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Information, trading and stock returns: Lessons from dually-listed securities

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Abstract

This paper compares the intra-day patterns on the NYSE and AMEX of volatility, trading volume and bid–ask spreads for European and Japanese dually-listed stocks with American stocks of comparable average trading volume and volatility. It is shown that the intra-day patterns for these stocks are remarkably similar even though public information flows differ markedly across these stocks during the trading day. In the early morning, all stocks have higher volatility than later in the day, but this phenomenon is most pronounced for Japanese stocks and affects American stocks the least. We argue that these patterns are consistent with markets reacting to the overnight accumulation of public information but are inconsistent with the view that early morning volatility can be attributed to monopolistic specialist behavior.

JEL classification: G10; G14

Keywords: ADR; Public information; Volatility; Volume; Bid–ask spread

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1. Introduction

Considerable effort has been devoted recently to learning about the determinants of stock return volatility. Trading noise, public information, private information and trading mechanisms have all been identified as potentially important determinants of the volatility of stock returns. To identify the relative importance of these determinants, contributions to the literature have focused mostly on experiments that exploit differences in trading mechanisms, in the arrival of public information, and in whether markets are open. For instance, French and Roll (1986) use the suspension of trading on some Wednesdays in 1968 to compare non-trading days to trading days with similar rates of arrival of public information. Barclay et al. (1990) look at weekend variance with and without Saturday trading on the Tokyo stock exchange to investigate whether additional private information revealed through trading on Saturday affects volatility. Stoll and Whaley (1990) make the case that the opening mechanism of the NYSE increases stock return volatility, whereas Amihud and Mendelson (1991) use the fact that the Tokyo Stock Exchange has two trading periods to argue that higher opening volatility is mostly the result of the incorporation of overnight information. Foster and George (1992) use trading and non-trading period returns of dually-listed stocks and control stocks that trade only in the U.S. to argue that the greater volatility at the open is due to the accumulation of orders at the open. This literature focuses on trading and nontrading period returns because there are no differences among stocks in the arrival of public information during the trading period for the experiments they conduct.

In this paper, we investigate the determinants of stock return volatility in a setting where the rate of arrival of public information differs predictably across stocks during the trading day. We compare the intra-day return behavior during the U.S. trading day of European, Japanese, and American stocks listed on the NYSE or the AMEX. [1] For European stocks, the arrival of public information drops off at the end of the morning in the U.S. as the European business day comes to an end. In contrast, for Japanese stocks, the arrival of public information is uniformly low during the U.S. trading day because the business day in Japan does not overlap with the trading day in the U.S. Hence, using these three classes of stocks, we compare stocks with very different patterns of public information arrival. Since the rate of public information arrival changes during the day across our sample, the sample is also well-suited to study the relation between the arrival of public

[1] In an interesting recent paper, Kleidon and Werner (1995) examine the intra-day patterns of cross-listed U.K. stocks from the open in London to their close in the U.S. to understand better the implications of 24-hour trading of stocks. In their paper, they do not provide the comparisons across classes of stocks with different arrival rates of public information, which are the focus of this paper. In this paper, we treat European stocks as a group and Japanese stocks as a group. Consequently, we do not investigate separately London-listed stocks. The results we report for the European sample are not inconsistent with those of Kleidon and Werner (1995), though.

information, volatility, trading volume, and bid–ask spreads. In particular, the sample is useful to address the issue of whether the arrival of public information leads to more trading, either because the arrivals of public and private information are correlated or because, as in the models of Varian (1989) and Harris and Raviv (1993), investors trade on public information because it changes their priors differently.

If public information is an important determinant of volatility, one would expect more of the daily volatility of European stocks than of American matching stocks to accrue before the end of the European business day. We find that indeed more of the daily volatility of European stocks accrues during the early morning than for American stocks with similar daily volume and volatility. Afterwards, the rate of volatility accrual does not differ significantly between American and European stocks in any of the four 65-minute trading periods from 10:35 to 14:55, but it differs significantly for the remainder of the day. Surprisingly, however, the cumulative difference in the rate of accrual of volatility between European stocks and the American matching stocks never exceeds 4.5% of total intra-day volatility, which seems economically small. Japanese stocks accrue more of their daily volatility early in the morning than matching American and even European stocks. This is unexpected since Japanese stocks are the only stocks in our sample whose home market is closed at that time. After the first hour of trading, 42% of the daily volatility of Japanese stocks has accrued compared to 30% of the daily volatility of European stocks. American matching stocks, however, accrue significantly more volatility than Japanese stocks from 11:40 to 14:55.

Our evidence raises troubling questions about existing explanations for the early morning volatility. It is difficult to reconcile with theories that emphasize the role of price discovery or of the NYSE specialist because these theories imply that early morning volatility should be smaller for foreign stocks. Since European and some Japanese stocks trade in Europe, a competing market for these stocks exists when New York opens, so that for these stocks the New York specialist faces competition at the open and his role in the price discovery process is limited. Explanations that rely on private information trading also seem to be inappropriate here since one would expect private information to be more important in New York for domestic stocks.

Our evidence suggests that trading on public information, which has been largely ignored in the theoretical literature, might be more important than previously recognized. To see this, suppose that stock trading is segmented internationally, in the sense that investors trade a stock in their home country if they can. [2]

[2] Kleidon and Werner (1995) show that the London and New York markets have separate, distinct intra-day patterns such that the New York intra-day pattern is not the continuation of the London intra-day pattern. Internationally segmented stock trading as defined here implies distinct intra-day patterns, but the converse is not true if a market's institutional arrangements play an important role in the intra-day patterns observed for the securities that trade on it.

This means that American investors trade foreign stocks in New York if they are listed there. When New York opens, American investors therefore adjust their portfolios based on how the information that accrued overnight affects their priors. Since markets have been open in the foreign countries after the previous close of New York trading, substantially more public information has accrued about foreign stocks than about domestic stocks. Hence, one would expect both more volatility and more trading for foreign stocks in the morning.

Investigating variance, volume and bid–ask spread patterns after the early morning, we find these patterns surprisingly similar across stock classes, so that whether a security's home market is open or closed during U.S. trading seems to have little impact on these patterns. Even though the home-country business day overlaps only partially or not at all with the U.S. business day for the foreign stocks in our sample, investors can infer changes in the value of the foreign stocks from information produced in the U.S. and from U.S. share price movements. Consequently, information flows in the U.S. affect foreign stock prices in the U.S. also. One would expect most of the information used this way to be public information. It may well be that these derived information flows produce similar patterns in variances, volume, and bid–ask spreads for foreign and U.S. stocks. If that is the case, though, it suggests that trading on private information may not be a very important determinant of patterns in variances, volume, and bid–ask spreads since little private information is expected to become known about foreign stocks during the U.S. trading day.

The paper proceeds as follows. In Section 2, we present our data and returns evidence. In Section 3, we show the volatility patterns. In Section 4 and Section 5, we discuss respectively the evidence on volume and bid–ask spreads. We conclude in Section 6.

2. Data and evidence on returns

The dataset is constructed as follows. Using the 1986 and 1987 ISSM tapes, we select all listings under the names ADR, New York Shares and Common Stocks from countries in the European time zone and from Japan. [3] To remain in the dataset, firms must have at least six trades a day on average, have 100 trading days in the year, and the lowest price in the year must be more than $3. For each foreign firm, we select three matching domestic stocks which have similar trading activity in terms of the average daily number of trades, similar volatility, and trade on the same exchange as the dually-listed share. We drop all observations from October 14, 1987 to October 30, 1987. The Appendix lists our sample of foreign

[3] Note that ADRs are not the shares of the foreign company but claims to these shares. This distinction is unimportant for our analysis.

stocks and the matching stocks. We have 13 European stocks in 1986 and 19 in 1987. There are 5 Japanese stocks in the sample for 1986 and for 1987; of the Japanese stocks, 2 are listed in London in 1986 and in 1987.

To investigate intra-day patterns, we treat the opening trade separately from the rest of the day, which is divided in five equally spaced intervals of 65 min from 9:30 a.m. to 2:55 p.m., one interval of 60 min from 2:55 to 3:55 p.m., and one interval of 5 min at the end of the day from 3:55 p.m. to 4:00 p.m. We consider separately the last five minutes of the trading day since several papers (Harris, 1986, 1989; Wood et al., 1985) show that these last five minutes have unusual return, volatility and volume characteristics. For the opening return, we use the return from the mid-point of the last bid–ask quote on the previous day to the mid-point of the first bid–ask quote. The return for each interval is computed from the mid-point of the last bid–ask quote before the end of the previous interval to the mid-point of the last bid–ask quote of the interval. If the bid–ask quote does not change during the interval, the return for the interval is set equal to zero. If the absolute value of the return is greater than 10% during the interval, it is ignored.

