Information and Volatility: Evidence from an Emerging Market
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Information and Volatility

Evidence from an Emerging Market

Abstract: *This study examines the volatility of daily stock returns and the volatility of returns during trading and non-trading hours for securities trading on the Istanbul Stock Exchange. Some unique characteristics of this exchange enable us to examine the reasons for the high volatility during trading hours. First, the price-determination procedure at the opening is the same as the pricing mechanism used during the rest of the day. Second, there is no specialist or market maker who sets prices. Third, there is a two-hour day break in trading during a business day. The volatility of daily return calculated from opening prices is found to be significantly higher than those calculated from closing prices in this market setting as well. Volatility of returns during trading periods is found to be higher than those during non-trading periods. Furthermore, per-hour volatility during the day break is higher than per-hour volatility during the night break. Findings of this study have some implications for the role of market maker and the impact of timing and length of a break in trading on the volatility of security returns.*

Key words: *automated order-matching system, emerging markets, Istanbul Stock Exchange, trading and non-trading hours, volatility.*

The volatility of returns has been of interest to many researchers and policymakers. The empirical studies show that returns are more volatile during trading periods than non-trading periods in the mature exchanges (Amihud and Mendelson 1987; Barclay et al. 1990; French and Roll 1986; Oldfield and Rogalski 1980) and in the emerging markets (Amihud et al. 1990; Chang et al. 1995; Güner and Önder 2001; Shastri et al. 1995). The pricing errors and the incorporation of private information into prices are considered to be causes of higher volatility during trading

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hours. Furthermore, it is shown in the literature that volatility of twenty-four-hour returns calculated from opening prices are higher than those calculated from closing prices (Stoll and Whaley 1990). Three possible explanations are given for this finding: (1) the difference in the price determination at the opening and the rest of the day, (2) the monopoly power exercised by the specialist or the market maker (Stoll and Whaley 1990), and (3) the long non-trading period preceding the opening (Amihud and Mendelson 1991).

In many of the markets studied empirically, the opening prices are determined by a call auction that is followed by a continuous auction during the day. Therefore, it is not possible to separate trading mechanism effects from the non-trading period effects on the volatility of trading period returns. However, in the Istanbul Stock Exchange (ISE), the price-determination procedure at the opening is the same as the pricing mechanism during the rest of the day. In other words, the ISE does not utilize the call auction procedure in determining opening prices, hence, it provides a unique opportunity to identify whether higher volatility at the opening is because of differences in pricing procedures or long non-trading period preceding the opening. Moreover, there is no specialist who has monopoly power in setting opening prices in the ISE. Therefore, volatility of returns is not affected from the profit-maximizing behavior of a monopolist market maker in setting prices at the market opening. In addition, the ISE has a short non-trading period during the day, therefore, it would be possible to identify the impact of length and timing of non-trading period preceding the opening on return volatilities.

The purpose of this paper is twofold. The first one is to examine the volatility of twenty-four-hour returns calculated from opening and closing prices in a market where trading mechanism effects are naturally separated from non-trading period effects, and where there is no market maker. The second one is to study the volatility of returns during two trading sessions and two non-trading periods of the ISE to gain insight on timing of information arrival to the market. This analysis also highlights the importance of timing and length of a break in trading on return volatilities. Furthermore, by documenting return volatilities in a market where there is no specialist, inferences about the role of market maker as a price stabilizer can be made indirectly.

The volatility of daily stock returns and the volatility of returns during trading and non-trading periods are examined for 216 stocks listed on the ISE from February 1997 to February 1998. It is found that the volatility of returns calculated from opening prices is significantly higher than that calculated from closing prices for all stocks and for all of the market value and trading volume quartiles. This finding indicates that the higher opening price volatility documented in earlier studies on other exchanges can be explained not only by the differences in price determination at the opening and the rest of the day but also by long non-trading hours before the opening. The analysis of autocorrelation of daily returns indicates that the higher volatility at the opening of the morning trading session is caused by more information-related trading, whereas that in the afternoon trading session is due to noise. Furthermore, empirical analyses show that the volatility of returns during the morning (the afternoon) trading hours is 25.37 (27.62) times the volatility of returns over the night break and is 5.93 (5.36) times the volatility of returns over the day break. This shows that per-hour volatility during the day break is much higher than per-hour volatility during the night break, indicating that the information production continues over the day break. Moreover, per-hour volatility of returns over trading periods is higher than that over non-trading periods.

The higher volatility during trading hours can be caused by noise or information-related trades. The impact of information-related trades will be permanent—that is, will not be reversed. As a result, this indicates no correlation between adjacent period returns if prices adjust to the information immediately. However, if information is incorporated into prices slowly, then a positive correlation between returns in adjacent trading and non-trading periods is expected. On the other hand, noise-related price changes will be transient and reversed. Therefore, noise leads to a negative correlation between adjacent period returns. To disentangle these two effects, the correlation of returns in adjacent trading and non-trading periods is examined. Although no clear-cut results are obtained for causes of higher volatility of returns in the morning session, the analyses suggest that changes in prices in the afternoon session are reversed in the following night break. Therefore, it can be concluded that the higher volatility in the afternoon session relative to non-trading periods is due to noise, but not due to information-related trades.

