An Analysis of Intraday Patterns and Liquidity on the Istanbul Stock Exchange

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Abstract

We examine the intraday behavior of spreads, depths, returns and volume on the Istanbul Stock Exchange by using detailed order and transaction data for all stocks. We find that spreads follow an L-shaped pattern whereas returns, number of trades and volume follow a U-shaped pattern. Another result is that traders use spreads and depths simultaneously to implement their strategies. In addition, spreads are higher on average for more risky stocks and for more active stocks. Information flow as measured by trades of unusual size causes the spreads to increase. Finally there are day-of-week effects on spreads, returns and share volume.

Keywords: *Intraday Patterns; Spreads; Returns; Depths; Transaction Volume; Market Liquidity; Limit Order Market; Istanbul Stock Exchange.*

JEL Classification: *G15; G20*

Özet: İstanbul Menkul Kıymetler Borsasındaki Gün İçi Davranışların ve Likiditenin Analizi

Bu çalışmada ayrıntılı emir ve işlem verisi kullanılarak, İstanbul Menkul Kıymetler Borsasında alış-satış fiyat aralığı, derinlik, getiri ve işlem hacminin gün içi davranışı incelenmektedir. Fiyat aralıklarının L şeklinde, getiri, işlem sayısı ve işlem hacminin ise U şeklinde bir davranış sergilediği bulunmuştur. Ayrıca yatırımcılar stratejilerini gerçekleştirirken fiyat aralığını ve derinliği aynı anda kullanmaktadırlar. Bu bulgulara ek olarak fiyat aralıklarının daha riskli ve daha aktif hisse senetleri için daha yüksek olduğu bulunmuştur. Normal üstü büyüklüğe sahip işlemler ile ölçülen bilgi akışı ise fiyat aralıklarının artmasına sebep olmaktadır. Son olarak, fiyat aralığı, getiri ve işlem hacminde "haftanın günü etkisi" bulunmuştur.

Anahtar Kelimeler: *Güniçi Davranışlar; Fiyat Aralıkları; Getiriler; Derinlik; İşlem Hacmi; Piyasa Likiditesi; Limitli Emir Piyasası; İstanbul Menkul Kıymetler Borsası*

JEL Sınıflaması: *G15; G20*

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Bu çalışma TÜBİTAK tarafından 108K530 no'lu proje kapsamında desteklenmiştir. Yazar çalışmada kullanılan verilerin sağlanmasında gösterdiği destek nedeniyle İMKB'ye teşekkür etmektedir. Bu çalışmada belirtilen görüşler yazara ait olup. Türkiye Cumhuriyet Merkez Bankası'nın görüşlerini yansıtmamaktadır.

1. Introduction

Intraday behavior of different liquidity variables have been analyzed extensively for different stock exchanges. One of the interesting findings is that many of these variables like spreads, returns, and volume follow a broad U-shaped pattern. The levels of these variables are high at the beginning of the day, decline continuously towards the mid-day and increase again towards the end of the day. Another interesting finding is that there are day-of-the week effects, i.e., behavior of the liquidity exhibits differences across days.

For example, Harris (1986) finds that Monday returns are different from returns in other days. McInish and Wood (1990) show that volatility of returns on the NYSE, and McInish and Wood (1990) show that returns and number of trades on the Toronto Stock Exchange follow a U-shaped pattern. Jain and Joh (1988) show that intraday returns are significantly different from each other and Wood, et al. (1985) show that beginning and end of day returns are higher when compared to mid-day returns. Jain and Joh (1988) also show that trading volume is significantly different across intraday time intervals and across days of the week. In addition, the literature discovers U-shaped patterns in intraday behavior of risk premiums, number of shares traded, number of trades, quote revisions, and trade size.[1]

Theoretical microstructure literature offers explanations for the intraday behavior of liquidity variables along the lines of liquidity risk and inventory management, and information asymmetry. Admati and Pfleiderer (1988) develops a model where the strategic behavior of liquidity traders and informed traders creates trade clustering and they suggest that market open and close can be special clustering points. Brock and Kleidon (1992) show that transactions demand at the market open and close is higher and less elastic than other times of the day because accumulated information while the market is closed most probably changes investors' optimal portfolio. Also, traders strategically try to close their positions before day's end because of the risks associated with open positions. As first analyzed by Stoll (1978), Ho and Stoll (1981), and Ho and Stoll (1983), the risk of carrying inventory induces a positive bid-ask spread. Madhavan

[1] See, for example, Yadav and Pope (1992), Foster and Viswanathan (1993), Ho and Cheung (1991), Chang, et al. (1995), Chan, et al. (1995), Aggarwal and Gruca (1993), Miller (1989), Copeland and Jones (2002), Ahn and Cheung (1999), Vo (2007), Tian and Guo (2007), Li, et al. (2005), and Chung, et al. (1999).

(1992) shows that spreads decrease over the day because trading reduces the information asymmetry between dealers and traders.

Intraday analysis of the liquidity variables for ISE stocks like bid-ask spreads and depths at the best prices are not available simply because of the lack of data.[2] Bildik (2001) and to some extent Akyol (2011) examine the intraday behavior of the ISE-100 Index. Yuksel (2002) focuses on volume–return relation on the ISE during the Russian crisis in 1998 and shows that there was a structural change regarding the positive relationship between absolute value of returns and trading volume. Kucukkocaoglu (2008) shows that returns of ISE30 Index stocks follow a U-shaped pattern. Finally, Kayahan, et al. (2002) examine intraday volatility behavior of the ISE100 index.

The aim of our study is to undertake a comprehensive analysis of the liquidity on the Istanbul Stock Exchange (ISE). Although it is the rapidly developing market of an emerging economy, intraday behavior of spreads, depths, returns and volume have not been analyzed for the ISE by using transaction level data for all stocks. To the best of our knowledge, this is the first study that examines the spreads and depths on the ISE by using the most comprehensive dataset.[3]

In the first part of this paper, we use detailed order and transaction data to estimate the limit order book (LOB) in event time and calculate the spreads and depths. Then we show that the intraday behavior of the spreads exhibit an L-shaped pattern in contrast to that found by several studies for other stock markets.[4] Spreads (depths) are higher (lower) at the beginning of the sessions and declines (increases) continuously towards the end of the sessions,[5] providing evidence that traders use spreads and depths simultaneously to implement their strategies as in Lee, et al. (1993), Harris (1994), and Kavajecz (1999). Therefore focusing on just the spreads to examine liquidity will be misleading for the ISE. In addition, we estimate a regression model to determine the relationship between the time-weighted percentage bid-ask spread and its determinants. Estimation results reveal that spreads are higher on average for more risky stocks and for more active stocks. Information flow as measured by trades of unusual size causes the spreads to increase.

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[2] Ekinci (2003) examines the intraday patterns for a single stock.
[3] Our dataset consists of the whole population of stocks, rather than a sample.
[4] McInish and Wood (1992) is one of the first studies that examine the intraday behavior of spreads.
[5] One of the unique features of the ISE is that there are two trading sessions: one morning and one afternoon session.

In the second part of the paper, we examine the intraday behavior of returns, number of trades, and both share and Turkish Lira (TL) volumes. We show that these variables follow a broad U-shaped pattern and that the means of these variables are significantly different for different time intervals in a given day. We also show that there are day-of-week effects on spreads, returns and share volumes. Finally, we find that the behaviors of share and TL volumes are different, suggesting that both of these variables should be considered when volume is utilized to examine liquidity.

The rest of the paper is organized as follows: Section 2 briefly describes the institutional details of the ISE, Section 3 analyzes the spreads and depths, Section 4 examines the returns, number of trades, and volume, and Section 5 concludes.

2. Istanbul Stock Exchange (ISE)

The ISE is a fully computerized order-driven, multi price, continuous auction limit order market with no market makers. Trading hours are as follows during our sample period: Orders are sent to the system between 09:30 and 09:40. There is an opening session between 09:40 and 09:45 during which a single price call auction is held. Continuous auction starts at 09:45 and continues until 12:00 when the first session ends. There is a two hour lunch break. Trading resumes at 14:00 (second session starts) and the market closes at 17:00.[6] ISE National-100 Index is the main market indicator of the Istanbul Stock Exchange and represents more than three fourths of the market in terms of market capitalization and trading volume.

Traders can submit only limit orders. Best five prices and depths at those prices as well as names of the brokerage houses on both sides of the market are displayed indicating a high level of post-trade transparency. There are no market orders[7] and order revision is limited in the sense that an order cannot be cancelled if it is not the very last order entered into the system. Price of an order can be bettered but not worsened and finally splitting orders is permitted.

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[6] Trading hours are as follows as of April 2012: Opening session: 9:30-9:50. Orders are collected between 9:30 and 9:45 and first quotation is determined by the system at 9:49 (by the market maker, which is new, for some illiquid stocks between 9:45-9:49). Continuous auction: 9:50-12:30; Lunch break: 12:30-14:00; Opening session: 14:00-14:15 (consisting of order collection (14:00-14:10) and determination of the first quotation (14:10-14:15) by the system or the market maker); Continuous auction: 14-15-17:17; Closing session (which is new): 17:17- 17:30. See http://www.ise.org/Markets/StockMarket.aspx for details. (retrieved on March 27, 2012)

[7] Traders can submit marketable limit orders.

Average daily dollar and share volume during our sample period (May-July 2008) were approximately $1 billion and 391.2 million shares, respectively, for 326 companies. Similar figures in 2012 as of March 26th, 2012 are $1.23 billion, 629.8 million shares, and 244 companies.