For the variance estimates, we compute the sum of squared returns, V_{it}, for each interval i across firms of the same class. [4] For each foreign firm, we compute the sum of squared returns of its matching firms. In this study, we use six different firm classes: European firms, Japanese firms, Japanese firms also listed in London, Japanese firms not listed in London, matching firms of European firms, and matching firms of Japanese firms.

To test for differences in intra-day patterns between two classes of firms, we pair them in the following system of equations:

$$\begin{aligned} V_{it} &= b_i b_P + e_{it} \\ V_{6t} &= \left(1 - \sum_{j=1}^{5} b_j\right) b_P + e_{6t} \\ V_{it}^* &= \left(b_i + b_i^*\right) b_P^* + e_{it}^* \\ V_{6t}^* &= \left(1 - \sum_{j=1}^{5} \left(b_j + b_j^*\right)\right) b_P^* + e_{6t}^* \end{aligned} \qquad i = 0,1,\ldots,5,7 \tag{1}$$

where $i = 0$ corresponds to the open, $i = 7$ is the closing, and the variables and coefficients with an asterisk are for the second firm class. In this setting, b_P is the sum of the intra-day variances excluding the opening and closing variances. The b_i, $i = 0,\ldots,5,7$, coefficients measure the opening, closing, and intra-day variances as a fraction of b_P, and the b_i^* coefficients measure the variance differences

[4] We also investigated two alternative measures. In one case, we computed average squared returns. In the other case, we computed the squared return after adjusting for the mean. In both cases, the results are very similar to those reported here.

between the first and the second firm class. This approach is inspired by the work of Foster and Viswanathan (1993). They estimate intra-day patterns separately for each firm and then derive implications from the distribution of these patterns across firms. The small number of dually-listed firms prevents us from focusing on the distribution of intra-day patterns across firms. Instead, we estimate the intra-day patterns for each class of firms directly.

In estimating Eq. (1), we use the generalized method of moments (GMM) procedure of Hansen (1982). GMM estimates are robust in the presence of cross-correlations and serial correlations, attributes that we would expect our data to have. We impose the following orthogonality conditions:

$$g_T(\boldsymbol{b}) = \frac{1}{T}\sum_{t=1}^{T}\begin{bmatrix} e_{0t} \\ e_{1t} \\ \cdots \\ e_{6t} \\ e_{7t} \\ e_{0t}^{*} \\ e_{1t}^{*} \\ \cdots \\ e_{6t}^{*} \\ e_{7t}^{*} \end{bmatrix} = 0. \tag{2}$$

To estimate $\boldsymbol{b}$, the vector of 16 unknown b_i coefficients, we minimize the quadratic form of $g'\mathbf{W}g$, where $\mathbf{W}$, a symmetric weighting matrix, is a consistent estimator of the inverse of the asymptotic covariance matrix of $T^{1/2}g_T(\hat{\boldsymbol{b}})$, where $\hat{\boldsymbol{b}}$ is the estimate of $\boldsymbol{b}$, after adjusting for serial correlation as suggested by Newey and West (1987). While the system is just identified and our GMM estimates coincide with those of ordinary least-squares, our standard errors are robust to heteroskedasticity and autocorrelation.

With $\boldsymbol{b}$ as the vector of estimates of b_i, and δ_T as the consistent estimator of

$$\frac{\partial g_T(\boldsymbol{b})}{\partial \boldsymbol{b}},$$

we have

$$\sqrt{T}\,(\hat{\boldsymbol{b}} - \boldsymbol{b}) \sim N\left(0, [\,\delta_T'\mathbf{W}\delta_T\,]^{-1}\right).$$

We test for significance of the estimates using this covariance matrix.

Volume for an intra-day interval refers to the normalized number of shares traded during that interval. We first calculate the number of shares traded over each interval. We then compute the firm average across all intervals and all days. To obtain the normalized volume during an interval, we divide the number of shares traded over that interval by the firm average, and take the average across

firms for the interval. To test for significance, we estimate Eq. (1) using the volume instead of the squared returns.

The bid–ask spread is measured as a percent of the bid–ask mid-point. It is observed at the market open and at the end of each interval. We then estimate Eq. (1) using the bid–ask spreads, but the estimated coefficients are scaled so that they can be interpreted as the bid–ask spread in an interval as a fraction of the bid–ask spread during the third trading interval (11:40–12:45).

Although this study focuses on the volatility, volume, and bid–ask intra-day patterns, we present evidence on the intra-day returns patterns in Table 1 and Fig. 1 for the sake of completeness. The t-statistics are obtained using the GMM approach discussed above. Intra-day returns follow a U-shaped pattern for all stocks similar to the one documented previously by Harris (1986). As evidenced by the last column of the table, closing returns are positive as documented in previous papers. The closing returns are five-minute returns. The closing returns are large for both domestic and foreign stocks. These results reinforce the result that the intra-day patterns of domestic and foreign stocks trading in New York are very similar. Both European and Japanese stocks have a significant and large overnight return. All stock groups have significant returns over the last two intervals. In contrast, the other intra-day returns are insignificant except for the return for European stocks in the first interval. Looking at the difference in returns

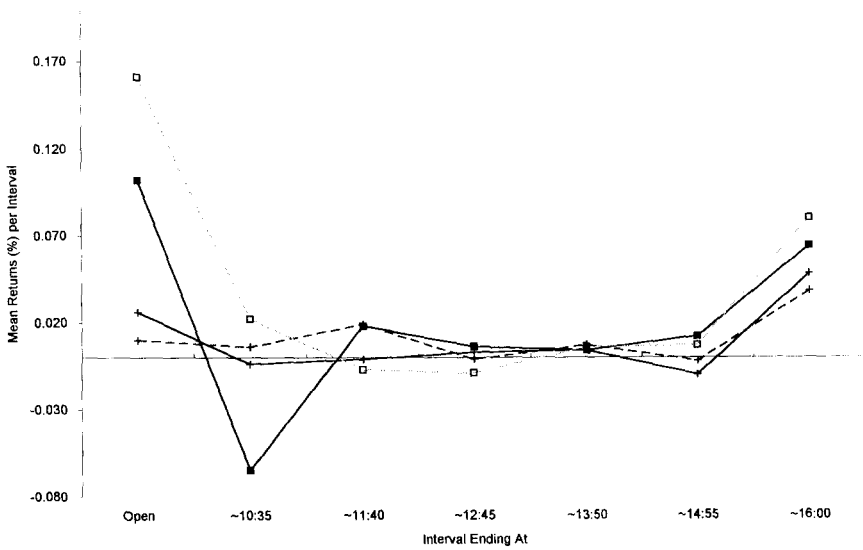

Fig. 1. Intraday returns for domestic matching stocks and foreign stocks traded on the NYSE/AMEX during the 1986–1987 period. Intraday returns for domestic stocks matched with European and Japanese stocks are on the straight and dotted lines respectively. ——— + ———: domestic; ——— ■ ———: European; – + –: domestic; · · · □ · · ·: Japan.

Table 1
Intra-day returns

	Open	~ 10:35	~ 11:40	~ 12:45	~ 13:50	~ 14:55	~ 15:55	~ Close	Intra-day total	Morning/afternoon [a]
A. *European vs. U.S.*										
(1) Domestic:	0.026	−0.004	−0.001	0.003	0.004	−0.010	0.027 *	0.021 *	0.065	−0.111
	(0.019)	(0.016)	(0.010)	(0.009)	(0.006)	(0.008)	(0.010)	(0.004)		(1.318)
(2) European:	0.102 *	−0.065 *	0.018	0.006	0.004	0.012	0.044 *	0.020 *	0.142	−0.671 *
	(0.031)	(0.017)	(0.012)	(0.011)	(0.010)	(0.007)	(0.009)	(0.004)		(0.527)
(1)–(2):	−0.077 *	0.061 *	−0.019 *	−0.003	0.000	−0.023 *	−0.016	0.001	−0.077	0.560
	(0.029)	(0.015)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.003)		(0.966)
B. *Japanese vs. U.S.*										
(1) Domestic:	0.010	0.006	0.019 *	−0.001	0.007	−0.002	0.025 *	0.013 *	0.078	0.797
	(0.017)	(0.016)	(0.009)	(0.008)	(0.007)	(0.007)	(0.010)	(0.004)		(0.747)
(2) Japan:	0.161 *	0.022	−0.007	−0.009	0.006	0.007	0.060 *	0.020 *	0.260	0.085 *
	(0.071)	(0.021)	(0.011)	(0.006)	(0.007)	(0.008)	(0.013)	(0.004)		(0.348)
(1)–(2):	−0.150 *	−0.016	0.026	0.009	0.001	−0.009	−0.035 *	−0.007	−0.182	0.712
	(0.071)	(0.025)	(0.014)	(0.008)	(0.009)	(0.011)	(0.010)	(0.005)		(0.819)

[a] The null is one for both domestic and foreign stocks.