Trading Mechanisms at the ISE

Empirical and theoretical studies have shown that microstructure characteristics of markets affect price determination and behavior of prices. The ISE has several microstructure characteristics that are different from other exchanges around the world, and these characteristics may result in distinct relationships between volatility of daily returns and volatility of trading and non-trading period returns. First of all, the ISE is a fully automated order-matching market. This system enables the fast dissemination of information among investors. Hence, it may increase the price volatility during trading hours.[1]

Second, the ISE operates two trading sessions with a two-hour break between the sessions like the Tokyo and Jakarta Stock Exchanges. Trading hours are from 10:00 A.M. to 12:00 P.M. and 2:00 P.M. to 4:00 P.M. every weekday for all stocks listed on the ISE–National market. Thus, there are two breaks in trading: a short one during business hours and a long one overnight. This enables us to study the impact of long versus short non-trading periods and the timing of a break in trading on return volatilities.

Third, unlike the New York Stock Exchange (NYSE) and the Tokyo Stock Exchange (TSE), the ISE employs a continuous auction during the entire trading period, including market opening. Therefore, the opening and the closing prices are determined by using the same procedure. The opening price of each session is the price of the transaction at the opening. If no orders are given at the opening of the market, then the opening price is set equal to the closing price of the previous trading session. In earlier studies, differences in trading mechanisms at the opening and during the rest of the day and long non-trading period preceding the opening transaction are offered as explanations for higher volatility at the opening. Since there is no difference in the trading mechanisms at the opening and during the rest of the day for the ISE securities, the impact of the non-trading period on return volatilities can be studied without being affected from differences in price determination at the opening and the closing in this market.

Fourth, unlike the exchanges in the United States, there is no market maker or specialist assigned to stocks trading on the ISE. Investors, by submitting limit orders, act like market makers and provide liquidity in this market. Nonexistence of a market maker, who is responsible for making an orderly market for a security, suggests a higher volatility during trading hours in the ISE.

Fifth, since there is no specialist or market maker in the ISE, a limit on the maximum price changes in a trading session is utilized to stabilize price movements.[2] In each session, a base value, which is the weighted average price in the previous trading session rounded up or down by the relevant price step, is calculated for each security. The price of a security during a session is allowed to change only within ±10 percent of the base price determined for that session.[3] This restriction puts a limit on volatility during trading hours.

Data and Sample

There are four different markets in the ISE: the National, the Regional, the Newly Established Enterprises, and the Watch markets. Because of differences in characteristics of stocks trading in these markets and differences in their market microstructures, we constrained our sample to stocks listed on the ISE–National market.[4] There were a total of 222 stocks trading on the ISE–National market as of February 1997.

The period from February 1997 to February 1998 is covered in the analyses.[5] Some stocks moved between the National and the Watch markets during this time period. Because of differences in trading mechanism of the four markets of the ISE, a stock is required to be trading on the ISE–National market during the entire sample period in order to be included in the sample. In other words, movement of securities between different markets of the ISE during the sample period of this study is not allowed. This restriction reduces our sample to 216 stocks. Furthermore, to avoid the volatility of stock prices due to initial public offerings, stocks being listed during our sample period are not included in the analysis.

The opening and closing prices of stocks in each trading session were obtained from the databases maintained by the Reuters Company.[6] The data have to be downloaded from this database at the end of each trading session of the ISE. The opening and the closing prices are adjusted for stock splits and dividends. The number of shares traded and number of trades during each session are also collected from this database. Market values of companies at the beginning of our sample period were hand-collected from the monthly bulletins of the ISE.

For the analyses of twenty-four-hour return volatilities, four continuously compounded return series are calculated:

Return from morning opening prices: $R_{o1,t} = \log (P_{o1,t}/P_{o1,t-1})$
Return from morning closing prices: $R_{c1,t} = \log (P_{c1,t}/P_{c1,t-1})$
Return from afternoon opening prices: $R_{o2,t} = \log (P_{o2,t}/P_{o2,t-1})$
Return from afternoon closing prices: $R_{c2,t} = \log (P_{c2,t}/P_{c2,t-1})$

Then, as is shown in Figure 1, a trading day is divided into four periods, covering two trading (AM, PM) and two non-trading (day break–DB, night break–NB) periods.

For the analyses of volatilities during trading and non-trading hours, four additional, continuously compounded return series are calculated:

Return during morning session: $R_{am,t} = \log (P_{c1,t}/P_{o1,t})$
Return during afternoon session: $R_{pm,t} = \log (P_{c2,t}/P_{o2,t})$
Return during day break: $R_{db,t} = \log (P_{o2,t}/P_{c1,t})$
Return during night break: $R_{nb,t} = \log (P_{o1,t}/P_{c2,t-1})$

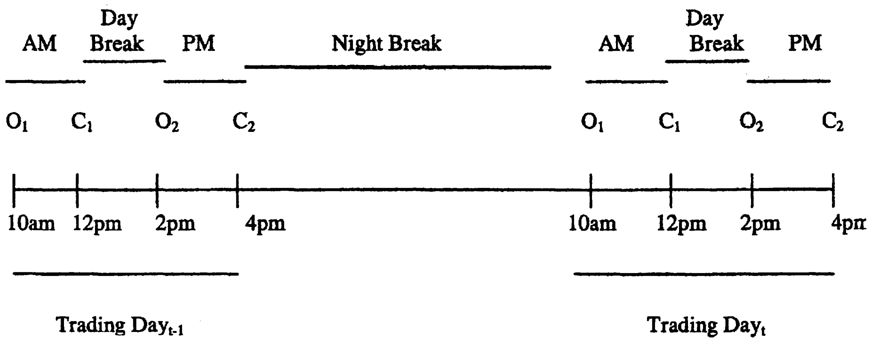
To study the differences in return volatilities of stocks with different market value and trading volume, stocks in the sample are grouped into market value and trading volume quartiles. Table 1 shows some descriptive statistics for all stocks in our sample, and for volume and market value quartiles. The average market value of 216 stocks at the beginning of our sample period is 25,119,383 million Turkish lira (TL) and it ranges from 117,500 million TL (minimum market value) to 382,500,000 million TL. The average daily trading volume and the average daily number of trades for all stocks in our sample are 15,872,096 shares and 289 trades, respectively. Stocks in the largest market value quartile accounts for 83 percent of the total capitalization of the ISE. Similarly, stocks in the largest trading volume quartile constitute 64 percent of the average daily trading volume of the ISE during our sample period.