3. Intraday Spreads and Depths

3.1. Data and Empirical Methodology

We use proprietary order book data obtained from the ISE that covers the three month period May-July 2008 for *all* ISE stocks to estimate the LOBs and calculate the spreads and depths.[8] Order data provide detailed info about the limit orders such as limit price, quantity, validity, and type (buy, sell, short sale, split, cancel). Orders are time stamped to the second.

We use a method similar to the one described in Kavajecz (1999) to estimate the LOBs. The LOB at the beginning of the day is empty since there are no orders on the ISE such as good-till-cancelled orders. Initial and each limit order book after that is updated sequentially depending on the placed orders, executions and cancellations. The result is the estimate of the LOBs at each point in time. Table 1 displays a snapshot of the LOB for Turkcell.

After the LOBs are estimated, following McInish and Wood (1992), we construct two spread measures: the first one is a minute-by-minute time series of percentage bid-ask spreads over the trading day for the market. The second measure is calculated for 15-min. intervals and used in the regression analysis that we will describe in more detail below.

To create the first spread measure, we first construct a time-series of second-by-second percentage bid-ask spread (*PSpread*) for each stock, where $PSpread = (ask - bid)/[(ask + bid)/2]$. Then for each trading second of the sample period, we average all of the percentage bid-ask spreads across stocks to construct a second-by-second time series of *market* percentage bid-ask spreads. We then average these percentage bid-ask spreads within each trading minute to create a minute-by-

[8] We repeat the whole analysis by using data from the periods January-April 2008 and September-December 2007 for robustness. We will emphasize differences, if any, in our discussion of the results.

minute time series of percentage bid-ask spreads for the market. We use this measure to visually examine the intraday behavior of the spreads.

Table 1. The Limit Order Book for Turkcell (Tcell) on June 9th, 2008 at 11:22:40

Side	Size	Price	Price	Size
Buy	343	8.30		
Buy	51	8.40		
Buy	1136	8.50		
Buy	10	8.60		
Buy	462	8.65		
Buy	1515	8.70		
Buy	770	8.75		
Buy	3512	8.80		
Buy	15250	8.85		
Buy	16283	8.90		
Buy	20707	8.95		
Buy	292825	9.00		
Buy	190485	9.05		
Sell			9.15	75082
Sell			9.20	21024
Sell			9.25	25837
Sell			9.30	21452
Sell			9.35	41262
Sell			9.40	9265
Sell			9.45	4164
Sell			9.50	102112
Sell			9.55	7444
Sell			9.60	1771
Sell			9.65	380
Sell			9.70	10166
Sell			9.75	823
Sell			9.80	989
Sell			9.85	130
Sell			9.90	2674
Sell			9.95	283
Sell			10.00	3120
Sell			10.05	110
Sell			10.10	118
Sell			10.15	210
Sell			10.20	2021

The second spread measure is calculated for 15-min intervals and used in the regression analysis to determine the relation between spread and its determinants identified in the literature. We follow the procedure described in McInish and Wood (1992). We first calculate the percentage bid ask spread (*PSpread*). Assume that in a 15-min interval (T, T'), which is measured in seconds, there are *N* quotation updates, at times t_i, $i = 1,...,N$, with spreads $PSpread_i$, $i = 1,...,N$ where $t_0 = T$ and $t_{N+1} = T'$. $PSpread_0$ is based on the quotation at the beginning of the 15-min time interval, i.e., the quotation outstanding at time T. Note that $PSpread_0$ does not exist in the first interval of the day since there is no outstanding quote before the first quote of the day. Time weighted percentage bid-ask spread is calculated as follows for the interval in which the first quotation of the day occurs:

$$TWPSpread_{i,t} = \sum_{i=1}^{N} \frac{PSpread_i (t_{i+1} - t_i)}{(T' - t_1)}$$

For subsequent intervals:

$$TWPSpread_{i,t} = \sum_{i=0}^{N} \frac{PSpread_i (t_{i+1} - t_i)}{(T' - T)}$$

In addition to spreads, we also examine depths. Lee, Mucklow and Ready (1993) and others[9] show that liquidity providers use both spreads and depths to actively manage information asymmetry risk. Wide spreads are accompanied by low depths, and vice versa. We create two depth measures to see if this is the case for ISE.

First we calculate a second-by-second time-series of total quoted depth (total depth at the best bid and ask prices) and total cumulative depth (total depth at the best five prices) for each stock scaled by shares outstanding. Then for each trading second of the sample period, we average all of total quoted depths and total cumulative depths to construct a second-by-second time series of *market* depths. We then average these depths within each trading minute to create a minute-by-minute time series of total quoted depth and total quoted cumulative depth for the market. We use these depth measures to examine the intraday behavior of the depths visually and compare their behavior to the spreads.

[9] For example, Harris (1994), and Kavajecz (1999).

Second, percentage spreads and depths (total depth and total cumulative depth) scaled by shares outstanding at the end of each 15-min interval for all stocks and days in the sample period are classified into one of 9 categories, based on whether the time weighted percentage spread and total quoted (and cumulative) depth in that interval are higher, lower or equal to their respective medians. Our aim is to conduct a nonparametric test similar to Lee, Mucklow and Ready (1993) to see if wide spreads are accompanied by low depths, and vice versa. We also calculate the correlation between spreads and depth to see is they are negatively correlated.

To summarize, we have the following time series of variables:

- A minute-by-minute time series of percentage spreads,
- A minute-by-minute time series of total quoted depth at the best prices scaled by shares outstanding,
- A minute-by-minute time series of total cumulative depth (total depth at the best five prices) scaled by shares outstanding.
- A time weighted percentage spread for each 15-min. interval (to be used in the regression analysis).
- Percentage spreads and depths (total depth and total cumulative depth) scaled by shares outstanding at the end of each 15-min interval to be used in the nonparametric test of association between spreads and depths.

We use a variety of exogenous variables in the regression analysis where the dependent variable is the time weighted percentage spread calculated for each 15-min. interval.[10] We use logarithms to mitigate the problem of outliers or heteroskedasticity. Our exogenous variables are measures of trading activity, level of risk, and the amount of information coming to the market. As discussed in McInish and Wood (1992), higher trading activity is associated with lower spreads because of the economies of scale in trading costs. The riskiness of a security is another determinant of the spreads: higher risks of holding a security are associated with higher spreads. Finally, as the amount of information coming to the market increases, traders increase the spread to protect

[10] McInish and Wood (1992) use similar exogenous variables.

themselves from the possibility of informed trading. We use the following exogenous variables:

$\log(Trades_{i,t})$: log of number of trades for each stock in each 15-min. interval;

$\log(Size_{i,t})$: log of average number of shares per trade for each stock for each 15-min. interval;

As the trading activity increases, spreads might decrease because of the economies of scale in trading costs or they might increase since higher activity might be a signal of informed trading. Which of these effects dominate is an empirically open question. McInish and Wood (1992) find that size is negatively related to spreads for their sample.

$Z\log(Size_{i,t})$: Normalized value of log(size);

Zlog(Size) is calculated by subtracting from log(size) its mean and dividing the result by its standard deviation. This variable is intended to measure the effect of unusually large or small trades relative to the average size of the trades for each stock.

We use two risk measures. Following the notation of McInish and Wood (1992), let $V_{i,t}$ be the standard deviation of the time-weighted quote midpoint for each stock i in interval t, let M_i be the mean of $V_{i,t}$ for stock i over all t, and let S_i be the standard deviation of $V_{i,t}$ for stock i over all t. The first measure of risk for stock i is M_i and the second risk measure for stock i in interval t is $(V_{i,t} - M_i)/S_i$. The first measure captures the cross sectional differences between stocks, and the second measure captures the differences of risks between different 15-min intervals for each stock.

$Risk1_i$: M_i;

$Risk2_{i,t} : (V_{i,t} - M_i)/S_i$;

As shown in some previous studies, stock price is also inversely related to the spread. Accordingly, we also include the following variable in our regression model.

$\log(Price_{i,t})$: log of average price for each stock i in interval t.

Table 2. Descriptive Statistics

Average of the variables used in the regression analysis.

Market Value Deciles	Percentage Spread	Number of Trades	Trade Size	Z(Trade Size)	Risk 1	Risk 2	Price
1	0.0391	18.3082	678.5772	0.0172	0.9110	0.0012	1.0158
2	0.0241	20.9512	623.7451	0.0009	0.4899	-0.0037	1.7477
3	0.0198	20.3425	511.6836	0.0168	7.7575	-0.0056	9.4542
4	0.0167	22.7649	627.6530	0.0158	0.8237	-0.0128	2.7512
5	0.0235	24.6662	972.5471	-0.0109	0.7071	0.0139	2.5120
6	0.0120	28.5051	749.9045	0.0115	10.3618	-0.0077	40.8825
7	0.0143	30.3814	1113.5889	0.0044	6.3716	0.0006	34.0857
8	0.0122	25.2018	1103.0815	0.0136	6.7336	0.0042	34.8764
9	0.0101	28.4313	1105.5592	0.0074	2.4224	-0.0017	8.3342
10	0.0130	58.0182	2748.5354	-0.0020	3.9545	0.0133	11.9209

Table 2 reports the mean values of the independent variables by market value deciles. Overall conclusion from this table is that the stocks of the companies with the highest market values generally have lower spreads, and higher trading activity in terms of number of trades and trade size.

