0.0068)	(0.0066)	(0.0064)
Obs	225,177	228,156	228,076	227,045	225,979	225,020	224,926	227,424	229,799
					Individuals				
β_1	0.0001	-0.1637**	-0.1889**	-0.3344**	-0.1588**	-0.1849	-0.2733**	-0.5694**	0.7254**
	(0.0091)	(0.0195)	(0.0279)	(0.0309)	(0.0366)	(0.0376)	(0.0374)	(0.0336)	(0.0296)
β_2	-0.0724**	-0.1163**	0.1263	0.1425**	0.1223*	0.1433**	0.1321**	0.0692**	0.0456**
	(0.0019)	(0.0042)	(0.0052)	(0.0057)	(0.0062)	(0.0066)	(0.0068)	(0.0066)	(0.0063)
Obs	225,203	228,156	228,076	227,045	225,979	225,020	224,926	227,424	229,799
					FII's				
β_1	0.0026	-0.0827**	-0.1059**	-0.1910**	-0.0587	-0.0481	-0.0845**	-0.1362**	-0.0983**
	(0.0082)	(0.0157)	(0.0231)	(0.0282)	(0.0309)	(0.0315)	(0.0304)	(0.0270)	(0.0227)
β_2	-0.0724**	-0.1250**	-0.1345**	-0.1560**	-0.1284**	-0.1508*	-0.1435**	-0.0947**	-0.0101**
	(0.0019)	(0.0041)	(0.0050)	(0.0056)	(0.0060)	(0.0064)	(0.0066)	(0.0064)	(0.0062)
Obs	225,203	228,156	228,076	227,045	225,979	225,020	224,926	227,424	229,799
					DII's				
β_1	0.0134	-0.0524**	-0.0179	-0.1229**	-0.1105**	-0.1459**	-0.1619**	-0.2724**	-0.2750**
	(0.0073)	(0.0140)	(0.0210)	(0.0256)	(0.0283)	(0.0289)	(0.0278)	(0.0248)	(0.0211)
β_2	-0.0746	-0.1249**	-0.1345**	-0.1557**	-0.1279**	-0.1497**	-0.1424**	-0.0932**	0.0119**
	(0.1140)	(0.0041)	(0.0050)	(0.0056)	(0.0060)	(0.0064)	(0.0066)	(0.0064)	(0.0062)
Obs	225,321	228,156	228,076	227,045	225,979	225,020	224,926	227,424	229,799

Standard deviations are in the parentheses; ** denotes significant at 1% and * denotes significant at 5%.

Table IX Intraday Search Time Effects on Buy Order by Firm Size (II)

Fixed-effect panel estimation, all investor types

A search equilibrium is characterized by shorter search time is accompanied by better liquidity and higher prices in the market. To further explore this relation across different intraday intervals and firm size, we performed a panel regression with fixed effect based on

$$BFT_{k,t} = \alpha + \beta_1 OPD_{k,t} + \beta_2 CTT_{k,t} + \beta_3 BSD_{k,t} + \varepsilon_{k,t},$$

where t=1,…,461 and k=1,…,525. *BFT, OPD*, *CTT* and *BSD* are the same as those defined for Table IV, *OPD* is the same as that defined in Table V, and *CTT* is the same as that defined in Table VI.