Results

Volatility of Daily Returns

Four daily return series, $R_{o1,t}$, $R_{o2,t}$, $R_{c1,t}$, and $R_{c2,t}$, are used in the analyses of the twenty-four-hour return volatilities. The variance ratio tests are employed in the analysis. The main premise of variance ratio tests is that information arrives uniformly during a day. If this information is incorporated into prices immediately, and the volatility is only caused by the arrival of new information, then per-hour volatility of daily returns, calculated from opening and closing prices of each trad-

Figure 1. **Trading and Non-Trading Periods in the ISE**



ing session, should be the same. To test this hypothesis, we look at twenty-four-hour return volatilities calculated from opening and closing prices of each session. Since the opening prices are determined by the continuous auction, just like any other prices, and there is no specialist in the ISE, any difference between twenty-four-hour return volatilities should be due to the non-trading period preceding the opening in this market.

First, the variances of four daily return series and the monthly variance ratios are calculated for each stock in each month during the sample period. These monthly variance ratios of individual securities are averaged across 216 stocks in each month. Then averages of these monthly variance ratios across twelve months in the sample are calculated[7] for the overall sample and for market value and trading volume quartiles. Finally, the null hypothesis of equality of daily return volatilities calculated from the opening and the closing prices of the morning and the afternoon trading sessions is tested using a *t*-statistic. If this null hypothesis holds, the average variance ratio should not be statistically significantly different from one. These average variance ratios and their corresponding standard errors and the statistical significance of these ratios are reported in Table 2.

Empirical results indicate that almost all of the variance ratios shown in Table 2 are statistically significantly different from one. It is found that the average ratio of volatility of open-to-open returns to that of close-to-close returns, calculated from prices of the morning (the afternoon) trading session, is 1.30 (1.67). Since there is no difference in the pricing procedures utilized at the opening and during the rest of the day in the ISE, this significant difference in volatility at the opening and at the closing of both sessions can be explained by non-trading hours before the opening. Moreover, the results indicate that the volatility of returns calculated using opening prices of the morning session is 1.54 times higher than the volatility of returns calculated using opening prices of the afternoon session. Since there are eighteen non-trading hours before the opening of the morning session, and only two non-trading hours before the opening of the afternoon session, the higher

Table 1

Characteristics of the Istanbul Stock Exchange

	Mean	Standard deviation	Minimum	Maximum
All stocks				
Market value (million TL)	25,119,383	60,000,909	117,500	382,500,000
Daily trading volume	15,872,096	30,436,725	189,023	302,579,264
Daily number of trades	289	265	19	1,991
Market value quartiles				
Smallest quartile				
Market value (million TL)	1,250,106	682,633	117,500	2,340,000
Daily trading volume	7,907,271	12,443,733	250,661	78,598,305
Daily number of trades	162	99	19	482
Second quartile				
Market value (million TL)	4,440,698	1,049,427	2,360,000	6,387,530
Daily trading volume	16,884,688	24,497,183	248,631	114,687,611
Daily number of trades	284	202	24	933
Third quartile				
Market value (million TL)	10,278,348	2,692,829	6,400,000	16,166,304
Daily trading volume	13,445,397	23,464,456	331,507	139,512,306
Daily number of trades	244	186	31	1,008
Largest quartile				
Market value (million TL)	84,508,380	98,798,867	16,200,000	382,500,000
Daily trading volume	25,251,029	47,866,178	189,023	302,579,264
Daily number of trades	463	386	72	1,991
Volume quartiles				
Smallest quartile				
Market value (million TL)	13,947,724	49,342,598	127,500	363,170,000
Daily trading volume	1,286,395	687,813	189,023	2,346,809
Daily number of trades	107	74	19	388
Second quartile				
Market value (million TL)	15,038,093	21,245,454	456,250	87,120,000
Daily trading volume	4,009,643	997,876	2,422,002	5,902,643
Daily number of trades	186	101	80	713

(continues)

Table 1 (continued)

	Mean	Standard deviation	Minimum	Maximum
Volume quartiles (continued)				
Third quartile				
Market value (million TL)	27,655,541	55,974,987	117,500	335,000,000
Daily trading volume	9,273,284	2,658,691	6,029,546	15,068,158
Daily number of trades	273	136	106	893
Largest quartile				
Market value (million TL)	43,836,174	89,391,071	462,500	382,500,000
Daily trading volume	48,919,062	47,246,944	15,256,147	302,579,264
Daily number of trades	588	337	246	1,991

volatility at the morning relative to the afternoon opening suggests that the length of the non-trading period prior to the opening affects the volatility at the opening.