* More than two standard errors from zero.

The GMM estimates for intra-day mean returns (%) are presented below for domestic matching stocks and foreign stocks traded on the NYSE/AMEX during the 1986–1987 period. Bid–ask mid-points are used to compute the intra-day return for each interval. The ratio of returns in the morning and in the afternoon, excluding both opening and closing returns, is presented in the last column. Standard errors (in parentheses) are computed using the Newey and West (1987) method with 15 lags.

between firm types, we find that European stocks have significantly higher returns in the second interval (which corresponds to the close in some European markets), the fifth interval and the sixth interval. In contrast, they have a significantly lower return in the first trading interval. Japanese stocks have a significantly higher return than their matching stocks in the sixth interval and have a significantly lower return in the second interval. We investigated, but do not report here, the difference in returns between Japanese stocks listed in London and those that are not. We found no significant differences.

3. Intra-day volatility patterns

Intra-day volatility patterns have previously been studied for U.S. stocks with the database we use. Wood et al. (1985) and McInish and Wood (1990), using minute by minute transactions data, show a U-shaped pattern for intra-day volatility. Harris (1986) also documents a strong U-shaped pattern for intra-day volatility using 15-minute returns. Finally, Foster and Viswanathan (1993) present results that are comparable to our study. They investigate the intra-day volatility for three groups of stocks. They divide the sample of NYSE stocks on the ISSM database that meet certain selection criteria into deciles of trading activity and select 20 stocks in the first, fifth and tenth deciles. They show that, for all three groups, there is significant intra-day variation in volatility, with volatility being the highest during the first half-hour of trading. For the first and tenth deciles, the coefficient estimates of regressions similar to Eq. (1) show a distinct U-shaped pattern, but no such pattern is present for the fifth decile.

Table 2 presents our coefficient estimates of Eq. (1). The results for European stocks are given in panel A. The estimates give the normalized variance for an interval, defined as a fraction of the total intra-day variance (ignoring the opening and closing variances). It is immediately apparent that the variance fractions follow a U-shaped pattern during the day and this is confirmed in Fig. 2. As expected, the opening variance has the highest fraction and the fractions decline thereafter until the interval from 12:45 to 1:50. After this period, the fractions increase again. The same pattern holds for the domestic comparison stocks.

Looking at the difference between the European and the domestic comparison stocks, the volatility patterns of these two categories of stocks differ significantly only in the first and the last two intervals. In the first interval, the normalized volatility of the European stocks is higher than that of the American stocks; this is reversed gradually over the day. Taking the first three intra-day intervals together and the last three intra-day intervals together, the ratio of morning normalized volatility to afternoon normalized volatility is significantly greater for European stocks than for matching American stocks. The difference in the accrual of volatility during the day seems small if one believes that the accrual of information during the day is substantially more important for American stocks. To see

Table 2
Intra-day variance as a fraction of intra-day total

	Open	~ 10:35	~ 11:40	~ 12:45	~ 13:50	~ 14:55	~ 15:55	~ Close	Intra-day total	Morning/afternoon [a]
A. *European vs. U.S.*										
(1) Domestic:	0.275 *	0.268 *	0.186 *	0.144 *	0.119 *	0.126 *	0.159	0.034 *	0.0048 *	1.482 *
	(0.025)	(0.006)	(0.004)	(0.004)	(0.004)	(0.004)		(0.004)	(0.0005)	(0.038)
(2) European:	0.753 *	0.300 *	0.190 *	0.153 *	0.109 *	0.116 *	0.132	0.027 *	0.0034 *	1.796 *
	(0.061)	(0.011)	(0.008)	(0.008)	(0.007)	(0.007)		(0.003)	(0.0003)	(0.089)
(1)–(2):	−0.478 *	−0.033 *	−0.004	−0.009	0.009	0.009	0.027	0.006 *	0.0014 *	−0.313 *
	(0.045)	(0.013)	(0.009)	(0.009)	(0.007)	(0.008)		(0.003)	(0.0003)	(0.089)
B. *Japanese vs. U.S.*										
(1) Domestic:	0.312 *	0.285 *	0.175 *	0.152 *	0.111 *	0.122 *	0.154	0.027 *	0.0007 *	1.580 *
	(0.036)	(0.012)	(0.008)	(0.007)	(0.006)	(0.007)		(0.006)	(0.0001)	(0.093)
(2) Japan:	5.343 *	0.419 *	0.149 *	0.109 *	0.086 *	0.096 *	0.141	0.023 *	0.0004 *	2.090 *
	(0.679)	(0.039)	(0.014)	(0.012)	(0.008)	(0.009)		(0.003)	(0.0000)	(0.214)
(1)–(2):	−5.032 *	−0.134 *	0.027	0.043 *	0.025 *	0.026 *	0.013	0.004	0.0003 *	−0.509 *
	(0.672)	(0.041)	(0.017)	(0.013)	(0.010)	(0.009)		(0.006)	(0.0001)	(0.214)

[a] The null is one for both domestic and foreign stocks.

* More than two standard errors from zero.

The GMM estimates for intra-day variance as a fraction of intra-day total variance are presented for domestic matching stocks and foreign stocks traded on the NYSE/AMEX during the 1986–1987 period. Intra-day variance for each interval is computed as squared bid–ask mid-points summed over stocks of the same class. For domestic matching stocks, the intra-day variance is divided by 3 since there are three matching stocks per foreign stock. The intra-day total variance excludes both opening and closing variances. The ratio of variances in the morning and in the afternoon, excluding the opening and closing, is presented in the last column. Standard errors (in parentheses) are computed using the Newey and West (1987) method with 15 lags.

this, note that in the first trading interval, only 3.3% more of their daily volatility accrues to European stocks than to American stocks; in the interval prior to the close, 2.7% less of their daily volatility accrues to European stocks than to American stocks. Over the four trading intervals in the middle of the day, almost the same fraction of total daily volatility accrues to both European and American stocks (0.568 versus 0.575, respectively) even though one would expect more public information to accrue to American stocks during those intervals than to European stocks. In contrast, there is a substantial difference in normalized volatility for the last two intervals: for the last intra-day period and the closing period, matching stocks have a significantly higher normalized volatility than European stocks.

In panel B of Table 2 and in Fig. 2, we present evidence for the Japanese stocks. Fig. 2 shows that the volatility of the Japanese stocks exhibits a U-shaped pattern like the European stocks. Panel B of Table 2 shows that the volatility of Japanese stocks during the U.S. trading day is much smaller than the volatility of European stocks. One is tempted to explain this by the fact that European stocks trade on their home market in the morning in the U.S. Paradoxically, the accrual of the Japanese daily volatility is concentrated in the morning. The Japanese stocks have a much higher fraction of their total intra-day volatility during the first interval, even though, in contrast to the European and American stocks, their home

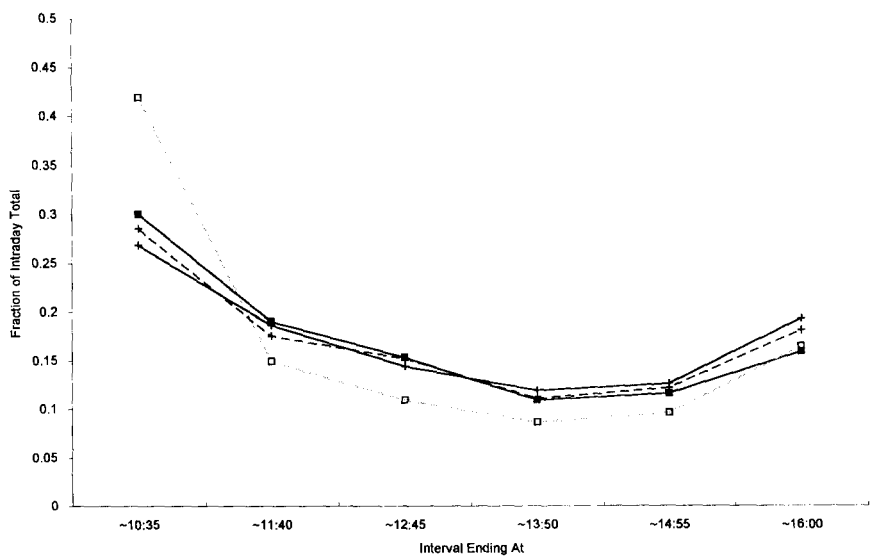

Fig. 2. Intraday variance as a fraction of intraday total variance for domestic matching stocks and foreign stocks traded on the NYSE/AMEX during the 1986–1987 period. Intraday variance fractions for domestic stocks matched with European and Japanese stocks are on the straight and dotted lines, respectively. ——— + ———: domestic; ——— ■ ———: European; – + –: domestic; · · · □ · · ·: Japan.

business and trading days are over. As a result, Japanese stocks have significantly higher normalized volatility than their comparison group during the first interval. In contrast, the comparison group has significantly higher normalized volatility over the third, fourth and fifth intra-day intervals. There is no significant difference in the normalized volatility during the last two intra-day intervals. The volatility patterns between Japanese and U.S. stocks appear to be more different than those between European and U.S. stocks. Finally, for the Japanese stocks, the differences in normalized volatility are more economically significant: the fraction of intra-day volatility that accrues to Japanese stocks in the first period of trading is almost 50% higher than the fraction that accrues to the comparison group of American stocks.