Our regression model is:

$$\begin{aligned} TWPSpread_{i,t} = {} & \beta_0 + \beta_1 \log(Trades_{i,t}) + \beta_2 \log(Size_{i,t}) + \beta_3 Z \log(Size_{i,t}) \\ & + \beta_4 Risk1_i + \beta_5 Risk2_{i,t} + \beta_6 \log(Price_{i,t}) \\ & + 20\ Interval\ Dummy\ Variables \\ & + 4\ Weekday\ Dummy\ Variables + \varepsilon_{i,t} \end{aligned} \quad (1)$$

where the $TWPSpread_{i,t}$ is the time weighted percentage bid-ask spread for stock *i*, in interval *t*, independent variables are as defined above, *Interval Dummy Variables* are dummies for each 15-min interval (15.15-15.30 is excluded), *Weekday Dummy Variables* are dummies for days of the week (Wednesday is excluded), and $\varepsilon_{i,t}$ is the error term. We estimate equation 1 by using both pooled OLS estimator using heteroskedasticity consistent standard errors and panel fixed effects estimator using heteroskedasticity and autocorrelation (HAC) consistent standard errors. To be able to compare the impact of independent variables on the dependent variable, we also estimate equation (1) by using standardized versions of all variables to obtain standardized coefficients (sometimes called beta coefficients).

3.2. Results

3.2.1. Minute-by-Minute Analysis

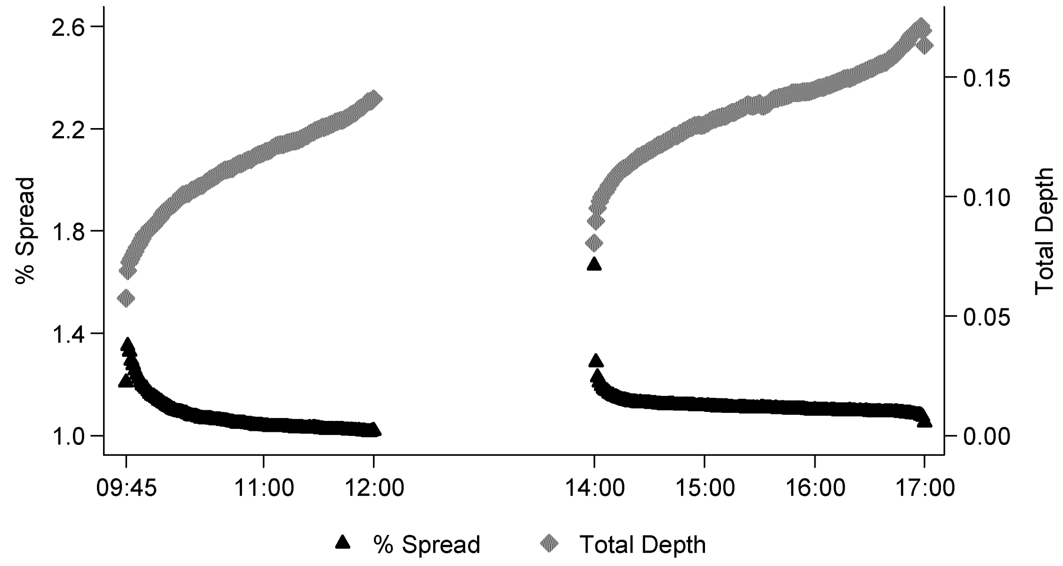
Figure 1 displays the minute-by-minute series for both percentage spreads and depths. Examination of this figure shows that spreads are high at the beginning of the first session and decline at a decreasing rate until the close of the session. Second session starts with wide spreads, but drops quickly in the first interval and keeps declining towards the end of the day.

Both total quoted depth and total cumulative depth are low at the beginning of the sessions and keep increasing at a decreasing rate towards the end of the session. Therefore, the liquidity is low at the beginning of each session when information asymmetry might be high, and it keeps increasing as more and more information is revealed to the market.[11] These results are consistent with findings of Lee, Mucklow and Ready (1993) that liquidity providers use both spreads and depths to manage information asymmetry risk at the ISE. Informed traders might try to exploit their overnight information at the beginning of the day and mostly uninformed limit order traders increase (decrease) the spread (depth) to protect themselves from possible informed trading. As trading continues, private information is incorporated into the prices and spreads decline (depths increase) since the informational disadvantage of the uninformed traders disappear. A similar argument holds to explain the low liquidity at the beginning of the second session. Higher liquidity at the end of both sessions when compared to the beginning of the sessions can be attributed to the cost of carrying inventory. The traders try to minimize the risk of carrying excess inventory during the lunch break or overnight by lowering the spreads and increasing depth at the end of the trading sessions to close their positions.

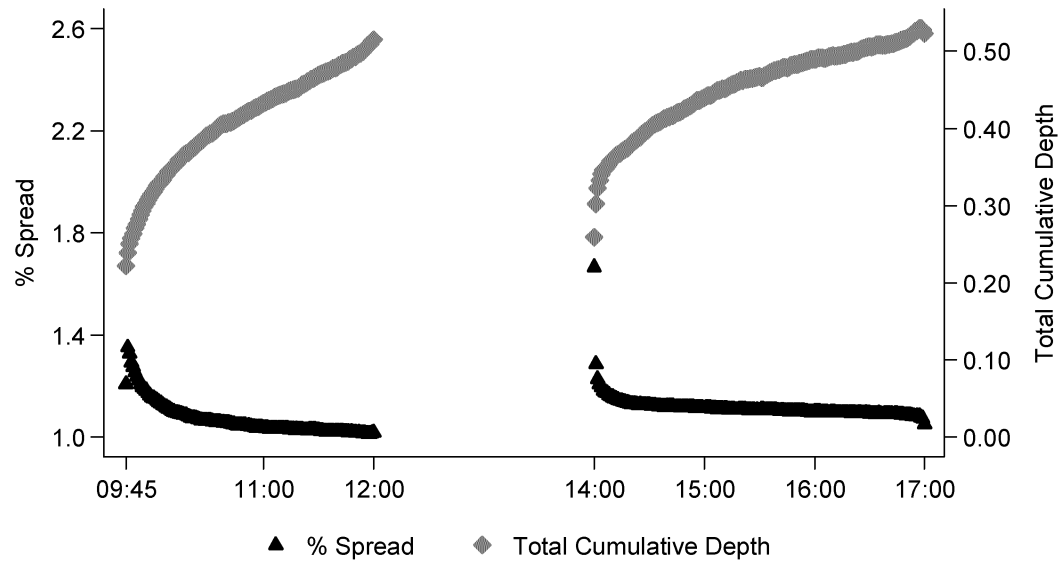
[11] The behavior of spreads and depths are similar for the periods January-April 2008 and September-December 2007.

Figure 1. Mean % Bid-Ask Spreads and Capitalization Weighted Depths for Each Minute of the Trading Day

a. Minute-by-minute % Spreads and Total Depth at the Best Prices



b. Minute-by-minute % Spreads and Total Cumulative Depth at the Best Five Prices



Note. Spread and depth measures are multiplied by 100.

Table 3. The Relation Between Spreads and Depths

Panels A and B reports the frequency distribution for spread and depth categories. Percentage spreads and depths (total depth and total cumulative depth) scaled by shares outstanding at the end of each 15-min interval for all stocks and days in the sample period are classified into one of 9 categories, based on whether the time weighted percentage spread and total quoted (and cumulative) depth in that interval are higher, lower or equal to their respective medians. Table values represent the number of 15-min intervals in each category. Values in parentheses are the expected number of 15-min intervals in each category under the null hypotheses that spreads and depths are uncorrelated. Panel C reports the correlation coefficients between all percentage spreads and depths at the end of each 15-min interval for each stock. Low (High) volume stocks are those stocks that have lower (higher) volume than the median volume over the sample period.

Panel A.

Relation of Spreads to Median Firm Spread	Relation of Depths to Median Firm Depth			
	Below	Equal	Above	Total
Below	101.285 (104,589)	534 (521)	106.054 (102,762)	207.873
Equal	8.654 (8,610)	12 (43)	8.447 (8,460)	17.113
Above	105.563 (102,302)	528 (510)	97.237 (100,516)	203.328
Total	215.502	1.074	211.738	428.314

Panel B.

Relation of Spreads to Median Firm Spread	Relation of Cumulative Depths to Median Firm Cumulative Depth			
	Below	Equal	Above	Total
Below	100.701 (109,236)	1.331 (1,305)	105.841 (97,332)	207.873
Equal	9.303 (8,993)	243 (107)	7.567 (8,013)	17.113
Above	115.073 (106,848)	1.114 (1,276)	87.141 (95,204)	203.328
Total	225.077	2.688	200.549	428.314

Panel C.

	Low Volume		High Volume	
Corr. Between Spread and Depth	Frequency	Percent	Frequency	Percent
Negative	125	76,69	102	62,58
Positive	38	23,31	61	37,42

	Low Volume		High Volume	
Corr. between Spread and Cumulative Depth	Frequency	Percent	Frequency	Percent
Negative	127	77,91	104	66,24
Positive	36	22,09	53	33,76

To support the results above statistically, we construct a table similar to what Lee, Mucklow and Ready (1993) have on p.360. Table 3 reports the frequency distribution for spread and depth categories as well as correlations. Percentage spreads and depths (total depth and total cumulative depth) scaled by shares outstanding at the end of each 15-min interval for all stocks and days in the sample period are classified into one of 9 categories, based on whether the time weighted percentage spread and total quoted (and cumulative) depth in that interval are higher, lower or equal to their respective medians. Table values in Panels A and B represent the number of 15-min intervals in each category. Values in parentheses are the expected number of 15-min intervals in each category under the null hypotheses that spreads and depths are uncorrelated. Unexpectedly large number of intervals in the upper right and lower left corner cells show that high (low) spreads tend to be associated with low (high) depths. The χ^2 statistic for this table strongly rejects the null hypothesis of independence in spread and depth levels.