When the volatilities of returns calculated from the morning and the afternoon closing prices are compared, the variance ratio of these return series is found to be 1.31. This result implies that the closing prices in the morning session are more volatile than those in the afternoon session. This finding is quite interesting and may be explained by the level of uncertainty faced by investors at the closing of each trading session. In empirical studies on the U.S. exchanges, it is found that the spread and the volatility of returns decline during the lunch hour (Chen et al. 1995; Wood et al. 1985). Furthermore, the analysis of the intraday bid–ask spread in these markets shows that the spread is highest at the beginning of trading and it declines over time. This finding indicates the existence of higher uncertainty at the beginning of trading and the resolutio
of the day. Hence, the findings of this study also suggest that investors in Turkey might face higher uncertainty in the morning trading session than the one in the afternoon session.[8] Due to higher uncertainty involved in trading securities, investors could be affected more from small changes in existing orders in the morning session. Hence, the volatility of daily returns calculated from prices of the morning trading session can be expected to be higher than the volatility of returns calculated from prices of the afternoon trading session.

The same analyses are repeated for volume and market value quartiles. The variance ratios are found to be statistically significantly different from one for almost all market value and volume quartiles with the exception of the variance ratio of returns calculated using opening prices of the morning and the afternoon trading sessions for the second market value and the second trading volume quartiles. In general, variance ratios are found to be highest for the lowest market

Table 2

Variance Ratio of Returns over Twenty-Four-Hour Period

		Market value quartiles				Volume quartiles			
	All stocks	Smallest quartile	2	3	Largest quartile	Smallest quartile	2	3	Largest quartile
$Var(R_{o1,t})/Var(R_{c1,t})$									
Mean	1.30[c]	1.40[c]	1.27[b]	1.25[c]	1.29[c]	1.37[c]	1.27[b]	1.28[b]	1.29[b]
Standard error	(0.09)	(0.10)	(0.09)	(0.08)	(0.09)	(0.08)	(0.09)	(0.10)	(0.11)
$Var(R_{o2,t})/Var(R_{c2,t})$									
Mean	1.67[b]	1.80[c]	1.73[b]	1.60[b]	1.54[a]	1.84[b]	1.60[b]	1.58[b]	1.65[b]
Standard error	(0.25)	(0.25)	(0.27)	(0.22)	(0.26)	(0.29)	(0.23)	(0.23)	(0.26)
$Var(R_{o1,t})/Var(R_{o2,t})$									
Mean	1.54[a]	1.72[a]	1.58	1.44[a]	1.40[b]	1.53[b]	1.69	1.58[a]	1.34[b]
Standard error	(0.28)	(0.36)	(0.38)	(0.22)	(0.16)	(0.20)	(0.47)	(0.32)	(0.15)
$Var(R_{c1,t})/Var(R_{c2,t})$									
Mean	1.31[c]	1.38[c]	1.32[c]	1.29[c]	1.26[c]	1.36[c]	1.28[c]	1.29[c]	1.32[c]
Standard error	(0.08)	(0.09)	(0.07)	(0.08)	(0.08)	(0.08)	(0.07)	(0.08)	(0.09)

Notes: [a], [b], and [c] show statistical significance at 10, 5, and 1 percent, respectively. The critical *t*-values are 1.796, 2.201, and 3.106 at the significance levels of 10, 5, and 1 percent, respectively.

value and the lowest volume quartiles, indicating that the difference between volatility of daily return series is high for the stocks in these quartiles. Furthermore, the variance ratios are lowest for the highest market value and volume quartiles. However, the trend is not monotonic.

Besides the effect of the length of the non-trading period preceding opening, there could be two more reasons for the higher volatility at the opening—noise and information. To disentangle these two competing hypotheses, autocorrelations of daily returns are examined next.

Autocorrelations of Daily Returns

The noise and the information hypotheses indicate different autocorrelation structures for daily returns. French and Roll (1986) suggest that negative autocorrelation in return series beyond lag one[9] indicates noise-induced volatility (the noise hypothesis), whereas zero or positive autocorrelation in returns indicates information-related volatility at the opening (the information hypothesis). In other words, according to the noise hypothesis, since price movements are not caused by fundamental changes, they are reversed in later periods. Therefore, return series are negatively correlated. On the other hand, according to the information hypothesis, price movements are induced by new information and, therefore, are not reversed. If new information is incorporated into prices during the day, then the information hypothesis suggests zero autocorrelation in daily return series. However, if it takes longer than one day for the information to be incorporated into prices, then there should be a positive autocorrelation.

To test these two hypotheses, average daily return autocorrelations and their standard deviations are estimated the same way the average variance ratios are calculated and are reported in Table 3. The autocorrelations of returns calculated from opening prices of the morning trading session for all of the stocks in the sample are positive and statistically significantly different from zero beyond lag one. Given the explanation above, positive autocorrelations beyond lag one indicate that the opening returns of the morning trading session are more volatile due to information but not due to noise. For the market value and volume quartiles, the average autocorrelations beyond lag one are either positive or zero but not negative. Only two out of thirty-two autocorrelations beyond lag one are statistically significantly less than zero. This finding is again consistent with the information hypothesis but not with the noise hypothesis.