	9:00~ 9:30	9:30~ 10:00	10:00~ 10:30	10:30~ 11:00	11:00~ 11:30	11:30~ 12:00	12:00~ 12:30	12:30~ 13:00	13:00~ 13:30
Market Cap=1 (Smallest)									
β_1	-0.0419**	-0.2738**	-0.3702**	-0.3011**	-0.1524*	0.0900	0.3671*	0.5179**	0.7713**
	(0.0163)	(0.0464)	(0.0629)	(0.0762)	(0.0820)	(0.0860)	(0.0820)	(0.0725)	(0.0618)
β_2	0.9887*	-12.771**	-16.325**	-20.625**	-21.107**	-27.666**	-21.785**	-27.559**	-30.280**
	(0.4234)	(`1.4095)	(`1.6870)	(`1.8946)	(2.0966)	(2.2850)	(2.2330)	(2.2285)	(2.2187)
β_3	-0.0333**	-0.0439**	0.1016**	0.1333**	0.1352**	0.1785**	0.1523**	0.1541**	0.1242**
	(0.0042)	(0.0115)	(0.0133)	(0.0148)	(0.0159)	(0.0170)	(0.0170)	(0.0162)	(0.0154)
Market Cap=2									
β_1	-0.0252	-0.5517**	-0.6281**	-0.2444**	-0.3136**	-0.0052	0.0417	0.5539**	0.55950**
	(0.0210)	(0.0438)	(0.0609)	(0.0711)	(0.0792)	(0.0817)	(0.0802)	(0.0720)	(0.0620)
β_2	0.4758	4.5081**	-0.4968	-7.4890**	-10.043**	-10.019**	12.172**	-12.694**	-12.759**
	(0.6262)	(1.4591)	(1.7796)	(2.0260)	(2.2435)	(2.4305)	(2.4806)	(2.4586)	(2.4828)
β_3	-0.0507**	0.0655**	0.1194**	0.1893**	0.1670**	0.1929**	0.1882**	0.1552**	0.1063**
	(0.0042)	(0.0131)	(0.0153)	(0.0169)	(0.0180)	(0.0193)	(0.0194)	(0.0188)	(0.0182)
Market Cap=3									
β_1	-0.0104	-0.5359**	-0.5950**	-0.4035**	-0.3215**	-0.3004**	-0.1449	-0.2823**	0.5512**
	(0.0238)	(0.0429)	(0.0598)	(0.0696)	(0.0785)	(0.0813)	(0.0786)	(0.0726)	(0.0663)
β_2	-0.4021	18.6389**	18.9507**	13.9461**	7.5927**	12.1156**	2.8241	5.3621*	9.5839**
	(0.8123)	(1.4429)	(1.7944)	(2.2024)	(2.2261)	(2.24433)	(2.4850)	(2.5175)	(2.6063)
β_3	-0.0392**	0.0506**	0.1456**	0.1861**	0.2028**	0.335**	0.2388**	0.1919**	0.1620**
	(0.0042)	(0.0136)	(0.0199)	(0.0175)	(0.0188)	(0.0197)	(0.0199)	(0.0198)	(0.0255)
Market Cap=4									
β_1	-0.0426	-0.5099**	-0.5583**	-0.3138**	-0.3580**	-0.2376**	-0.0827	0.0995	0.4741**
	(0.0210)	(0.0438)	(0.0631)	(0.0739)	(0.0826)	(0.0843)	(0.0842)	(0.0771)	(0.0717)
β_2	0.7200	20.1114**	17.4318**	13.9524**	8.4216**	9.3327**	-1.1557	-1.0602	1.1527
	(0.9012)	(1.3871)	(1.7499)	(1.9864)	(2.2042)	(2.3554)	(2.4184)	(2.4372)	(2.5400)
β_3	-0.0308**	0.0718**	0.1274**	0.1548**	0.1777**	0.1878**	0.2382**	0.2414**	0.1727**
	(0.0041)	(0.0130)	(0.0154)	(0.0168)	(0.0179)	(0.0187)	(0.0189)	(0.0189)	(0.0189)
Market Cap=5 (Largest)									
β_1	0.0445	-0.4068**	-0.7751**	-0.4486**	-0.5954**	-0.6978**	-0.3341**	-0.2686**	0.2366*
	(0.0372)	(0.0562)	(0.0789)	(0.0923)	(0.1041)	(0.1060)	(0.1037)	(0.0996)	(0.0971)
β_2	-2.6756	8.9855**	12.0087**	4.3972**	1.0497	-2.1917	-7.1827**	-17.024**	-6.4493**
	(1.3749)	(1.6531)	(2.1629)	(2.4560)	(2.7349)	(2.9089)	(2.9726)	(3.6724)	(3.2807)
β_3	-0.0304**	0.1543**	0.1813**	0.2674**	0.3065**	0.3149**	0.3334**	0.3500**	0.3043**
	(0.0040)	(0.0128)	(0.0151)	(0.0164)	(0.0176)	(0.0183)	(0.0185)	(0.0191)	(0.0198)

Standard deviations are in the parentheses; ** denotes significant at 1% and * denotes significant at 5%.

Table X   Intraday Search Time Effects on Sell Order by Firm Size (II)

Fixed-effect panel estimation, all investor types

A search equilibrium is characterized by shorter search time is accompanied by better liquidity and higher prices in the market. To further explore this relation across different intraday intervals and firm size, we performed a panel regression with fixed effect based on

$$SFT_{k,t} = \alpha + \beta_1 OPD_{k,t} + \beta_2 CTT_{k,t} + \beta_3 BSD_{k,t} + \varepsilon_{k,t},$$

where t=1,…,461 and k=1,…,525. *SFT, OPD*, *CTT* and *BSD* are the same as those defined for Table IV, *OPD* is the same as that defined in Table V , and *CTT* is the same as that defined in Table VI.