Panel C reports the correlation coefficients between all percentage spreads and depths at the end of each 15-min interval for each stock according to trading volume categories. Low (High) volume stocks are those stocks that have lower (higher) volume than the median volume over the sample period. Approximately 77% (63%) of all low (high) volume stocks have negative correlations between percentage spreads and depths. Similarly, approximately 78% (66%) of all low (high) volume stocks have negative correlations between percentage spreads and cumulative depths. These results suggest that liquidity providers use both spreads and depths to manage information asymmetry risk on the ISE for most stocks. The percentage of negative coefficients is higher for low volume stocks, possibly because it is more necessary for the traders to use both variables to implement their strategies because of the low volume.

3.2.2. Interval Analysis

Table 4 presents the results from estimating our regression model. All estimated coefficients (except for coefficients of some dummy variables) are significant at the 1% level. The signs and statistical significance of the coefficients are same for both pooled OLS estimator and panel fixed effects estimator.

The coefficient of $\log(Trades)$ is positive implying that higher trading activity is associated with higher spreads. This is possibly because uninformed traders increase the

Table 4. Regression Results

This table reports results from estimating equation (1). The dependent variable is the time weighted percentage spread. ***, **, and * denote significance level at the 1%, 5%, and 10% levels, respectively. Test5 and Test24 are F statistics for pooled OLS and chi-square statistics for panel-fixed-effects estimator that test the null hypothesis that weekday dummies and 15-min time interval dummies are all equal to zero, respectively. t-statistics are calculated by using heteroskedasticity consistent standard errors for OLS estimator and heteroskedasticity and autocorrelation (HAC) consistent standard errors for panel fixed effects estimator. "Std. C." columns report coefficients obtained from the same regressions by using standardized variables.

Panel A.	**Pooled OLS**				**Panel Fixed Effects with HAC Errors**			
Independent Variables	**Coefficients**	***t*-stat**		**Std. C.**	**Coefficients**	***t*-stat**		**Std. C.**
Intercept	0.02036919	89.71	***		0.02173929	36.83	***	
log(Trades)	0.00065257	8.18	***	0.06	0.00088587	8.35	***	0.08
log(Size)	-0.00183389	-30.99	***	-0.24	-0.00147258	-8.34	***	-0.19
Zlog(Size)	0.00255704	24.08	***	0.13	0.00139626	5.51	***	0.07
Risk 1	0.00007338	8.70	***	0.14				
Risk 2	0.00425703	10.89	***	0.31	0.00435916	10.84	***	0.32
log(Price)	-0.00367955	-36.95	***	-0.35	-0.00653518	-14.44	***	-0.63
9:45-10.00	0.00548917	32.59	***		0.00503207	33.94	***	
10.00-10.15	0.00145253	10.87	***		0.00129062	10.61	***	
10.15-10.30	0.00073010	8.84	***		0.00057933	8.42	***	
10.30-10.45	0.00050739	5.73	***		0.00042223	5.85	***	
10.45-11.00	0.00032098	3.47	***		0.00030354	3.76	***	
11.00-11.15	0.00015664	1.80	*		0.00019951	2.74	***	
11.15-11.30	0.00012942	1.38			0.00019279	2.44	**	
11.30-11.45	0.00020134	1.93	*		0.00027395	2.96	***	
11.45-12.00	0.00035135	2.40	**		0.00027915	2.01	**	
14.00-14.15	0.00255301	18.12	***		0.00118491	11.44	***	
14.15-14.30	0.00120042	10.05	***		0.00060427	6.68	***	
14.30-14.45	0.00084940	7.78	***		0.00033333	4.42	***	
14.45-15.00	0.00077376	4.32	***		0.00018458	1.15		
15.00-15.15	0.00002017	0.26			0.00003731	0.64		
15.30-15.45	-0.00004555	-0.60			-0.00004840	-0.81		
15.45-16.00	0.00000197	0.02			-0.00002540	-0.38		
16.00-16.15	-0.00002277	-0.28			-0.00002260	-0.38		
16.15-16.30	-0.00008504	-0.83			-0.00010262	-1.15		
16.30-16.45	0.00000758	0.09			-0.00001496	-0.22		
16.45-17.00	-0.00037268	-3.73	***		-0.00067032	-6.33	***	
Monday	0.00020403	2.93	***		0.00016753	2.02	**	
Tuesday	0.00017250	2.02	**		0.00012688	1.33		
Thursday	-0.00002700	-0.32			-0.00001503	-0.15		
Friday	-0.00004286	-0.59			-0.00001087	-0.13		
$Test_5$	5.45***				1718.97***			
$Test_{24}$	90.79***				7.53**			
R^2	0.16				0.13			
N	214608				214608			

spread during higher trading activity to protect themselves from possibility of informed trading. $\log(Size)$ affects the spread negatively because of the economies of scale in trading costs. The coefficient of $Z\log(Size)$ is significantly positive demonstrating that the information flow as measured by trades of unusual size causes the spreads to increase.

The coefficients of $Risk1$ and $Risk2$ are significantly positive showing that spreads are higher for more risky stocks and during intervals of higher risk.[12] Finally, the significantly negative coefficient of $\log(Price)$ shows that stocks with higher prices have smaller spreads.

The coefficients of interval dummy variables generally decrease starting from the beginning of the sessions supporting the spread behavior displayed in Figure 1. As more and more information is incorporated into the prices, spreads get smaller and smaller towards the end of the sessions. $Test_{24}$ is the F statistics for pooled OLS and *chi-square* statistics for panel-fixed-effects estimator *that* tests the null hypothesis that 15-min time interval dummies are all equal to zero, respectively. This statistic is significant at the 1% level, showing that mean spreads for different intervals are significantly different.

The coefficients of the weekday dummies for Monday and Tuesday are significant, i.e., there are day-of-week effects for spreads. The sign of the coefficients indicate that on average, spreads on Monday and Tuesday are higher than other days of the week. $Test_5$ is the F statistics for pooled OLS and *chi-square* statistics for panel-fixed-effects estimator that tests the null hypothesis that weekday dummies are all equal to zero respectively. This statistic is significant at the 1% level, showing that weekday mean spreads are significantly different.

The columns titled "Std. C." report the standardized coefficients.[13] These coefficients can be used to assess the *importance* of variables in terms of their effects on spreads. Since all variables are standardized in these regressions, the magnitudes of the coefficients are interpreted in terms of standard deviations and they are comparable across independent variables. For example, pooled OLS results indicate that, when log(*Trades*) increase by 1 standard deviation, time weighted percentage spread increases

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[12] Since *Risk*1 does not vary over time, its effect on spreads cannot be estimated by panel fixed effects estimator.
[13] The standardized coefficients for dummy variables are not reported for simplicity.

by 0.06 standard deviations. The magnitudes of standardized coefficients are somewhat different for pooled OLS and panel fixed effects estimator, but the message from these coefficients is clear: First, the most important variable, in terms of economic significance, is the price level of the stocks, followed by *Risk*2 (measure of the differences of risks between different 15-min intervals for each stock) and log(*Size*). The impacts of these three variables are also economically large. When log(*Price*) and log(*Size*) increase by 1 standard deviation, the time weighted spread decreases by 0.35 (0.63) and 0.24 (0.19) standard deviations, respectively, based on pooled OLS (panel fixed effects) estimator. In addition, a 1 standard deviation increase in *Risk*2 cause the time weighted spread to increase by 0.31 (0.32) standard deviations based on pooled OLS (panel fixed effects) estimator.

4. Intraday Returns, Number of Trades and Volume

4.1. Data and Empirical Methodology

We use proprietary transaction data obtained from the ISE that covers the three month period May-July 2008 for all ISE stocks to calculate the returns, number of trades and volumes for 15-min. intervals.[14] These intervals are 09:45-10:00, … , 11:45-12:00, 14:00-14:15, … , 16:45-17:00. Transaction data provides detailed info about the transactions such as date, time, session, quantity, price, IDs of buy and sell orders that have been matched and transactions are time stamped to the second.

We calculate the returns for each stock as $r_t = 100 \cdot (\log(P_t) - \log(P_{t-1}))$ where P_t is the stock price at the end of 15-min. interval t and adjusted for dividends and changes in capitalization. We then calculate the average of returns for all stocks across each 15-min. interval to obtain what we call the *market returns*.

To investigate the trading volume and number of trades, we first calculate the volume, TL volume, and number of trades for each stock for each 15-min. interval. Then we divide these variables by the number of shares outstanding to make meaningful comparisons. Finally, we calculate the means for all stocks across each 15-min. interval to obtain the *market* variables. We also report the intraday behavior of returns, number

[14] The behavior of these variables is generally similar for the periods January-April 2008 and September-December 2007.

of trades, and volume for days of the week, to see if there exist week-of-the-day effects reported in the literature for different stock exchanges.

4.2. Results

Returns

Figure 2 presents the trading day market returns plotted against 15-min. intervals for the whole sample and for the days of the week. The pattern in the first graph shows high initial returns (around 0.21%), followed by a drop to -0.09% for the second 15-min. interval. The market return increases to 0.08% in the last interval of the first session. Market returns on the ISE displays a U-shaped pattern in the first session similar to the findings of Wood, McInish and Ord (1985) and others. Second session starts with negative returns (-0.17%) followed by an increase to returns that span zero until the interval 16:30-16:45 in which the market return drops to -0.14%. ISE closes the day with a positive return of 0.22%.