Table 3 provides a measure of how volatility accrues during the trading day. Note that the intra-day total volatility excludes the opening and closing volatilities. Panel A shows that a significantly larger cumulative fraction of total daily volatility has accrued for European stocks by 10:35 than for their matching stocks. The gap in volatility accrual existing at 10:35 grows over the next two trading periods and then becomes smaller, but only very slowly, until 2:55. 4/5th of the gap existing at 10:35 gets resorbed over the last intra-day trading period. Panel B shows that the fraction of total daily volatility that has accrued for Japanese stocks in excess of their comparison group during the first interval is four times higher than the fraction of total daily volatility that has accrued to European stocks in excess of their comparison group. Yet, the excess volatility accrual of Japanese stocks early in the morning dissipates faster than for the European stocks: by 2:55, this excess volatility accrual becomes insignificantly different from zero.

There are several possible explanations for the evidence we uncover in Tables 2 and 3. First, following Amihud and Mendelson (1991), one could argue that opening prices are noisy estimates of public information, so that the first hour of trading incorporates public information that was already available at the opening into prices. Since the Japanese business day closes after the end of the Japanese trading day, Japanese public information accrues after the close of the trading day in Japan. For stocks not listed in Europe, this information can only be incorporated into prices when the NYSE opens. In contrast, for stocks listed in Europe, there is trading when the NYSE opens, so stock prices provide more precise estimates of the existing public information. The price discovery hypothesis suggests that morning volatility accrual should be less for the stocks listed in London. We investigated this hypothesis by dividing the Japanese stocks into stocks listed in London and stocks not listed in London, but do not report the detailed results. In the first trading period, there is no difference between the two groups, whereas in the second period, London-listed stocks have higher normalized volatility than non-London-listed stocks. This evidence does not support the price discovery hypothesis. The second trading period corresponds to the London close; hence, the Japanese stocks listed in London have an increase in volatility around the London close, so that their intra-day volatility in the U.S. inherits both the U-shaped

Table 3
Cumulative intra-day variance as a fraction of intra-day total

	~ 10:35	~ 11:40	~ 12:45	~ 13:50	~ 14:55	~ 15:55	Intra-day total
A. *European vs. U.S.*							
(1) Domestic:	0.268 *	0.453 *	0.597 *	0.716 *	0.841 *	1.000	0.0048 *
	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)		(0.0005)
(2) European:	0.300 *	0.490 *	0.642 *	0.752 *	0.868 *	1.000	0.0034 *
	(0.011)	(0.014)	(0.011)	(0.009)	(0.009)		(0.0003)
(1)–(2):	−0.033 *	−0.037 *	−0.045 *	−0.036 *	−0.027 *	0.000	0.0014 *
	(0.013)	(0.015)	(0.012)	(0.010)	(0.007)		(0.0003)
B. *Japanese vs. U.S.*							
(1) Domestic:	0.285 *	0.461 *	0.612 *	0.723 *	0.846 *	1.000	0.0007 *
	(0.012)	(0.015)	(0.014)	(0.012)	(0.012)		(0.0001)
(2) Japan:	0.419 *	0.568 *	0.676 *	0.763 *	0.859 *	1.000	0.0004 *
	(0.039)	(0.029)	(0.022)	(0.017)	(0.013)		(0.0000)
(1)–(2):	−0.134 *	−0.107 *	−0.064 *	−0.039 *	−0.013	0.000	0.0003 *
	(0.041)	(0.032)	(0.024)	(0.018)	(0.012)		(0.0001)

* More than two standard errors from zero.

The GMM estimates for cumulative intra-day variance as a fraction of intra-day total are presented for domestic matching stocks and foreign stocks traded on the NYSE/AMEX during the 1986–1987 period. Cumulative intra-day variance for each interval is computed by cumulating the intra-day variances from 9:30 after the opening. The intra-day variances are computed as in Table 2. Standard errors (in parentheses) are computed using the Newey and West (1987) method with 15 lags.

pattern of London stocks and the U-shaped pattern of U.S. stocks. In contrast, but similar to Kleidon and Werner (1995), panel A of Table 2 shows that the European stocks do not exhibit such a significant increase in volatility at the close of the European markets.

Although the New York specialist does not have a monopoly position at the opening for European stocks and for Japanese stocks listed in London, the higher first period normalized volatility can be attributed to specialist behavior only if one believes that American investors would not always switch to the foreign market to avoid specialist rent-seeking. Whereas such a view is plausible given the higher transaction costs abroad, one would still expect to observe greater volatility for domestic stocks for the simple reason that there are fewer alternatives for investors wishing to trade domestic stocks than for investors wishing to trade foreign stocks. Hence, it is hard to view our evidence as supportive of the argument advanced by Stoll and Whaley (1990).

It could well be that the massive overnight arrival of public information for foreign stocks is accompanied by an equally massive arrival of short-lived private information. If this were the case, one would expect investors to trade on this private information early in the day. With this view, though, one would expect the volatility increase to be smaller for Japanese stocks traded in London than for Japanese stocks not traded in London simply because some of the private information will be traded upon in London. As explained above, this is not the case.

The final explanation we consider is inspired by the trading models of Varian (1989) and Harris and Raviv (1993). In these models, investors trade on public information because new information leads them to change their priors. Hence, American investors in Japanese or European stocks trade on the overnight public information as the New York market opens if there is segmented trading. Since we do not assume that these investors have valuable private information which would be lost if they did not trade before New York opens, one would not expect them to use the London market. Since London trading does not reflect how American investors react to overnight public information, the lack of a volatility difference in the first period of trading between Japanese stocks listed in London and those which are not is not inconsistent with our explanation. If our explanation is correct, though, one would expect more trading early in the morning for foreign stocks. We turn to a comparison of intra-day patterns in volume next.

All the above analysis is done by computing returns using the mid-point between the bid and ask quotes. We interpret this mid-point as the efficient market price, so that changes in that mid-point correspond to the incorporation of new information into prices. It could be, though, that the mid-point moves around because of microstructural considerations, such as inventory concerns. This raises the question of whether these concerns could make our inferences from the data invalid. One approach would be to follow the time-series analysis of Hasbrouck (1991) and allow explicitly for a transitory component in the mid-point of the

bid–ask quote. Instead, we investigated the robustness of our inferences using transaction prices but do not report these results here. The results we emphasize in this paper hold equally if we use transaction prices instead of mid-points between bid and ask prices.

4. Intra-day patterns in volume

Jain and Joh (1988) report the hourly trading volume of the NYSE and demonstrate a U-shaped pattern in trading volume during the day. Foster and Viswanathan (1993) examine the intra-day volume pattern for their three categories of stocks. They find intra-day differences in volume for all deciles, but the differences are most pronounced for the most actively traded stocks. For all deciles, though, the intra-day pattern has a U-shape with volume highest in the first half hour, falling until the fourth hour and then increasing again. The highest volume coincides with the highest variance, which is supportive of the model of concentrated trading of Admati and Pfleiderer (1988). Foster and Viswanathan (1993) investigate formally the relation between the regression coefficients of the volume regressions and of the volatility regressions. For deciles one and ten they find a significant positive relation between the coefficients of the two regressions.

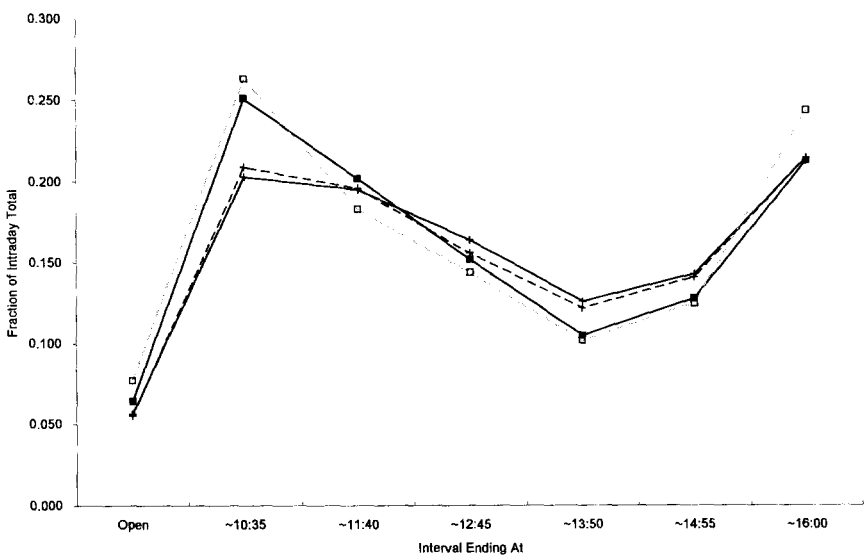

Fig. 3. Normalized intraday volume as a fraction of intraday total volume for domestic matching stocks and foreign stocks traded on the NYSE/AMEX during the 1986–1987 period. Intraday volume fractions for domestic stocks matched with European and Japanese stocks are on the straight and dotted lines, respectively. ——— + ———: domestic; ——— ■ ———: European; – + –: domestic; · · · □ · · ·: Japan.