The analysis of autocorrelations suggests that the higher volatility at the opening of the morning trading session may be explained by more information-induced trading during that time period. There are two types of information—public and private. If it is public information, it should affect all four return series the same way without causing any difference in volatilities across these return series. If it is private information, then it could affect price volatilities differently depending on the severity of asymmetric information in each period. Asymmetric information at

Table 3

Average Autocorrelations of Daily Returns

		Market value quartiles				Volume quartiles			
Lag length	All stocks	Smallest quartile	2	3	Largest quartile	Smallest quartile	2	3	Largest quartile
Panel A – R_{o1} daily return calculated from opening prices of the morning trading session									
1	–0.029[c]	–0.038[b]	–0.026	0.006	–0.060[c]	–0.061[c]	–0.014	–0.022	–0.020
	(0.008)	(0.017)	(0.016)	(0.015)	(0.014)	(0.019)	(0.016)	(0.015)	(0.013)
2	0.017[b]	0.010	0.010	0.014	0.036[b]	–0.001	0.016	0.018	0.037[c]
	(0.007)	(0.013)	(0.014)	(0.013)	(0.013)	(0.014)	(0.013)	(0.014)	(0.011)
3	0.034[c]	0.017	0.035[b]	0.044[c]	0.039[b]	0.015	0.032[b]	0.051[c]	0.036[b]
	(0.007)	(0.015)	(0.013)	(0.012)	(0.013)	(0.014)	(0.014)	(0.013)	(0.012)
4	0.050[c]	0.031[b]	0.052[c]	0.081[c]	0.035[c]	0.042[c]	0.040[c]	0.059[c]	0.058[c]
	(0.006)	(0.012)	(0.012)	(0.014)	(0.010)	(0.013)	(0.011)	(0.013)	(0.013)
5	–0.009	–0.004	–0.001	–0.025[a]	–0.004	–0.033[b]	–0.017	0.001	0.014
	(0.006)	(0.012)	(0.010)	(0.013)	(0.013)	(0.012)	(0.013)	(0.011)	(0.011)

	Panel B – R_{o2} daily return calculated from opening prices of the afternoon trading session								
1	−0.070[c]	−0.087[c]	−0.068[c]	−0.075[c]	−0.051[c]	−0.094[c]	−0.062[c]	−0.070[c]	−0.055[c]
	(0.007)	(0.015)	(0.016)	(0.013)	(0.011)	(0.016)	(0.014)	(0.012)	(0.013)
2	−0.130[c]	−0.107[c]	−0.132[c]	−0.147[c]	−0.135[c]	−0.099[c]	−0.161[c]	−0.140[c]	−0.121[c]
	(0.007)	(0.016)	(0.015)	(0.016)	(0.012)	(0.017)	(0.014)	(0.015)	(0.013)
3	0.107[c]	0.099[c]	0.096[c]	0.130[c]	0.104[c]	0.075[c]	0.123[c]	0.111[c]	0.120[c]
	(0.007)	(0.014)	(0.015)	(0.014)	(0.011)	(0.014)	(0.012)	(0.016)	(0.012)
4	−0.046[c]	−0.019	−0.022	−0.052[c]	−0.091[c]	−0.024	−0.047[c]	−0.040[c]	−0.073[c]
	(0.007)	(0.014)	(0.014)	(0.015)	(0.011)	(0.014)	(0.013)	(0.012)	(0.015)
5	−0.073[c]	−0.040[b]	−0.082[c]	−0.077[c]	−0.092[c]	−0.044[c]	−0.088[c]	−0.091[c]	−0.068[c]
	(0.007)	(0.016)	(0.014)	(0.017)	(0.011)	(0.014)	(0.014)	(0.015)	(0.016)

Notes: [a], [b] and [c] show statistical significance at 10, 5, and 1 percent, respectively. The critical t-values are 1.796, 2.201, and 3.106 at the significance levels of 10, 5, and 1 percent, respectively.

the opening of the market in the morning might be higher because of the long non-trading period, and this could explain the higher volatility in this period. Then, the finding that the opening prices of the morning trading session are statistically more volatile than any other daily return series for low market value and low trading volume stocks is consistent with the results of Önder and Güner (1998). They found a higher spread for the low market value and low volume stocks, implying that the asymmetric information is more severe for them.[10]

On the other hand, the autocorrelations of returns obtained from opening prices of the afternoon trading session are mostly negative. For this return series, twenty-one out of thirty-two autocorrelations beyond lag one are statistically significantly less than one, as shown in Table 3. This result indicates that the higher volatility of opening prices of the afternoon trading session is because of noise but not due to information-related trading. However, this finding is not as compelling as the evidence for opening prices of the morning session.

Return Volatilities Over Trading and Non-Trading Periods

In theoretical market microstructure models (Admati and Pfleiderer 1988; Easley and O'Hara 1987; Kyle 1985), the private information is assumed to affect prices through trading. As a result, return volatility during trading hours is expected to be higher than during non-trading periods. Empirical studies provide supporting evidence for this relationship. For example, French and Roll (1986) find that per-hour return variance during trading days is approximately thirteen times per-hour volatility during mid-week holidays and seventy times per-hour volatility during weekends for the NYSE listed stocks. They explain this higher volatility during trading hours by the volatility associated with trading and the incorporation of private information into prices through trading. Similarly, Amihud and Mendelson (1991) study the same issue for fifty most actively traded stocks listed on the TSE, which has two trading sessions during the day. They find that the average return variance of the morning (afternoon) trading period is 5.4 (4.5) times greater than the average return variance of the midday break.[11] Since the TSE and the NYSE utilize a call auction at the opening and there is a specialist determining the opening prices in the NYSE, the higher volatility during trading hours in these markets cannot be completely attributed to the incorporation of information into prices of securities.