U-shaped pattern seems to exist for each day of the week, although it is less pronounced for some days. Positive beginning of the day returns exist for all days except for Tuesday. The second session starts with a negative return and ends with a positive return for all days. Very high beginning of the day returns for Wednesday (0.57%) seems to be an interesting finding.

The intraday behavior displayed in Figure 2 depicts some differences across day of the week. To see if these differences are statistically significant and Monday returns are different from other weekdays as found in some of the earlier literature,[15] we perform analysis of variance (ANOVA) tests across 15-min. intervals and across days. Table 5 reports average returns for each time interval of each day of the week. F_5 tests whether the five weekday return means are equal, F_{Mon} tests whether Monday means are equal to the means for the rest of the days, and F_4 tests whether weekday means except for Monday are equal to each other. ***, ** and * denotes significance levels at the 1%, 5% and 10% levels, respectively. As indicated by insignificant values of F_{Mon}, mean of Monday returns is not very different from the other days.

[15] See, for example, Harris (1986).

Figure 2. Mean 15-Min Returns in Percent

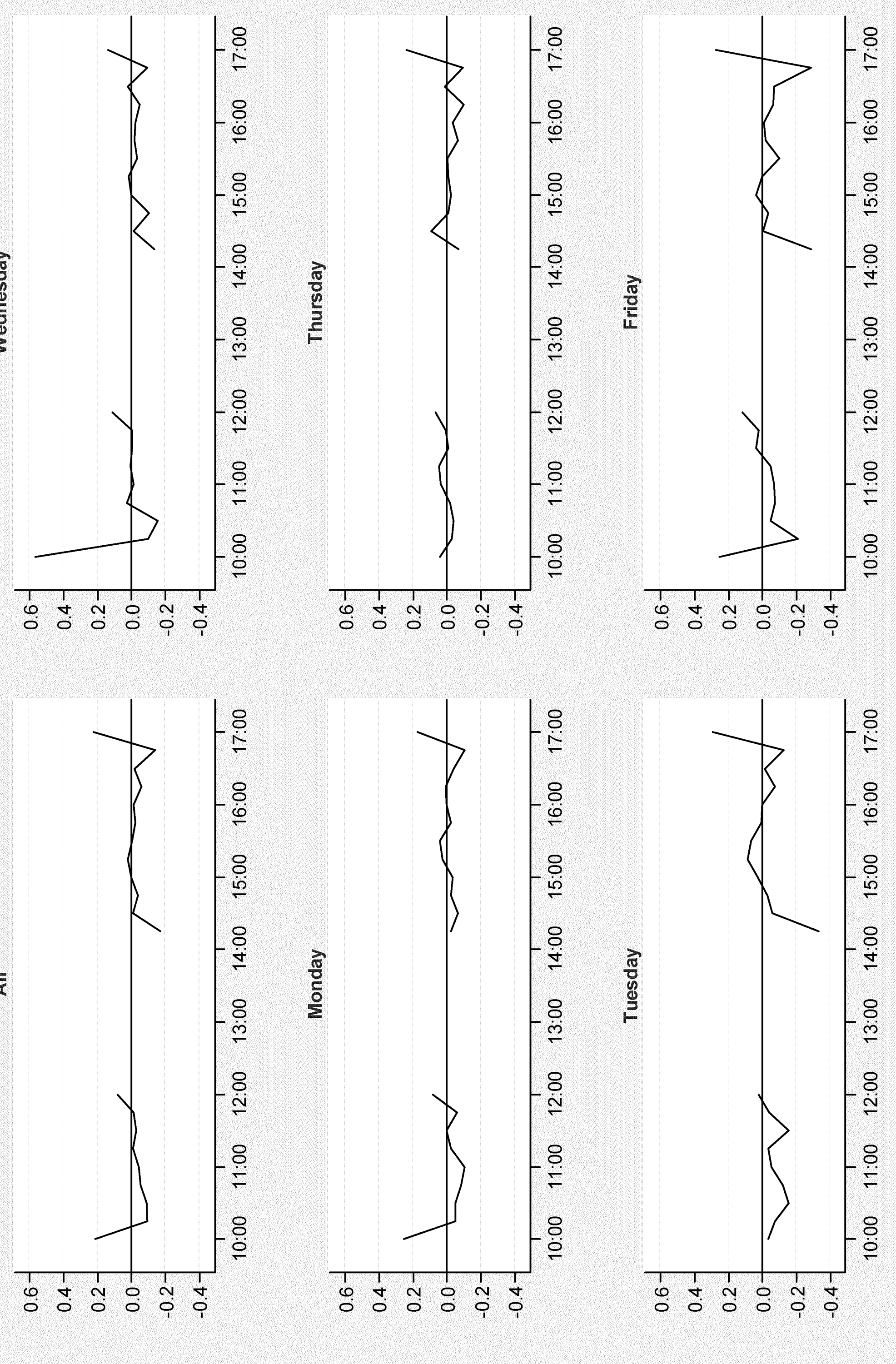

Table 5. Mean 15-Min. Returns in Percent

15-minute Interval	Means in Percent									
	Mon	Tue	Wed	Thu	Fri	F_5		F_{Mon}	F_4	
Session 1										
09:45-10:00	0.2515	-0.0309	0.5679	0.0405	0.2533	1.61		0.05	2.07	
10:00-10:15	-0.0507	-0.0744	-0.1005	-0.0295	-0.2108	1.30		0.53	1.52	
10:15-10:30	-0.0507	-0.1542	-0.1519	-0.0365	-0.0506	1.05		0.51	1.11	
10:30-10:45	-0.0818	-0.1169	0.0250	-0.0194	-0.0716	1.31		0.44	1.46	
10:45-11:00	-0.1037	-0.0553	-0.0151	0.0354	-0.0709	1.45		2.38	1.27	
11:00-11:15	-0.0211	-0.0335	0.0049	0.0483	-0.0459	0.95		0.13	1.09	
11:15-11:30	0.0000	-0.1550	-0.0041	-0.0098	0.0385	3.55	**	0.46	3.96	**
11:30-11:45	-0.0588	-0.0399	-0.0022	0.0063	0.0236	0.98		2.14	0.61	
11:45-12:00	0.0824	0.0235	0.1116	0.0662	0.1194	0.83		0.00	1.13	
Session 2										
14:00-14:15	-0.0253	-0.3316	-0.1311	-0.0681	-0.2858	1.88		2.49	1.43	
14:15-14:30	-0.0640	-0.0587	-0.0119	0.0927	-0.0030	1.00		0.95	1.11	
14:30-14:45	-0.0238	-0.0277	-0.1057	-0.0074	-0.0345	0.46		0.10	0.53	
14:45-15:00	-0.0326	0.0259	0.0018	-0.0237	0.0361	0.66		1.06	0.68	
15:00-15:15	0.0267	0.0887	0.0197	-0.0081	0.0000	0.86		0.00	0.99	
15:15-15:30	0.0430	0.0659	-0.0324	-0.0041	-0.0970	2.91	**	1.83	2.87	**
15:30-15:45	-0.0225	0.0066	-0.0181	-0.0640	-0.0177	0.18		0.00	0.21	
15:45-16:00	0.0026	0.0007	-0.0211	-0.0328	-0.0080	0.22		0.26	0.18	
16:00-16:15	0.0055	-0.0725	-0.0463	-0.1001	-0.0640	0.64		2.00	0.19	
16:15-16:30	-0.0379	-0.0157	0.0216	0.0114	-0.0675	0.83		0.33	0.83	
16:30-16:45	-0.1021	-0.1219	-0.0910	-0.0929	-0.2852	2.59	**	0.54	2.88	**
16:45-17:00	0.1723	0.2946	0.1372	0.2360	0.2741	1.42		1.00	1.36	
F_{24}	2.35***	2.95***	6.13***	1.01	4.88***					
$F_{Session}$	0.00	3.29*	5.55**	0.26	2.01					
F_{Open1}	7.21***	0.10	25.61***	0.01	1.02					
F_{Open2}	1.49	7.00***	5.65**	0.05	1.17					
F_{Inner1}	1.23	2.63***	1.36	1.14	2.83***					
F_{Inner2}	1.72*	1.98**	1.51	0.94	1.75**					
F_{Close}	9.84***	23.09***	3.70*	11.38***	20.19***					

Values of F_5 are significant for three intervals (11:15-11:30, 15:15-15:30, 16:30-16:45) showing that mean returns are different across days for these intervals. Since both F_5 and F_4 are significant for the intervals above but not F_{Mon}, the significant differences in means seem to be between days of the week other than Monday.

Table 5 also reports results of ANOVA tests that examine equality of intraday means for each weekday. F_{24} tests whether the mean returns on a given weekday are equal within each 15-min. interval, $F_{Session}$ tests whether the session means are equal, F_{Open1} tests whether the mean of the first 15-min. returns is different from the mean of the rest of the intervals, F_{Open2} tests whether the mean of the first two 15-min. intervals is different from the mean of the rest of the intervals, F_{Inner1} tests whether the means of the intervals other than the first and last one (close) are equal, F_{Inner2} tests whether the means of the intervals other than the first two and last one (close) are equal, and finally F_{Close} tests whether the mean of the last 15-min returns is different from the mean of the other intervals.