Table 4
Normalized intra-day volume as a fraction of intra-day total

	Open	~ 10:35	~ 11:40	~ 12:45	~ 13:50	~ 14:55	~ 15:55	~ Close	Intra-day total	Morning/afternoon [a]
A. *European vs. U.S.*										
(1) Domestic:	0.056 *	0.203 *	0.195 *	0.164 *	0.126 *	0.143 *	0.170	0.045 *	606.446 *	1.282 *
	(0.001)	(0.004)	(0.004)	(0.003)	(0.002)	(0.003)		(0.002)	(15.240)	(0.023)
(2) European:	0.064 *	0.251 *	0.202 *	0.152 *	0.105 *	0.128 *	0.161	0.052 *	608.881 *	1.536 *
	(0.004)	(0.006)	(0.004)	(0.004)	(0.003)	(0.005)		(0.003)	(21.661)	(0.051)
(1)–(2):	−0.008 *	−0.048 *	−0.008	0.011 *	0.021 *	0.015 *	0.008	−0.007 *	−2.435	−0.254 *
	(0.003)	(0.006)	(0.005)	(0.005)	(0.003)	(0.005)		(0.003)	(18.808)	(0.052)
B. *Japanese vs. U.S.*										
(1) Domestic:	0.055 *	0.209 *	0.196 *	0.156 *	0.122 *	0.141 *	0.177	0.038 *	606.522 *	1.278 *
	(0.002)	(0.009)	(0.007)	(0.004)	(0.003)	(0.004)		(0.002)	(16.696)	(0.043)
(2) Japan:	0.077 *	0.263 *	0.183 *	0.144 *	0.102 *	0.125 *	0.183	0.061 *	606.978 *	1.441 *
	(0.003)	(0.006)	(0.007)	(0.006)	(0.004)	(0.005)		(0.004)	(30.071)	(0.044)
(1)–(2):	−0.023 *	−0.054 *	0.012	0.012	0.020 *	0.016 *	−0.006	−0.023 *	−0.456	−0.163 *
	(0.004)	(0.009)	(0.009)	(0.006)	(0.006)	(0.006)		(0.004)	(31.699)	(0.059)
C. *Japanese-LSE vs. Japanese-non-LSE*										
(1) J-non-LSE:	0.069 *	0.268 *	0.188 *	0.141 *	0.107 *	0.122 *	0.174	0.058 *	606.806 *	1.481 *
	(0.003)	(0.006)	(0.009)	(0.006)	(0.005)	(0.005)		(0.004)	(35.718)	(0.058)
(2) J-LSE:	0.090 *	0.256 *	0.176 *	0.149 *	0.094 *	0.129 *	0.197	0.066 *	606.006 *	1.385 *
	(0.008)	(0.011)	(0.009)	(0.011)	(0.006)	(0.010)		(0.006)	(34.743)	(0.066)
(1)–(2):	−0.022 *	0.013	0.012	−0.008	0.013	−0.006	−0.023	−0.008	0.799	0.096
	(0.010)	(0.013)	(0.011)	(0.012)	(0.007)	(0.012)		(0.006)	(38.017)	(0.086)

[a] The null is one for both domestic and foreign stocks.

* More than two standard errors from zero.

The GMM estimates for normalized intra-day volume as a fraction of intra-day total are presented below for domestic matching stocks and foreign stocks traded on the NYSE/AMEX during the 1986–1987 period. Intra-day volume for each interval is normalized by dividing the number of shares traded over the interval by the average of all intervals. The intra-day total volume excludes both opening and closing volumes. The ratio of volumes in the morning and in the afternoon, excluding the opening and closing, is presented in the last column. Standard errors (in parentheses) are computed using the Newey and West (1987) method with 15 lags.

In Table 4 and Fig. 3, we present our results for the intra-day variation in normalized volume. In panel A, we show the results for the European stocks. It is immediately clear that these stocks exhibit a U-shaped intra-day pattern and this is shown in Fig. 3. There seems to be some difference in the intra-day patterns between American and European stocks: European stocks have significantly more of their daily volume in the morning, American stocks have significantly more in the afternoon, except in the last period. The difference in volume is especially striking in the first period where the normalized volume of European stocks is a fifth higher than the normalized volume of the matching stocks and in the fourth period where the normalized volume of European stocks is almost a fifth lower than the normalized volume of matching stocks. To investigate further the concentration of trading, we compute Herfindahl indices as the sum of the squared volume accrual rates. This index would take a value of one if all trading is concentrated in one period and a value of $1/6$ if trading takes place equally in each period. The Herfindahl index is 0.180 for European stocks and 0.171 for American matching stocks. Hence, both European and American stocks seem to have equally concentrated trading when measured this way. We saw in Table 2 that the normalized variance of European stocks exceeds the normalized variance of American comparison stocks by 3.3% of total intra-day variance during the first trading interval; during that interval, there is a similar normalized volume difference of 4.8%. Whereas European stocks have significantly higher volume in the morning, they have significantly lower volume in the afternoon except during the five minutes closing trading period where European stocks have significantly higher volume than matching stocks by 0.7%.

Panel B of Table 4 provides results for the Japanese stocks. For these stocks, we again observe a U-shaped pattern which is also apparent in Fig. 3. This pattern is more pronounced than for American matching stocks: a higher fraction of Japanese stock trading accrues in the first and last trading intervals than for American stocks. For both the Japanese and matching American stocks, the fraction of daily volume which accrues during the last two intervals is roughly comparable to the fraction of daily volume which accrues during the first interval. The higher end-of-day volume of the Japanese stocks is not accompanied by higher volatility. Except for the last interval, though, Japanese stocks have greater volatility when they have greater volume. The differences in volume are smaller in magnitude than the differences in volatility. For example, the fraction of volume that accrues to Japanese stocks in excess of the fraction of volume that accrues to American stocks during the first interval is only 5.4% of the daily total in contrast to 13.4% for the variance as shown in Table 2. The small differences explain why the Herfindahl index for trade concentration of Japanese stocks, 0.183, is so close to the one for matching American stocks, 0.173. As for the comparison with European stocks, the Japanese stocks have lower normalized volume each period from 10:35 to 2:55 and higher normalized volume in the first and last two intervals.

Table 5
Cumulative normalized intra-day volume as a fraction of intra-day total

	~ 10:35	~ 11:40	~ 12:45	~ 13:50	~ 14:55	~ 15:55	Intra-day total
A. *European vs. U.S.*							
(1) Domestic:	0.203 *	0.398 *	0.562 *	0.688 *	0.830 *	1.000	606.446 *
	(0.004)	(0.006)	(0.004)	(0.004)	(0.004)		(15.240)
(2) European:	0.251 *	0.453 *	0.606 *	0.711 *	0.839 *	1.000	608.881 *
	(0.006)	(0.007)	(0.008)	(0.006)	(0.004)		(21.661)
(1)–(2):	−0.048 *	−0.055 *	−0.044 *	−0.023 *	−0.008	0.000	−2.435
	(0.006)	(0.008)	(0.008)	(0.007)	(0.004)		(18.808)
B. *Japanese vs. U.S.*							
(1) Domestic:	0.209 *	0.405 *	0.561 *	0.683 *	0.823 *	1.000	606.522 *
	(0.009)	(0.009)	(0.008)	(0.008)	(0.007)		(16.696)
(2) Japan:	0.263 *	0.446 *	0.590 *	0.692 *	0.817 *	1.000	606.978 *
	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)		(30.071)
(1)–(2):	−0.054 *	−0.041 *	−0.029 *	−0.010	0.006	0.000	−0.456
	(0.009)	(0.011)	(0.011)	(0.010)	(0.009)		(31.699)
C. *Japanese-LSE vs. Japanese-non-LSE*							
(1) J-non-LSE:	0.268 *	0.456 *	0.597 *	0.704 *	0.826 *	1.000	606.806 *
	(0.006)	(0.009)	(0.009)	(0.008)	(0.008)		(35.718)
(2) J-LSE:	0.256 *	0.432 *	0.581 *	0.675 *	0.803 *	1.000	606.006 *
	(0.011)	(0.013)	(0.012)	(0.012)	(0.011)		(34.743)
(1)–(2):	0.013	0.025	0.016	0.030 *	0.023	0.000	0.799
	(0.013)	(0.016)	(0.015)	(0.013)	(0.014)		(38.017)

* More than two standard errors from zero.