In this paper, the volatility of returns during trading and non-trading periods are also examined for stocks listed on the ISE. The two-hour non-trading period of the ISE during business hours gives an opportunity to identify the impact of length and timing of the non-trading period on return volatilities. If private and public information is produced at the same rate during business hours, regardless of the exchange being open or not, and trading is not necessary for the incorporation of private information into prices, then volatility of returns is expected to be the same over trading and non-trading periods during business hours. However, if trading is necessary for the incorporation of the private information into prices—that is, trading contributes to return volatility—then volatility of returns during trading hours will be higher than volatility of returns during the day break.

Per-hour return variances in each of the trading and non-trading periods are calculated because return volatility over periods of different lengths is compared in this analysis. Since the two trading periods and the non-trading period during the day are all two hours long, the variance of returns over these periods is divided by two. Similarly, the variance of returns over the night break is divided by eighteen to determine the hourly return volatility. Then, ratios of hourly variances in different periods are calculated for each stock in each month during our sample period. These monthly variance ratios for each stock are averaged across 216 stocks in each month. Then overall averages for twelve months are calculated from monthly average variance ratios. Finally, the null hypothesis of equality of return volatilities in all trading and non-trading periods in a day is tested using a t-statistic. In order for this null hypothesis to be true, the average variance ratio should not be statistically significantly different from one. The variance ratios for the market value and trading volume quartiles are also calculated to see whether there are any differences in the volatility of returns across size and volume quartiles. These average variance ratios and their corresponding standard errors and the statistical significance of these ratios are reported in Table 4.

First, the volatility of returns during two trading periods is compared. The ratio comparing the variance of returns in the morning trading session to the one in the afternoon for all stocks in our sample has a value of 1.30, but is not statistically significantly different from one at conventional significance levels. This result indicates that the returns in the morning session are as volatile as those in the afternoon session. The insignificant variance ratios are also observed for all market value and volume quartiles.

Second, the volatility of trading period returns is compared to the volatility of non-trading period returns. This comparison shows that, in general, trading increases the volatility of returns. The average return variance during the morning (afternoon) session is 5.93 (5.36) times higher than the average return variance during the day break. Even though these trading and non-trading periods are all during business hours, there seems to be differences in the production of information and the incorporation of that information into security prices when the exchange is open and when it is not. The volatility of returns during trading sessions is also compared to the volatility of overnight returns. Relative to returns during the overnight non-trading period, returns in the morning (afternoon) trading session is 25.37 (27.62) times more volatile. Compared to the U.S. exchanges, for which the same ratio is 16.20 times, trading period volatility is much higher relative to the overnight non-trading period volatility in the ISE.

Third, the per-hour return variance during the day break is compared to the per-hour volatility of returns over the night break. Volatility of returns during the day break could be the same as the volatility of those over the night break since the closure falls into the lunch break and investors may not be very active in

Table 4

Variance Ratios of Returns for Intraday Periods

	All stocks	Market value quartiles: Smallest quartile	2	3	Largest quartile	Volume quartiles: Smallest quartile	2	3	Largest quartile
$Var(R_{am,t})/Var(R_{pm,t})$									
Mean	1.30	1.43	1.31	1.27	1.19	1.44	1.30	1.24	1.23
Standard error	(0.22)	(0.24)	(0.22)	(0.21)	(0.20)	(0.26)	(0.22)	(0.20)	(0.21)
$Var(R_{am,t})/Var(R_{db,t})$									
Mean	5.93[c]	5.40[c]	5.82[c]	5.80[c]	6.69[c]	5.04[c]	5.54[c]	6.10[c]	7.03[c]
Standard error	(0.97)	(0.91)	(0.98)	(0.98)	(1.14)	(0.86)	(0.90)	(1.04)	(1.20)
$Var(R_{am,t})/Var(R_{nb,t})$									
Mean	25.37[c]	21.94[c]	25.46[c]	25.36[c]	28.71[c]	21.80[c]	22.73[c]	25.46[c]	31.48[c]
Standard error	(3.72)	(2.97)	(3.65)	(4.04)	(4.59)	(3.17)	(3.11)	(3.91)	(5.04)
$Var(R_{pm,t})/Var(R_{db,t})$									
Mean	5.36[c]	4.71[c]	5.02[c]	5.17[c]	6.54[c]	4.56[c]	4.93[c]	5.54[c]	6.40[c]
Standard error	(0.55)	(0.54)	(0.51)	(0.51)	(0.80)	(0.52)	(0.49)	(0.59)	(0.71)
$Var(R_{pm,t})/Var(R_{nb,t})$									
Mean	27.62[c]	23.39[c]	27.83[c]	27.14[c]	32.12[c]	23.99[c]	24.25[c]	27.65[c]	34.60[c]
Standard error	(1.71)	(1.41)	(1.90)	(1.77)	(2.58)	(1.56)	(1.48)	(1.73)	(3.04)
$Var(R_{db,t})/Var(R_{nb,t})$									
Mean	7.22[c]	7.57[c]	7.55[c]	7.17[c]	6.58[c]	7.90[c]	6.83[c]	7.13[c]	7.01[c]
Standard error	(0.84)	(0.96)	(0.93)	(0.91)	(0.72)	(0.95)	(0.96)	(0.84)	(0.78)

Notes: [a], [b], and [c] show statistical significance at 10, 5, and 1 percent, respectively. The critical *t*-values are 1.796, 2.201, and 3.106 at the significance levels of 10, 5, and 1 percent, respectively.