	9:00~ 9:30	9:30~ 10:00	10:00~ 10:30	10:30~ 11:00	11:00~ 11:30	11:30~ 12:00	12:00~ 12:30	12:30~ 13:00	13:00~ 13:30
					Market Cap=1 (Smallest)				
β_1	0.0126	0.0132	0.1097	0.1575*	0.2569**	0.2950**	0.0665	-0.1003**	0.0436**
	(0.0157)	(0.0473)	(0.0656)	(0.4788)	(0.0848)	(0.0893)	(0.0865)	(0.0763)	(0.0647)
β_2	-0.6152	-11.815**	-19.159**	-19.952**	-27.596**	-26.699**	-28092**	-27.167**	-11.928**
	(0.4074)	(1.4468)	(1.7653)	(1.9652)	(2.1769)	(2.3776)	(2.4624)	(2.3483)	(2.3282)
β_3	-0.0696**	-0.0925**	-0.0798**	-0.0955**	-0.0433**	-0.0896**	-0.0748**	-0.0266	0.0043**
	(0.0042)	(0.0119)	(0.0140)	(0.0154)	(0.00165)	(0.0177)	(0.0180)	(0.0171)	(0.0161)
					Market Cap=2				
β_1	-0.0150	-0.0436	-0.0023	-0.2130**	0.0098	-0.0816**	-0.0786	-0.5454**	-0.7587**
	(0.0200)	(0.0452)	(0.0646)	(0.0758)	(0.0843)	(0.0865)	(0.0872)	(0.0774)	(0.0661)
β_2	0.4427	-9.6521**	-24.864**	-28.747**	-32.130**	-41.509**	-41.414**	-39.578**	-19.621**
	(0.5978)	(1.5124)	(1.8896)	(2.1621)	(2.3915)	(2.5744)	(2.6964)	(2.6411)	(2.6442)
β_3	-0.0765**	-0.1053**	-0.0473**	-0.0745**	-0.0375	-0.0082	-0.0060	0.0630**	0.1017**
	(0.0042)	(0.0137)	(0.0163)	(0.0180)	(0.0192)	(0.0205)	(0.0211)	(0.0202)	(0.0194)
					Market Cap=3				
β_1	-0.0065	-0.2892**	-0.2779**	-0.5128**	-0.3625**	-0.3653**	-0.3483**	-0.8880**	-1.0974**
	(0.0226)	(0.0438)	(0.0630)	(0.0732)	(0.0819)	(0.0846)	(0.0843)	(0.0762)	(0.0686)
β_2	0.5760	-8.0758**	-25.377**	-39.925**	-40.943**	-48.542**	-44.495**	-48.397**	-32.061**
	(0.7701)	(1.4768)	(1.8856)	(2.1288)	(2.3653)	(2.5443)	(2.6626)	(2.6428)	(2.6972)
β_3	-0.0737**	-0.0241**	0.0526**	0.1052**	0.1103**	0.1158**	0.0822**	0.2221**	0.2853**
	(0.0041)	(0.0140)	(0.0168)	(0.0184)	(0.0196)	(0.0205)	(0.0213)	(0.0208)	(0.0203)
2					***Market Cap=4***				
β_1	0.0027	0.2608**	-0.4636**	-0.6977**	-0.4043**	-0.4157**	0.5424**	0.7965**	-0.9459**
	(0.0251)	(0.0448)	(0.0657)	(0.0772)	(0.0863)	(0.0879)	(0.0891)	(0.0800)	(0.0737)
β_2	-1.6088	-11.631**	-29.125**	-42.274**	-50.844**	-54.392**	-57.293**	-52.102**	-32.361**
	(0.8664)	(1.4195)	(1.8282)	(2.0745)	(2.3014)	(2.4549)	(2.5593)	(2.5292)	(2.6123)
β_3	-0.0665**	0.0258	0.1005**	0.1702**	0.2060**	0.2082**	0.2434	0.2547	0.03224
	(0.0041)	(0.0133)	(0.0160)	(0.0176)	(0.0187)	(0.0195)	(0.0200)	(0.0196)	(0.0195)
					Market Cap=5 (Largest)				
β_1	0.0023	-0.4455**	-0.3595**	-0.9100**	-0.8235**	-0.8944**	-0.9173**	-0.8227**	-0.8662**
	(0.0358)	(0.0564)	(0.0796)	(0.0931)	(0.1062)	(0.1075)	(0.1080)	(0.1008)	(0.0963)
β_2	2.6891*	-17.828**	-42.420**	-62.469**	-65.726**	-77.145**	-85.173**	-75.937**	-66.325**
	(1.3225)	(1.6588)	(2.1811)	(2.4771)	(2.7921)	(2.9493)	(3.0959)	(3.1028)	(3.2541)
β_3	-0.0755**	-0.1826**	0.2741**	0.3038**	0.3325**	0.3578**	0.4059**	0.4076**	0.4792**
	(0.0040)	(0.0128)	(0.0152)	(0.0166)	(0.0179)	(0.0186)	(0.0192)	(0.0193)	(0.0196)

Standard deviations are in the parentheses; ** denotes significant at 1% and * denotes significant at 5%.