The GMM estimates for cumulative normalized intra-day volume as a fraction of intra-day total are presented for domestic matching stocks and foreign stocks traded on the NYSE/AMEX during the 1986–1987 period. Cumulative intra-day volume for each interval is computed by cumulating the normalized intra-day volume from 9:30 after the opening. The normalized intra-day volume is computed as in Table 4. Standard errors (in parentheses) are computed using the Newey and West (1987) method with 15 lags.

Table 5 provides results on cumulative intra-day volume. It shows that the normalized volume of American stocks catches up with the normalized volume of Japanese stocks more quickly during the day than it catches up with the normalized volume of European stocks. By 1:50, the accrual of daily volume for American comparison stocks is approximately equal to that for Japanese stocks; for European stocks, this occurs after 2:55. This evidence is consistent with the view that investors receive more information to trade upon late in the morning for European stocks than for Japanese stocks.

The private information story would suggest more accumulation of volume early in the day for Japanese stocks which do not trade on the London Stock Exchange. In panels C of Tables 4 and 5, we report some evidence that (1) Japanese stocks listed in London trade more at the open and (2) volume accumulates faster after the opening for Japanese stocks not listed in London. Interestingly, the greater normalized volume at the open for London-listed stocks is approximately offset by the lesser normalized volume of these stocks during the first two trading intervals. Hence, availability of the London market does lead to a shift in trading towards the open. The volume results contrast with the variance results since, as discussed in the previous section, there is no significant difference in variance accrual rates between Japanese stocks listed in London and those that are not. Hence, one can interpret this evidence as indicating that investors are more willing to trade at the open when a competing exchange is open. Two possible reasons for this are: (a) opening prices are less noisy or (b) trading is cheaper because of competition. Given that the rate of volatility accrual for Japanese stocks not listed in London is not higher following the open, it is hard to argue that the data is supportive of (a). To investigate (b), we have to look at bid–ask spreads, which we do next.

5. Bid–ask spread intra-day patterns

We now turn to a comparison of the bid–ask intra-day patterns. Existing evidence for American stocks documented in McInish and Wood (1992), Hasbrouck (1991) and Foster and Viswanathan (1993) indicates that there is a U-shaped pattern in bid–ask spreads. Foster and Viswanathan show that there are significant differences in adverse selection costs during the day, but that these differences are hard to reconcile with models of concentrated trading which suggest that the bid–ask spread should be lower when trading is highest. Their evidence is stronger for the most actively traded firms, however.

In Table 6, we provide our evidence on intra-day patterns in bid–ask spreads. In panel A, we report the results for European stocks. At the open, the spread for European stocks is 1.04%, which is much lower than the 1.13% for the matching stocks. At the open, however, the normalized spread for European stocks, i.e., the spread divided by its midday value, is significantly higher than for American

Table 6
Intra-day bid–ask spread relative to midday

	Open	~ 10:35	~ 11:40	~ 12:45	~ 13:50	~ 14:55	~ 15:55	~ Close	Midday spread [a]
A. *European vs. U.S.*									
(1) Domestic:	1.111 *	1.032 *	1.005	1.000	0.996	0.994	1.013 *	1.005	1.014 *
	(0.005)	(0.003)	(0.003)		(0.003)	(0.004)	(0.004)	(0.007)	(0.027)
(2) European:	1.164 *	1.040 *	1.016 *	1.000	0.988	1.000	0.983 *	0.971 *	0.893 *
	(0.007)	(0.007)	(0.007)		(0.006)	(0.007)	(0.007)	(0.006)	(0.024)
(1)–(2):	−0.053 *	−0.008	−0.011	0.000	0.008	−0.005	0.031 *	0.034 *	0.121 *
	(0.009)	(0.008)	(0.007)		(0.007)	(0.007)	(0.007)	(0.006)	(0.020)
B. *Japanese vs. U.S.*									
(1) Domestic:	1.101 *	1.024 *	1.000	1.000	0.988 *	0.988 *	1.007	0.999	0.849 *
	(0.006)	(0.006)	(0.004)		(0.003)	(0.005)	(0.006)	(0.008)	(0.018)
(2) Japan:	1.241 *	1.056 *	1.003	1.000	0.991	0.974 *	0.994	0.992	0.490 *
	(0.026)	(0.012)	(0.012)		(0.009)	(0.008)	(0.012)	(0.010)	(0.011)
(1)–(2):	−0.139 *	−0.032 *	−0.003	0.000	−0.003	0.014	0.014	0.007	0.360 *
	(0.026)	(0.013)	(0.011)		(0.010)	(0.010)	(0.014)	(0.012)	(0.020)

[a] The null is zero for the midday spread.

* More than two standard errors from one.

The GMM estimates for intra-day bid–ask spread relative to midday are presented below for domestic matching stocks and foreign stocks traded on the NYSE/AMEX during the 1986–1987 period. The bid–ask spread for each interval is computed as a percent of the bid–ask mid-point observed at the end of the interval, and is reported below as a fraction of the midday bid–ask spread observed during 11:40–12:45. Standard errors (in parentheses) are computed using the Newey and West (1987) method with 15 lags.

stocks: 164% versus 111%. Hence, the existence of a competing market for the European stocks does not imply a smaller spike in spread in the morning, which makes it hard to explain this spike by the monopolist behavior of NYSE specialists. The normalized spread for European stocks tends to fall throughout the day. Except for the open, the normalized spread for European stocks is never significantly greater than for matching stocks and is significantly lower in the last two periods. Consequently, as shown in Fig. 4, European stocks do not exhibit a U-shaped pattern of bid–ask spreads. The matching stocks do not exhibit much of a U-shaped pattern either: the bid–ask spread of matching stocks at the end of the day is not significantly higher than the bid–ask spread at midday.

Panel B of Table 6 and Fig. 4 provide evidence for Japanese stocks. Again, for these stocks the bid–ask spread at midday is far lower than for the matching stocks. Similarly to the European stocks, however, the normalized spread for Japanese stocks is higher at the open than for their matching stocks. Contrary to the European stocks, though, the bid–ask spread for Japanese stocks at the end of the day is not significantly lower than at midday. There is no evidence that competition by foreign markets eliminates the bid–ask spread peak in the morning. The absence of a higher normalized bid–ask spread at the end of the day cannot be attributed to competition since foreign markets are closed at that time. Further, in our sample, the behavior of the Japanese stocks at the end of the day is not different from their matching stocks.

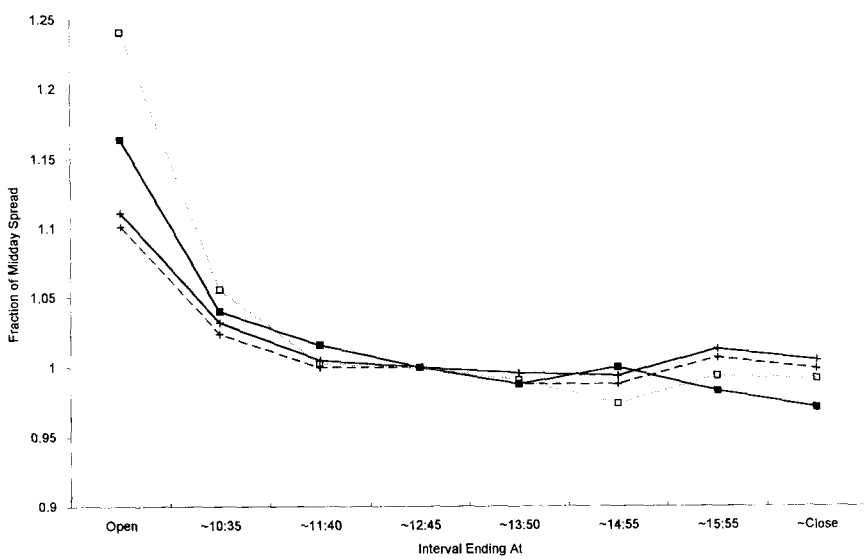

Fig. 4. Intraday bid–ask spread as a fraction of midday spread for domestic matching stocks and foreign stocks traded on the NYSE/AMEX during the 1986–1987 period. Intraday spread fractions for domestic stocks matched with European and Japanese stocks are on the straight and dotted lines, respectively. ——— + ———: domestic; ——— ■ ———: European; – + –: domestic; · · · □ · · ·: Japan; – × –.