Values of F_{24} are significant at the 1% level (except for Thursday), confirming the results presented in Figure 2. Intraday 15-min. mean returns are significantly different. $F_{Session}$ is significant at the 10% and 5% levels for Tuesday and Wednesday, respectively, indicating that the mean of the 15-min returns for the first session is significantly different than the second session. There are no significant differences between session means for the other days. Values of F_{Open1} and F_{Open2} show that mean of the beginning-of-the-day returns is significantly different from the mean of the returns for the rest of the day for the first three days of the week. F_{Inner1} and F_{Inner2} are statistically significant for Tuesday and Friday, revealing that means of the intervals except for opening and closing intervals are significantly different. Finally, F_{Close} is significant for all days, showing that mean of end-of-day returns is significantly different from the rest of the day.

Number of Trades

Figure 3 shows the intraday behavior of the mean number of trades within each 15-min. interval. Mean number of trades is high at the beginning of the first session, declines continuously towards the end of the session and somewhat increases in the last interval. Mean number of trades at the beginning-of-the-first session is almost twice as much as the mean number of trades at the end of this session and its behavior in the first session seems to be different on Thursdays.

Figure 3. Mean 15-Min. Number of Trades in Percent

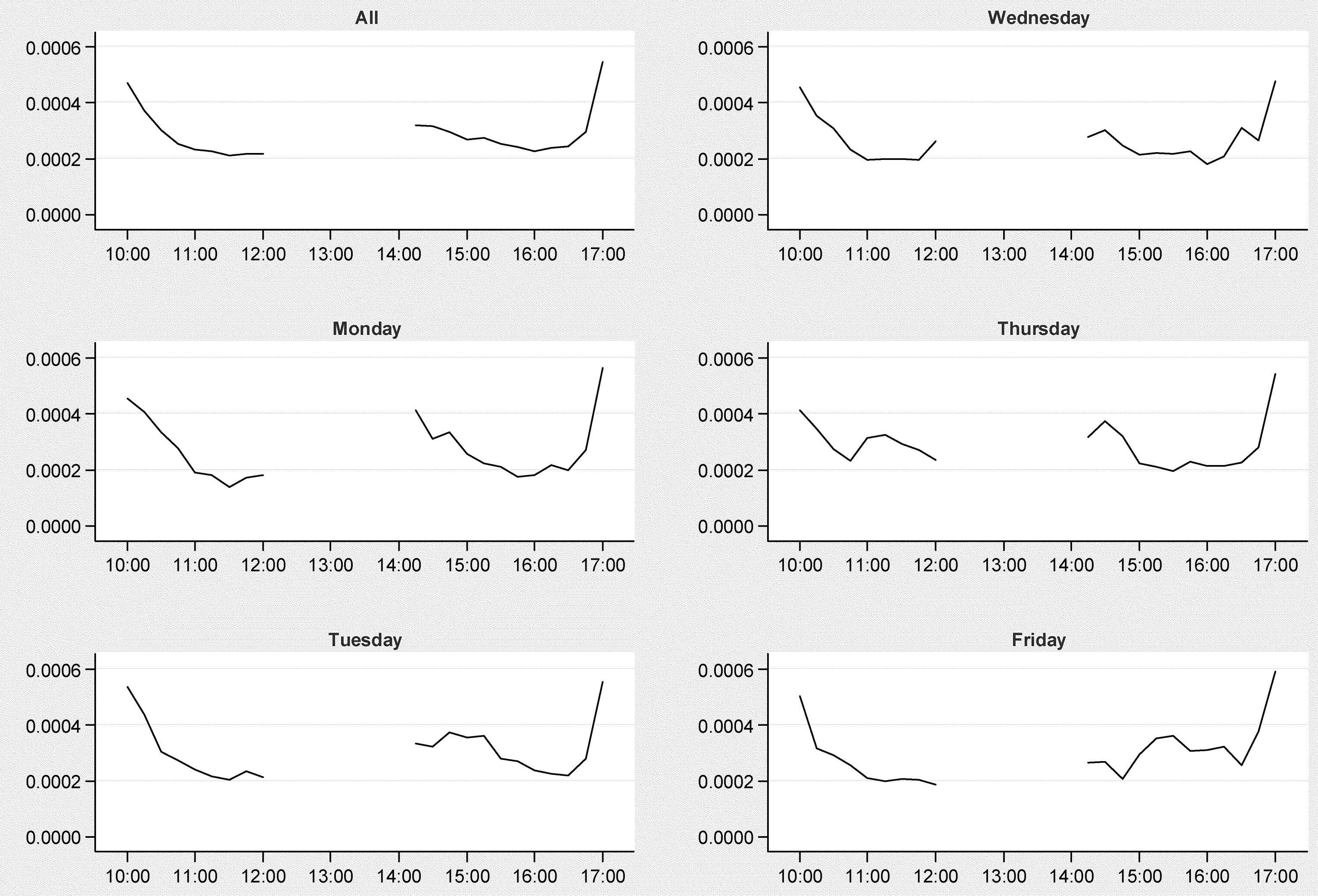

Table 6. Mean 15-Min. Number of Trades in Percent

15-minute Interval	Means in Percent					F_5	F_{Mon}		F_4
	Mon	Tue	Wed	Thu	Fri				
Session 1									
09:45-10:00	0.00046	0.00054	0.00045	0.00041	0.00050	0.63	0.08		0.82
10:00-10:15	0.00041	0.00044	0.00035	0.00035	0.00032	0.87	0.54		1.13
10:15-10:30	0.00033	0.00030	0.00031	0.00027	0.00029	0.21	0.57		0.17
10:30-10:45	0.00028	0.00027	0.00023	0.00023	0.00026	0.24	0.36		0.26
10:45-11:00	0.00019	0.00024	0.00020	0.00031	0.00021	1.79	1.28		1.84
11:00-11:15	0.00018	0.00022	0.00020	0.00033	0.00020	1.60	1.05		1.77
11:15-11:30	0.00014	0.00021	0.00020	0.00029	0.00021	1.71	3.39	*	1.01
11:30-11:45	0.00017	0.00023	0.00020	0.00027	0.00021	0.66	1.09		0.49
11:45-12:00	0.00018	0.00021	0.00026	0.00023	0.00019	0.60	0.74		0.49
Session 2									
14:00-14:15	0.00041	0.00033	0.00028	0.00032	0.00027	0.36	1.14		0.24
14:15-14:30	0.00031	0.00032	0.00030	0.00037	0.00027	0.28	0.01		0.39
14:30-14:45	0.00034	0.00037	0.00025	0.00032	0.00021	1.10	0.41		1.43
14:45-15:00	0.00026	0.00036	0.00021	0.00022	0.00030	1.09	0.06		1.34
15:00-15:15	0.00022	0.00036	0.00022	0.00021	0.00035	1.16	0.56		1.15
15:15-15:30	0.00021	0.00028	0.00022	0.00020	0.00036	0.75	0.33		0.75
15:30-15:45	0.00017	0.00027	0.00023	0.00023	0.00031	0.64	1.44		0.32
15:45-16:00	0.00018	0.00024	0.00018	0.00021	0.00031	0.71	0.55		0.65
16:00-16:15	0.00022	0.00022	0.00021	0.00021	0.00032	0.63	0.14		0.70
16:15-16:30	0.00020	0.00022	0.00031	0.00023	0.00026	1.41	1.72		1.15
16:30-16:45	0.00027	0.00028	0.00027	0.00028	0.00038	1.37	0.39		1.59
16:45-17:00	0.00056	0.00055	0.00048	0.00054	0.00059	0.82	0.16		1.12
F_{24}	3.19***	3.3***	4.05***	2.62***	1.82**				
$F_{Session}$	0.41	0.70	0.05	0.79	3.44*				
F_{Open1}	13.00***	21.17***	23.18***	6.51**	4.53**				
F_{Open2}	18.12***	14.18***	17.96***	9.64***	1.21				
F_{Inner1}	1.38	1.07	1.20	0.95	0.49				
F_{Inner2}	1.67*	1.16	1.45	0.78	0.53				
F_{Close}	21.01***	19.01***	25.79***	25.16***	16.01***				

In the second session, the behavior of the mean number of trades exhibits a U-shaped pattern. But again, there seems to be some differences between days of the week. Another noteworthy observation is that the level of trading at the end of the day is a little more than the beginning of the day.

Table 6 reports the mean number of trades (scaled by shares outstanding) for each time interval of each day of the week. F-statistics are defined similar to the above. We don't find any evidence of day-of-the-week effects. Almost all values of F_4, F_5, and F_{Mon} are insignificant. Apparent intraday behavior in Figure 2 causes the value of F_{24} to be highly significant, however, confirming the observation that mean number of trades for each time interval is significantly different from each other. $F_{Session}$ is significant at the 10% level for Friday only, showing that mean number of trades is close to each other for the first and the second sessions. Figure 2 also reveals a clear U-shaped pattern in the behavior of the mean number of trades. This is confirmed by the values of F_{Open1}, F_{Open2}, F_{Inner1}, F_{Inner2} and F_{Close}. F_{Open1} and F_{Open2} are highly significant indicating that beginning-day trading is very different than the rest of the day. Similarly, F_{Close} is significant at the 1% level showing that end-of-day trading is different from the rest of the day. Finally, values of F_{Inner1} and F_{Inner2} are not significant, which confirms the flat behavior seen in Figure 2 for inner day trading.