information gathering during lunch time and the arrival of public information could be low as well.[12] On the other hand, since people can trade on the information that they gathered during the day break within a short period of time, this closure of exchange may not reduce the incentives to collect and produce information. Hence, the volatility during the day break is expected to be higher than during the night break. It is found that the volatility of returns during the day break is 7.22 times higher than the volatility of those during the night break. Based on these results, it seems that information continues to arrive during the day break even though trading has been suspended. As reported in Berry and Howe (1994), if the public information arrival rate is lowest during the day break, the higher volatility during this time period might be due to the production of private information to be used in the following trading period. Low volatility of returns during the lunch break is also reported for the U.S. exchanges and the TSE.[13]

Finally, return volatilities of stocks in different market value and volume quartiles are compared. Results show that those in the highest market value quartile have the highest ratio for volatility of trading and non-trading period returns and those in the lowest market value quartile have the lowest ratio. However, the trend is not monotonic. On the other hand, the variance ratio of trading and non-trading period returns increases monotonically as the trading volume increases. This finding indicates that stocks that are traded more frequently have a higher volatility during trading hours relative to non-trading hours. If volume of trading is associated with revelation and incorporation of private information into prices, then stocks with a higher trading volume reflect more private information in their prices than those with a lower trading volume. Since more information causes higher volatility in prices, this explains the higher variance ratios for stocks with higher trading volume. Similarly, the variance ratio of returns during the night break to those during the day break decreases as the market value of stocks increases. A similar pattern, though not monotonic, is observed for volume quartiles.

The higher volatility during trading hours could be because of noise or information. These hypotheses suggest different covariance structures in returns of adjacent periods. These two hypotheses, in explaining the higher volatility during trading hours, are tested in the next section by analyzing covariances of returns in adjacent trading and non-trading periods.

Correlation of Returns in Adjacent Periods

Table 5 presents the estimated average correlation coefficients between the returns in adjacent trading and non-trading periods during the day. Standard errors of the correlation coefficients are reported in parentheses. All of the correlation coefficients are found to be negative and statistically significantly different from zero. For example, the average correlation of the morning trading period returns with the following day break returns is –0.061 and statistically significantly different from zero at 10 percent. This finding is consistent with the noise hypothesis, suggesting

Table 5

Average Correlation of Returns for Trading and Non-Trading Hours During Trading Day

		Market value quartiles				Volume quartiles			
	All stocks	Smallest quartile	2	3	Largest quartile	Smallest quartile	2	3	Largest quartile
$Corr(R_{nb,t}, R_{am,t})$	−0.224[c]	−0.278[c]	−0.218[c]	−0.210[c]	−0.192[c]	−0.271[c]	−0.217[c]	−0.226[c]	−0.184[c]
	(0.035)	(0.034)	(0.037)	(0.036)	(0.036)	(0.034)	(0.039)	(0.037)	(0.037)
$Corr(R_{am,t}, R_{db,t})$	−0.061[a]	−0.056	−0.051	−0.075[b]	−0.061	−0.084[b]	−0.081[b]	−0.061	−0.018
	(0.031)	(0.032)	(0.036)	(0.030)	(0.035)	(0.031)	(0.032)	(0.038)	(0.030)
$Corr(R_{db,t}, R_{pm,t})$	−0.310[c]	−0.318[c]	−0.329[c]	−0.305[c]	−0.289[c]	−0.331[c]	−0.298[c]	−0.317[c]	−0.295[c]
	(0.072)	(0.067)	(0.071)	(0.074)	(0.077)	(0.069)	(0.076)	(0.071)	(0.075)
$Corr(R_{pm,t-1}, R_{nb,t})$	−0.117[c]	−0.113[c]	−0.112[c]	−0.126[c]	−0.118[c]	−0.150[c]	−0.124[c]	−0.118[c]	−0.077[a]
	(0.030)	(0.028)	(0.029)	(0.036)	(0.039)	(0.026)	(0.037)	(0.034)	(0.038)

Notes: [a], [b], and [c] show statistical significance at 10, 5, and 1 percent, respectively. The critical *t*-values are 1.796, 2.201, and 3.106 at the significance levels of 10, 5, and 1 percent, respectively.

that any pricing error in the opening or during the morning trading session is corrected in the next period. However, results for market value and volume quartiles tell a different story. The correlations of returns in the morning trading session and those during the day break are not statistically significantly different from zero for all market value and trading volume quartiles with the exception of the third market value and the first and the second trading volume quartiles. Therefore, it can be concluded that the higher volatility of returns in the morning trading session for securities in these quartiles is due to information-related trading but not noise. On the other hand, for the third market value and the first and the second trading volume quartiles, the correlations are statistically significantly less than zero, indicating that the higher volatility of returns during the morning trading session is due to noise for securities in these quartiles.

Furthermore, returns in the afternoon trading session have statistically significant negative correlations with the returns in the preceding and following non-trading periods. This finding suggests that the higher volatility during the afternoon trading period is due to noise as well. Hence, these pricing errors in the afternoon trading session are corrected in the following non-trading period.

These statistically significant negative correlation coefficients between returns in adjacent trading and non-trading periods can also be caused by transaction prices bouncing between the bid and the ask prices. Unfortunately, there is no way of controlling for this market microstructure effect in this setting since data at the transaction level are not available for the ISE securities during the sample period analyzed in this study.

Conclusions

In this paper, the relationship between daily return volatilities, calculated from the opening and the closing prices, and volatilities of trading and non-trading period returns are examined for 216 stocks listed on the ISE for the period from February 1997 to February 1998 using a variance ratio test. The ISE has several distinct microstructure characteristics that may make the generalization of findings in other mature and emerging markets to the ISE stocks impossible.