It is difficult to believe that the greater normalized spread of foreign stocks early in the morning reflects greater adverse selection than later in the day. This is because, presumably, private information trading is more likely to take place on the deeper home market of a security and during the foreign business day. It may well be, though, that in the morning, as American investors react to overnight public information, there is a substantial risk for the specialist of large changes in his inventory resulting from changes in the American investors' demand for foreign securities. The specialist would protect himself from such changes by posting a greater bid–ask spread relative to the rest of the day.

6. Concluding remarks

In this paper, we investigate the intra-day volatility, volume, and bid–ask spread patterns for stocks that differ markedly in the arrival rate of public information. We find that, in spite of the differences in the arrival rate of public information, all groups of stocks have U-shaped patterns of volume and volatility. The U-shaped patterns in volatility cannot be explained by the contemporaneous arrival of public information for the different stocks. Models with trading on private information do not seem to be consistent with our results. This is because, for Japanese stocks, one would expect volatility to be less for the stocks listed in London than for the other stocks if private information is a major determinant of volatility because investors with private information presumably take advantage of the opportunity to trade in London. We find no support for this.

A plausible story for our results is that investors in the U.S. trade on the basis of the accumulated stock of public information since the last closing of the U.S. markets. This stock of information is the largest for Japanese stocks since a whole business day takes place between their close and U.S. open, the second largest for European stocks since more than half a business day takes place between their U.S. close and the open, and smallest for American stocks. With this view, investors trade on the public information because it changes their priors. The process of demand revelation causes prices to exhibit greater volatility. Consequently, the opening price is not a noisy estimate of the fundamentals known at the open; rather, the demand by American investors is revealed only over time as they react to the accumulated public information. The volatility of matching American stocks is lower in the morning because not much has happened to change investors' priors. Bid–ask spreads are larger in the morning for foreign stocks relative to later in the day because there is more uncertainty about demand.

Acknowledgements

We are grateful to Yakov Amihud and two anonymous referees for comments, and to Tom George and Hans Stoll for useful discussions.

Appendix A. Sample of foreign stocks and American matching stocks

For each foreign stock in the sample and its three American matching stocks, this Appendix provides the ticker symbol, the firm name, the CUSIP number, the number of trading days for the year, the average number of trades per day (NTPD), the standard deviation of hourly returns, the firm size in units of $1000 (the average price for the year times the number of shares outstanding at the beginning of the year), the exchange where the stock is listed at the end of the year (N denotes NYSE and A denotes AMEX), and the lowest price for the year.

A.1. European Stocks Listed on NYSE / AMEX in 1986

OBS	SYM	NAME	CUSIP	DAYS	NTPD	Std dev.	SIZE	EX	LOWPRI
1	AUS	AUSIMONT COMPO N V	05211510	236	21.86	0.008601	561388	N	12.3
2	BP	BRITISH PETE LTD	11088940	236	30.15	0.003672	67021344	N	30.1
3	BTI	B A T INDS P L C	05527020	236	53.55	0.006001	8701392	A	4.2
4	BTY	BRITISH TELECOMMS P L C	11102130	233	13.13	0.004164	179571440	N	24.6
5	ETZ	ETZ LAVUD LTD	29788210	236	6.67	0.011485	20641	A	8.4
6	ICI	IMPERIAL CHEM INDS PLC	45270450	236	58.67	0.003337	8841772	N	42.1
7	KLM	KLM ROYAL DUTCH AIRLS	48251610	236	46.32	0.005569	799275	N	17.5
8	LAS	LASER INDS LTD	51806110	236	30.85	0.012002	49078	A	9.8
9	NHY	NORSK HYDRO A S	65653160	118	15.68	0.004812	1733943	N	16.9
10	NVO	NOVO INDUSTRI A S	67010020	236	49.69	0.006409	787331	N	25.9
11	RD	ROYAL DUTCH PETE CO	78025760	236	139.78	0.003106	21352752	N	59.8
12	SC	SHELL TRANS and TRADING LTD	82270350	236	39.33	0.003527	13319805	N	36.0
13	UN	UNILEVER N V	90478450	236	35.39	0.003406	6078483	N	137.7
American matching stocks in 1986									
1	ALN	ALLEN GROUP INC	01763410	236	23.87	0.008507	152105	N	14.8
1	ELE	ELECTROSPACE SYS INC	28616210	236	17.70	0.008630	215784	N	13.6
1	NBI	NBI INC	62873510	236	25.89	0.008503	107740	N	7.5
2	IOR	IOWA RES INC	46253710	236	32.04	0.004157	345430	N	22.0
2	IWG	IOWA ILL GAS and ELEC CO	46247010	236	25.97	0.004176	528383	N	34.5
2	WPL	WISCONSIN PWR and LT CO	97682610	236	32.21	0.003831	660131	N	39.0
3	HFI	HUDSON FOODS INC	44378210	211	43.74	0.009961	188198	A	10.8
3	MAX	MATRIX CORP N J	57682910	236	53.61	0.009588	214216	A	14.3
3	OZA	OZARK HLDGS INC	69263210	182	49.64	0.006308	192495	A	11.6
4	BDG	BANDAG INC	05981510	236	15.31	0.004221	641599	N	57.0
4	CYL	CYCLOPS CORP	23252510	236	11.30	0.004185	252007	N	51.4
4	WIC	WICOR INC	92925310	236	14.17	0.004283	219106	N	29.4
5	HMN	HANDYMAN CORP	41033510	233	6.31	0.011701	87494	A	26.5
5	JEC	JACOBS ENGR GROUP INC	46981410	236	6.01	0.011409	37597	A	6.3
5	TDX	TRIDEX CORP	89590610	236	6.91	0.011295	14240	A	6.5
6	SPS	SOUTHWESTERN PUB SVC CO	84574310	236	65.27	0.003918	1266701	N	25.3
6	TE	TECO ENERGY INC	87237510	236	67.51	0.003681	1210587	N	34.0
6	WPC	WISCONSIN ELEC PWR CO	97665610	236	60.44	0.003569	1724923	N	38.4
7	EFU	EASTERN GAS and FUEL ASSOC	27646110	236	46.79	0.005555	611956	N	22.3
7	IR	INGERSOLL RAND CO	45686610	236	39.14	0.005471	1182693	N	50.9
7	SLN	SEA LD CORP	81140810	181	37.81	0.005460	571807	N	19.8
8	GMN	GREENMAN BROS INC	39537010	236	34.69	0.011844	89292	A	8.4
8	HHH	HERITAGE ENTMT INC	42722710	179	29.80	0.012112	27569	A	6.6
8	NLI	NEWMARK and LEWIS INC	65157610	236	31.49	0.012223	54844	A	10.8
9	CCP	CECO IND	15003610	225	14.44	0.004825	171764	N	28.5
9	CSN	CINCINNATI BELL INC	17187010	236	16.78	0.004857	415561	N	36.3

9	LG	LACLEDE GAS CO	50558810	236	13.28	0.004835	302117	N	28.0
10	HRB	BLOCK H and R INC	09367110	236	52.41	0.006388	514800	N	35.8
10	KSF	QUAKER ST OIL REFNG CORP	74741910	236	41.74	0.006368	684398	N	23.0
10	RAD	RITE AID CORP	76775410	236	58.80	0.006481	1245727	N	24.3
11	AIT	AMERICAN INFO TECHS CORP	02680410	236	136.91	0.004159	12365377	N	98.0
11	ED	CONSOLIDATED EDISON CO N Y I	20911110	236	124.83	0.003929	5827416	N	37.6
11	SBC	SOUTHWESTERN BELL CORP	84533310	236	154.61	0.003525	9948680	N	79.0
12	CNT	CENTEL CORP	15133410	236	41.61	0.004067	1524205	N	45.0
12	LOU	LOUISVILLE GAS and ELEC CO	54667610	236	43.51	0.003772	710030	N	29.0
12	MDA	MAPCO INC	56509710	236	38.09	0.004131	1432451	N	36.0
13	AD	AMSTED INDS INC	03217710	102	40.60	0.002767	502821	N	41.3
13	ORU	ORANGE and ROCKLAND UTILS INC	68406510	236	31.62	0.004445	416818	N	26.3
13	SWX	SOUTHWEST GAS CORP	84489510	236	34.98	0.004571	203265	N	16.6