Volume

We examine the behavior of both share volume and TL volume since for the same number of shares, more capital is put at risk for higher-priced stocks. Figure 4 displays the behavior of mean share volume scaled by shares outstanding. Volume is high at the beginning of the day and declines towards the end of the first session. Volume level at the beginning of the second session is somewhat higher than the level at the end of the first session. The volume in the second session follows a U-shaped pattern. It decreases towards the middle of the second session and closes the day at a level that is higher than the level seen at the beginning of the day.

Table 7 reports the mean volume for time intervals and days of the week. There exists evidence for the day-of-week effects in volume behavior. Values of F_5 and F_{Mon} are significant for 09:45-10:00, 10:00-10:15, 11:15-11:30 and 11:30-11:45, but F_4 statistics are not significant. This provides evidence that mean volume on Monday is significantly different than the rest of the weekdays for the beginning and end of the first session. There is a similar finding for the intervals of 15:30-15:45 and 16:00-16:15. When we examine the F-statistics for the equality of the means for a given day, we see that almost all F-statistics (F_{Open1}, F_{Open2}, F_{Inner1}, F_{Inner2} and F_{Close}. F_{Open1} and F_{Open2}) are significant providing evidence for significant intraday differences. The session means seem not to be very different, however, except for Monday. Overall, Table 7 suggests that Monday volume is different from the rest of the weekdays, and there exist significant intraday differences between time-intervals.

We also examine TL volume to determine possible differences with share volume. Figure 5 displays the intraday behavior of the TL volume for different days of the week. The patterns seen in Figure 5 are similar to Figure 4 in the sense that TL volume is high at the beginning of the day and decreases towards the session end. The difference is that the U-shaped pattern for TL volume in the second session is not as smooth as the one in Figure 4. For example on Friday and Thursday, TL volume first increases, followed by a decrease and then it increases again towards the end of the day. Wednesday's pattern seems like U-shaped overall, but again, the line pattern is not smooth. The first graphs of Figures 4 and 5 seem to be similar however.

Figure 4. Mean 15-Min. Share Volumes in Percent

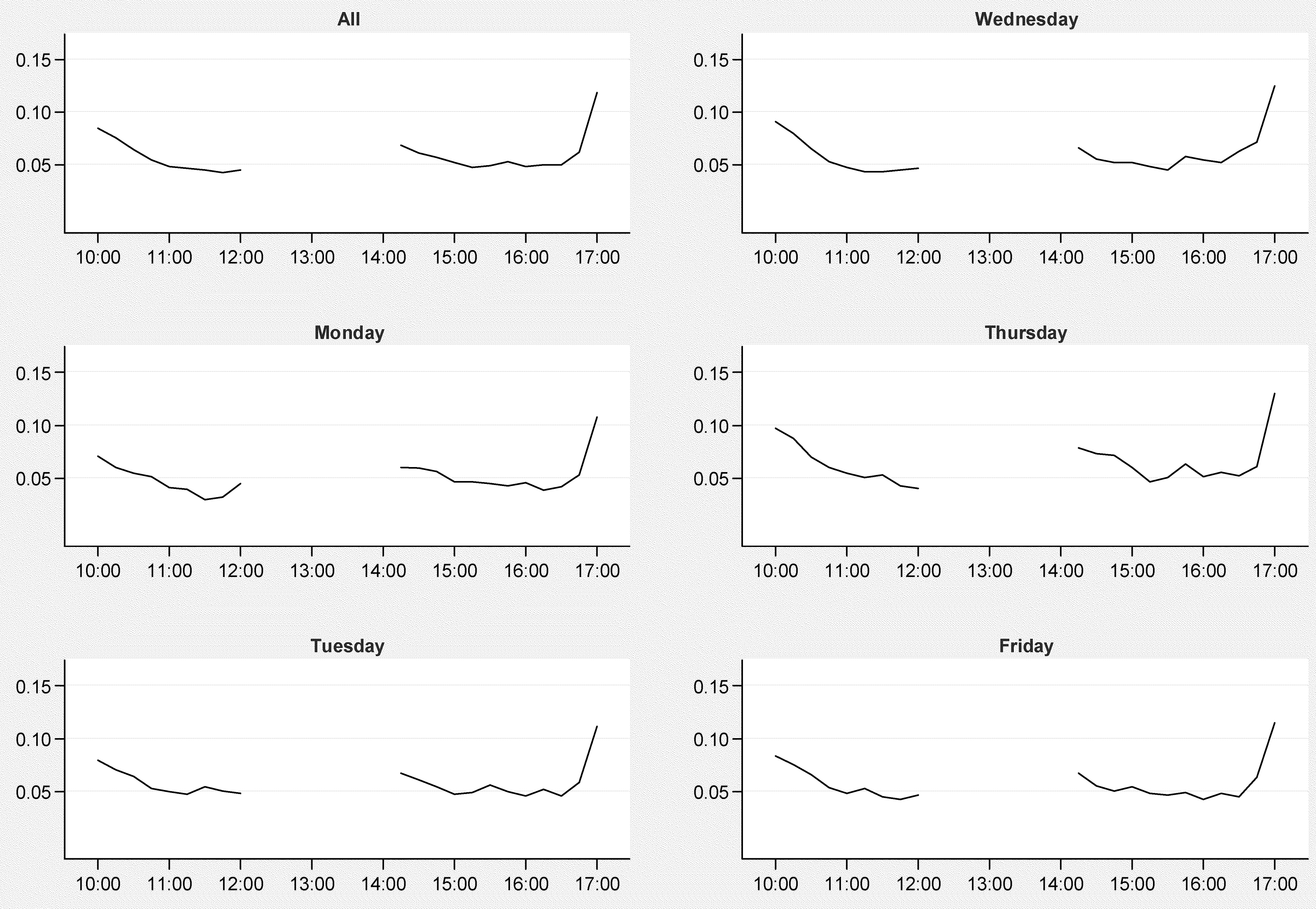

Table 7. Mean 15-Min. Share Volumes in Percent

15-minute Interval	Means in Percent					F_5		F_{Mon}		F_4
	Mon	Tue	Wed	Thu	Fri					
Session 1										
09:45-10:00	0.0707	0.0799	0.0909	0.0970	0.0836	2.25	*	4.95	**	1.27
10:00-10:15	0.0603	0.0708	0.0797	0.0879	0.0757	2.59	**	6.20	**	1.20
10:15-10:30	0.0546	0.0644	0.0649	0.0701	0.0657	0.82		2.81	*	0.21
10:30-10:45	0.0517	0.0532	0.0533	0.0601	0.0542	0.34		0.31		0.51
10:45-11:00	0.0411	0.0499	0.0471	0.0544	0.0485	1.01		2.71		0.48
11:00-11:15	0.0392	0.0474	0.0438	0.0503	0.0527	1.29		3.15	*	0.68
11:15-11:30	0.0296	0.0550	0.0431	0.0528	0.0449	5.04	***	14.25	***	1.64
11:30-11:45	0.0325	0.0509	0.0452	0.0426	0.0425	2.17	*	6.34	**	0.75
11:45-12:00	0.0452	0.0483	0.0463	0.0401	0.0465	0.59		0.00		0.78
Session 2										
14:00-14:15	0.0607	0.0672	0.0658	0.0789	0.0672	1.28		1.79		1.02
14:15-14:30	0.0598	0.0607	0.0556	0.0732	0.0555	1.60		0.05		2.13
14:30-14:45	0.0565	0.0549	0.0525	0.0716	0.0503	1.38		0.02		1.77
14:45-15:00	0.0470	0.0473	0.0523	0.0601	0.0550	1.07		1.20		0.87
15:00-15:15	0.0468	0.0489	0.0486	0.0463	0.0480	0.04		0.03		0.05
15:15-15:30	0.0452	0.0559	0.0448	0.0507	0.0465	0.62		0.40		0.65
15:30-15:45	0.0425	0.0497	0.0578	0.0632	0.0492	2.24	*	3.98	**	1.41
15:45-16:00	0.0457	0.0459	0.0547	0.0511	0.0423	0.77		0.19		0.90
16:00-16:15	0.0388	0.0520	0.0523	0.0554	0.0478	1.95		6.49	**	0.43
16:15-16:30	0.0419	0.0460	0.0624	0.0521	0.0453	2.17	*	2.21		1.87
16:30-16:45	0.0530	0.0583	0.0718	0.0611	0.0636	1.41		2.56		0.94
16:45-17:00	0.1079	0.1114	0.1243	0.1301	0.1151	1.82		2.41		1.47
F_{24}	9.3***	8.17***	10.89***	11.33***	10.70***					
$F_{session}$	4.76**	0.02	1.99	1.55	0.00					
F_{Open1}	9.94***	16.41***	26.48***	29.18***	25.57***					
F_{Open2}	15.27***	16.56***	15.18***	33.27***	19.72***					
F_{Inner1}	2.62***	1.38	1.70**	3.71***	1.96**					
F_{Inner2}	1.86**	0.81	1.53*	2.65***	1.33					
F_{Close}	97.64***	93.52***	1.32***	89.8***	0.91***					

Statistical results about TL volume can be found in Table 8. None of F_4, F_5 and F_{Mon} are significant showing that daily means of TL volumes are not significantly different. This result is in contrast with the one for mean share volume, which was found to be different between Monday and other days for certain time intervals. As the insignificant values of F_{Inner1} and F_{Inner2} show, another difference is that means TL volumes for inner intervals are not significantly different from each other unlike the ones for share volume. F_{Open1} and F_{Open2} indicates that mean TL volume for the beginning of the day is different from other intervals, but the statistical significance is not as strong as the ones seen in Table 7. Friday's F_{Open1} and F_{Open2} values are not significant at all, indicating that mean TL volume for the first intervals is not significantly different from rest of the day. Finally, end-of-the-day mean volume is different from the rest for both TL volume and share volume.