In this study, first, differences in twenty-four-hour return volatilities calculated from opening and closing prices are examined. It is found that volatility of returns calculated from opening prices is significantly different from that calculated from closing prices for the overall sample and for stocks in all market value and trading volume quartiles. This finding indicates that high opening price volatilities reported in the literature for other exchanges can be explained by the long non-trading period preceding the opening of trading as well as the differences in price-determination procedures of these exchanges at the opening and during the rest of the day. The analysis of autocorrelations of daily return series indicates that the higher volatility at the opening of the morning trading session might be explained by more information-related trading. On the other hand, the higher volatility at the opening of the afternoon trading session is mostly due to noise.

Second, the volatilities of trading and non-trading period returns are examined. The ISE has two breaks in trading: one strictly during business hours and another one overnight. The break during business hours gives an opportunity to identify the impact of length and timing of a non-trading period on return volatilities. The empirical analyses show that the volatility of returns during trading hours is much higher than that during either of the non-trading periods. Furthermore, per-hour volatility during the day break is higher than per-hour volatility during the night break, indicating that the information production continues over the day break. On the other hand, per-hour volatility of returns during the day break is lower than per-hour volatility during trading periods. This result indicates that trading increases the volatility of returns. The examination of correlation of returns in adjacent trading and non-trading periods suggests that the higher volatility of returns in the afternoon session is due to noise for all stocks in the sample and for all market value and volume of trading quartiles. Similarly, higher volatility of returns in the morning session for all stocks in the sample is caused by noise. However, results for market value and trading volume quartiles are not uniform. The higher volatility of morning trading period returns for the third market value and the first and second trading volume quartiles are due to information-based trading. On the other hand, the higher volatility of morning trading period returns for the remaining market value and volume of trading quartiles is caused by noise. Similarly, this analysis suggests that the higher volatility of returns in the afternoon trading session is due to noise.

Compared to the mature exchanges in the United States, trading period volatility is much higher for the ISE securities. There could be three explanations for this finding. First of all, the ISE has a very short history and is not a mature market. Therefore, prices might be more volatile in the ISE. Second, there is no specialist or market maker responsible for maintaining an *orderly market* in the ISE. Even though there are limits on the maximum allowable changes in prices during each trading session, these limits may not be effective in stabilizing prices and reducing volatility. The higher volatility of returns in the ISE relative to the U.S. exchanges provides an indirect support for the price-stabilizing and volatility-reducing role of the specialist in the NYSE. Even though specialists are criticized for having and using their monopolistic power in determining opening prices, the results in this paper suggest that, without a specialist, the market would have been even more volatile. Finally, the level of asymmetric information in the ISE might be higher relative to other markets examined empirically in earlier studies.

Notes

1. See Chang et al. (1997) and Naidu and Rozeff (1994).
2. The role of market makers is not the same in all markets. For example, although one of the functions of the specialist is to reduce the volatility of stock prices while providing

liquidity to the market in the NYSE, the role of market maker in the U.K. market is to provide liquidity without being too concerned about the volatility of stock prices. We would like to thank an anonymous referee for bringing this point to our attention.

3. There is an exception to this rule. Companies can call the ISE and ask for a wider price change range to be allowed during a trading session or a day if there is a flow of information to the market about the company.

4. The Regional market and the market for Newly Established Enterprises were established in 1995. Stocks of corporations that do not satisfy the listing requirements of the National market are traded in these markets. The Watch market is used under extraordinary conditions for corporations listed on the ISE. This market operates for only fifteen minutes, between 9:15 A.M. and 9:30 A.M.

5. Because of a major religious holiday during the second week of February 1997, our sample period begins on February 12, 1997.

6. At the beginning of each trading session, the values of these variables are initialized by Reuters. Data belonging to previous session are not kept, but are overwritten with the information on the current session. Therefore, data for each session have to be downloaded before the next trading session starts.

7. The same approach is used by Stoll and Whaley (1990). Ronen (1997) shows that this method of calculating average variance ratios reduces the contemporaneous correlation problem that causes the test statistic to be biased against the null in small samples.

8. This explanation is not consistent with findings in Önder and Güner (1998). They show that the bid–ask spread is higher at the closing of the afternoon trading session than that of the morning trading session. However, the sample period of our study does not completely coincide with the sample period of their study.

9. Autocorrelations at lag one are not analyzed since these autocorrelations will be affected from transaction prices bouncing between the bid and the ask prices. As a result, it would be hard to conclude that a negative autocorrelation in security returns at lag one is caused only by noise.

10. George et al. (1991) report higher adverse selection components of spread for small firms relative to large firms listed on the NASDAQ. Lin et al. (1995) show that the adverse selection component of spread is higher for less frequently traded NYSE securities than more frequently traded ones.

11. George and Hwang (1995) study a diverse sample of Japanese stocks and conclude that the most actively traded stocks examined by Amihud and Mendelson (1991) are not representative of the TSE stocks in general. Furthermore, George and Hwang (1995) conclude that results documented by Amihud and Mendelson (1991) cannot be generalized to all the stocks listed on the TSE.

12. Berry and Howe (1994) find that the arrival of public information is at its lowest level between 12:00 P.M. and 2:00 P.M., which coincides with the day break of the ISE.

13. Even though U.S. markets do not have a day break, Wood et al. (1985) find that the volatility of transaction prices is lower during the lunch hour.

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