Overall, mean share volume seems to be different for different intervals and days but this finding is not very strong for TL volume. Therefore, while evaluating liquidity by examining the volume behavior, it seems important to look at both the share volume and TL volume.

5. Conclusion

We analyze different dimensions of liquidity on the ISE by using detailed order and transaction data for all ISE stocks. Specifically, we estimate the limit order book on the ISE at each point in time and we examine the intraday behavior of spreads, depths, returns and volume.

One of our main findings is that the intraday behavior of the spreads exhibits an L-shaped pattern. In addition, wide spreads are accompanied by low depths and vice versa indicating that that traders use spreads and depths simultaneously to carry out their strategies. Therefore focusing on just the spreads to examine liquidity might be misleading for the ISE. According to the estimation results from a regression model, spreads are higher on average for more active and more risky stocks. Information flow as measured by trades of unusual size causes the spreads to increase.

Figure 5. Mean 15-Min. TL Volumes in Percent

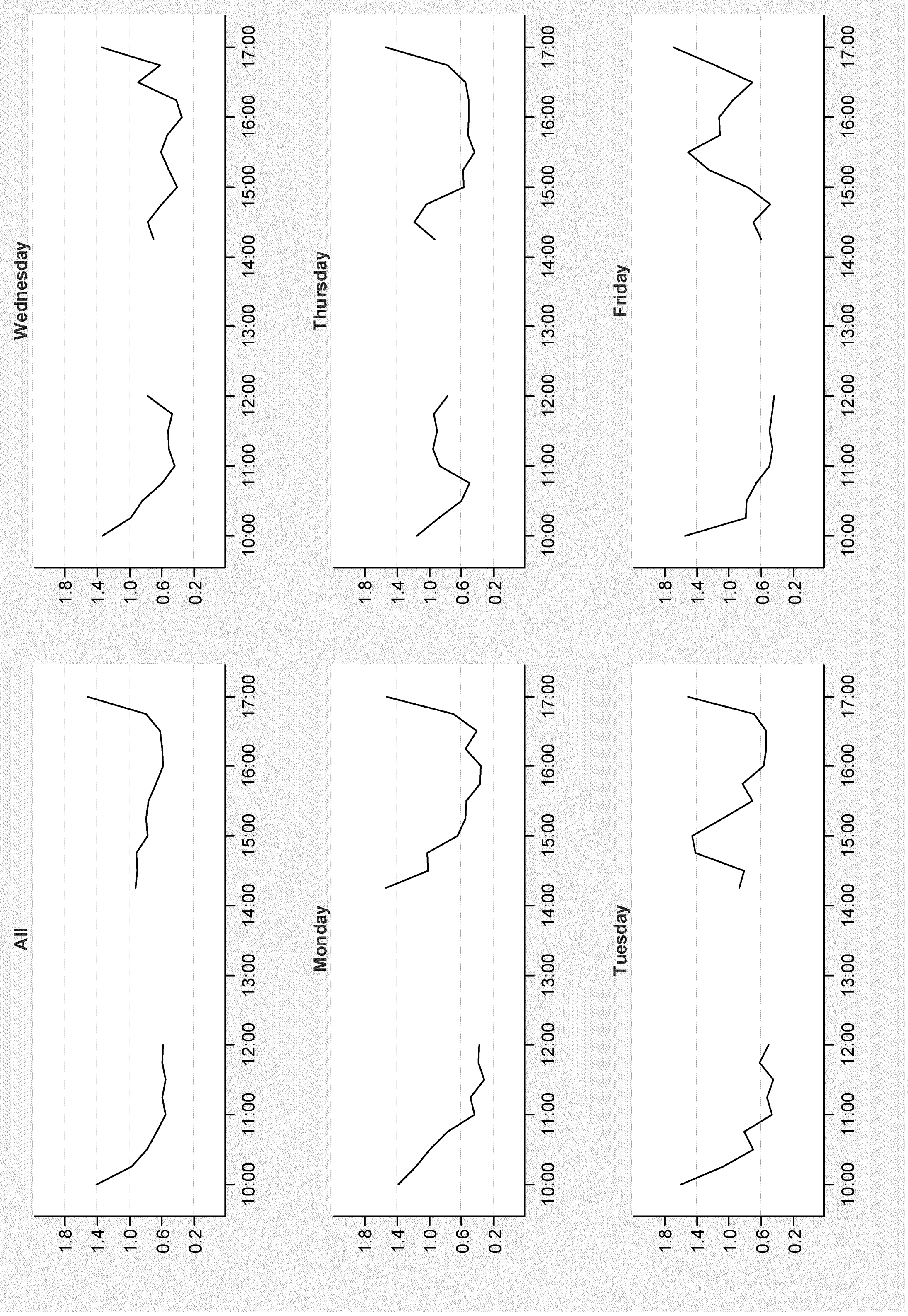

Table 8. Mean 15-Min. TL Volumes in Percent

15-minute Interval	Means in Percent					F_5	F_{Mon}	F_4
	Mon	Tue	Wed	Thu	Fri			
Session 1								
09:45-10:00	1.3926	1.6010	1.3386	1.1604	1.5513	0.45	0.00	0.61
10:00-10:15	1.1649	1.0787	0.9901	0.8858	0.7887	0.49	0.91	0.40
10:15-10:30	0.9976	0.7017	0.8452	0.6055	0.7883	0.59	1.49	0.53
10:30-10:45	0.7692	0.8141	0.5936	0.5045	0.6596	0.29	0.23	0.31
10:45-11:00	0.4466	0.4697	0.4419	0.8791	0.5028	1.92	0.65	2.05
11:00-11:15	0.4951	0.5342	0.5139	0.9512	0.4575	1.08	0.29	1.30
11:15-11:30	0.3254	0.4529	0.5254	0.9075	0.5018	1.85	2.11	1.54
11:30-11:45	0.3904	0.6263	0.4760	0.9469	0.4754	1.12	1.01	1.00
11:45-12:00	0.3863	0.5161	0.7794	0.7760	0.4410	0.71	0.94	0.54
Session 2								
14:00-14:15	1.5372	0.8776	0.7072	0.9332	0.6073	0.56	2.02	0.33
14:15-14:30	1.0128	0.8139	0.7725	1.1855	0.7076	0.32	0.12	0.50
14:30-14:45	1.0216	1.4132	0.6019	1.0335	0.4924	1.02	0.10	1.30
14:45-15:00	0.6546	1.4534	0.4119	0.5691	0.7692	1.49	0.13	1.68
15:00-15:15	0.5497	1.0826	0.5146	0.5820	1.2447	1.12	0.64	1.07
15:15-15:30	0.5409	0.7144	0.6138	0.4415	1.5115	0.81	0.24	0.82
15:30-15:45	0.3754	0.8303	0.5295	0.5208	1.1125	0.81	0.97	0.62
15:45-16:00	0.3578	0.5707	0.3524	0.5154	1.1257	0.85	0.51	0.79
16:00-16:15	0.5525	0.5397	0.4248	0.5158	0.9540	0.61	0.03	0.70
16:15-16:30	0.4131	0.5377	0.8980	0.5491	0.7097	1.44	2.09	1.04
16:30-16:45	0.7021	0.6947	0.6279	0.7791	1.1808	1.56	0.32	1.80
16:45-17:00	1.5311	1.5066	1.3437	1.5349	1.6908	0.42	0.00	0.61
F_{24}	1.70**	1.56*	2.75***	1.47*	1.02			
$F_{Session}$	0.21	1.56	0.87	0.62	3.67*			
F_{Open1}	6.60**	6.06**	17.47***	1.96	1.34			
F_{Open2}	15.14**	3.31*	12.05***	5.17**	0.06			
F_{Inner1}	1.08	1.01	1.02	0.89	0.58			
F_{Inner2}	1.49	1.13	1.26	0.81	0.60			
F_{Close}	6.80***	5.15**	15.49***	10.31***	4.84**			

Results from analyzing the intraday behavior of returns, number of trades, and volume reveal that these variables follow a broad U-shaped pattern. The means of these liquidity variables are significantly different for different time intervals in a given day and there are day-of-week effects on spreads, returns and share volumes. Finally, we find that the behaviors of share and TL volumes are different, suggesting that both of these variables should be considered when volume is utilized to examine liquidity.

The Istanbul Stock Exchange has taken some steps to increase the liquidity during the last couple of years. For example, on November 13th, 2009, an opening session at the beginning of the second session is made possible, which should contribute to the price discovery. In addition, traders can cancel their orders or decrease the order size starting from October 8th, 2010, which was not possible before. ISE also introduced a closing session on March 2nd, 2012 to enhance liquidity at the end of the trading day. Finally, on October 3rd, 2012, market making became possible for some low liquidity stocks. These are all useful policies and should enhance liquidity on the ISE. These policies should also have an impact on the intraday behavior of the variables documented in this paper. Therefore, it would be useful to examine the intraday behavior of liquidity on the ISE by using more recent data to assess the impact of recent policies.

One important step to enhance liquidity, in our view, that ISE should take is to make trading continuous throughout the day, as in NYSE for example, by removing the lunch break. Halting the trade for 90 minutes during the midday causes unnecessary decrease in the liquidity at the beginning of the second session as uninformed traders become more cautious because of the accumulated information during the lunch break.

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