A.2. European Stocks Listed on NYSE / AMEX in 1987

OBS	SYM	NAME	CUSIP	DAYS	NTPD	Std Dev.	SIZE	EX	LOWPRI
1	AUS	AUSIMONT COMPO N V	05211510	219	20.36	0.011999	556687	N	10.0
2	BAB	BRITISH AWYS PLC	11041920	192	40.39	0.009332	1631031	N	16.1
3	BCM	BANCO CENTRAL S A	05947020	219	8.56	0.008319	1816074	N	16.5
4	BP	BRITISH PETE LTD	11088940	219	74.66	0.004757	28168704	N	43.3
5	BTI	B A T INDS P L C	05527020	219	31.50	0.009717	12737035	A	6.7
6	BTY	BRITISH TELECOMM P L C	11102140	219	18.74	0.004617	25450848	N	31.5
7	GLX	GLAXO HLDGS PLC	37732730	115	298.97	0.010945	12517367	N	7.9
8	HAN	HANSON TR PLC	41135230	219	118.06	0.009615	6860159	N	5.3
9	ICI	IMPERIAL CHEM INDS PLC	45270450	219	66.11	0.005343	13866652	N	62.6
10	KLM	KLM ROYAL DUTCH AIRLS	48251610	219	46.31	0.009301	1043989	N	13.3
11	LAS	LASER INDS LTD	51806110	219	22.66	0.017963	49357	A	4.8
12	NHY	NORSK HYDRO A S	65653160	219	22.70	0.007587	2400634	N	19.5
13	NVO	NOVO INDUSTRI A S	67010020	219	37.94	0.009127	4215200	N	17.3
14	NW	NATL WESTMINSTER BK PLC	63853940	219	16.47	0.005247	7526411	N	24.0
15	PHG	PHILIPS N V	71833750	151	42.66	0.007944	5453637	N	14.3
16	RD	ROYAL DUTCH PETE CO	78025760	219	153.58	0.007034	31114320	N	94.4
17	SC	SHELL TRANS and TRADING LTD	82270350	219	36.99	0.005408	21249600	N	58.1
18	TEF	COMPANIA TELEFONICA NACIONAL	20390120	113	79.82	0.014821	6601878	N	16.0
19	UN	UNILEVER N V	90478450	219	68.70	0.008492	5053540	N	38.0
American matching stocks in 1987									
1	ALN	ALLEN GROUP INC	01763410	219	25.82	0.011544	128434	N	5.5
1	NBI	NBI INC	62873510	219	27.92	0.015625	90199	N	3.6
1	RGC	REPUBLIC GYPSUM CO	76047310	219	16.71	0.011975	86392	N	4.6
2	EMH	EMHART CORP VA	29121010	219	37.10	0.009455	1072660	N	16.0
2	HMX	HARTMARX CORP	41711910	219	38.11	0.009327	565145	N	18.3
2	KSU	KANSAS CITY SOUTHN INDS INC	48517010	219	35.86	0.009275	551515	N	35.0
3	FLA	FLORIDA EAST COAST INDS	34063210	219	8.76	0.008149	488469	N	39.5
3	HNM	HANNA M A CO	41052210	219	9.58	0.008524	242836	N	17.0
3	HSI	HI SHEAR INDS INC	42839910	219	7.81	0.008438	111761	N	12.3
4	IOR	IOWA RES INC	46253710	219	23.72	0.004723	476730	N	17.4
4	IWG	IOWA ILL GAS and ELEC CO	46247010	219	20.07	0.004135	519974	N	34.5
4	WPL	WISCONSIN PWR and LT CO	97682610	219	25.00	0.003975	633860	N	42.5
5	HFI	HUDSON FOODS INC	44378210	219	38.26	0.012773	183181	A	4.9
5	MAX	MATRIX CORP N J	57682910	219	65.59	0.017764	145393	A	3.9
5	PGI	PLY GEM INDS INC	72941610	219	29.26	0.010525	114196	A	9.0
6	BDG	BANDAG INC	05981510	219	30.57	0.010335	495473	N	42.0
6	IPW	INTERSTATE PWR CO	46107410	219	18.06	0.004662	225179	N	19.4
6	WIC	WICOR INC	92925310	219	12.69	0.004651	216358	N	26.8

7	CHA	CHAMPION INTL CORP	15852510	219	257.84	0.011147	3428698	N	23.3
7	CRR	CONSOLIDATED RAIL CORP	20986410	163	258.46	0.011211	2160351	N	19.9
7	KM	K MART CORP	48258410	219	321.97	0.011188	5777130	N	21.6
8	CCC	COMMERCIAL CR CO	20161510	219	100.43	0.009460	1223291	N	17.0
8	FDS	FEDERATED DEPT STORES INC	31409910	219	129.51	0.009456	2872442	N	28.4
8	LIL	LONG ISLAND LTG CO	54267110	219	94.82	0.009484	1085744	N	6.1
9	SPS	SOUTHWESTERN PUB SVC CO	84574310	219	59.72	0.005091	1138007	N	22.1
9	TE	TECO ENERGY INC	87237510	219	71.83	0.004263	1026238	N	22.0
9	WWP	WASHINGTON WTR PWR CO	94068810	219	56.42	0.005298	589680	N	22.3
10	AVT	AVNET INC	05380710	219	48.84	0.009388	1109094	N	18.5
10	EFU	EASTERN GAS and FUEL ASSOC	27646110	219	38.88	0.008399	615672	N	19.0
10	IR	INGERSOLL RAND CO	45686610	219	86.11	0.013390	1006405	N	22.5
11	CRW	CROWN CRAFTS INC	22830910	219	22.23	0.017845	23572	A	10.9
11	GMN	GREENMAN BROS INC	39537010	219	24.99	0.021383	52163	A	3.3
11	NLI	NEWMARK and LEWIS INC	65157610	219	22.58	0.018443	64452	A	3.5
12	CSN	CINCINNATI BELL INC	17187010	219	18.71	0.008233	552254	N	19.4
12	LG	LACLEDE GAS CO	50558810	219	11.25	0.005481	260349	N	26.4
12	UGI	UGI CORP	90268610	219	26.15	0.007552	256967	N	21.8
13	HRB	BLOCK H and R INC	09367110	219	85.09	0.011157	1054739	N	20.0
13	I	FIRST INTST BANCORP	09367110	219	71.52	0.011157	2436599	N	35.0
13	RAD	RITE AID CORP	76775410	219	64.66	0.008882	1427739	N	15.6
14	FMO	FEDERAL MOGUL CORP	31354910	219	13.81	0.005302	509553	N	29.1
14	RTC	ROCHESTER TEL CORP	77175810	219	19.17	0.005162	447986	N	37.0
14	SW	STONE and WEBSTER INC	86157210	219	14.07	0.005093	485467	N	48.8
15	HP	HELMERICH and PAYNE INC	42345210	219	41.22	0.008154	650234	N	17.5
15	KLT	KANSAS CITY PWR and LT CO	48513410	219	40.51	0.008135	841510	N	21.0
15	NOB	NORWEST CORP	66938010	219	49.05	0.008118	1247907	N	31.8
16	AIT	AMERICAN INFO TECHS CORP	02680410	219	141.67	0.005867	8947835	N	74.0
16	ED	CONSOLIDATED EDISON CO N Y I	20911110	219	123.38	0.004496	5279819	N	37.5
16	SBC	SOUTHWESTERN BELL CORP	84533310	219	205.31	0.007478	6349327	N	21.5
17	CNT	CENTEL CORP	15133410	219	53.99	0.005091	1616308	N	32.8
17	LOU	LOUISVILLE GAS and ELEC CO	54667610	219	34.82	0.004420	697810	N	30.1
17	MDA	MAPCO INC	56509710	219	32.28	0.004814	1197977	N	39.9
18	KB	KAUFMAN and BROAD INC	48617010	219	79.46	0.014393	347861	N	9.0
18	SGL	SUPERMARKETS GEN CORP	86844310	162	76.01	0.014455	1490665	N	25.1
18	TW	TRANS WORLD CORP	87311810	218	65.09	0.015628	802520	N	9.3
19	ORU	ORANGE and ROCKLAND UTILS INC	68406510	219	27.48	0.005185	389971	N	25.0
19	SWX	SOUTHWEST GAS CORP	84489510	219	41.12	0.006703	304204	N	18.3
19	TMC	TIMES MIRROR CO	88736010	219	78.42	0.008437	5286628	N	60.4

Appendix B

B.1. Japanese stocks listed on NYSE / AMEX in 1986

OBS	SYM	NAME	CUSIP	DAYS	NTPD	Std Dev.	SIZE	EX	LOWPRI
1	HIT	HITACHI LTD [a]	43357850	236	28.54	0.003292	156296944	N	35.5
2	HMC	HONDA MTR LTD	43812830	236	44.36	0.003629	62379856	N	55.0
3	KYO	KYOCERA LTD [a]	50155620	236	9.53	0.003809	7372510	N	39.6
4	MC	MATSUSHITA ELEC INDL LTD	57687920	236	33.51	0.003424	159667536	N	60.0
5	SNE	SONY CORP	83569930	236	52.37	0.004886	4769083	N	18.1
American matching stocks in 1986									
1	IOR	IOWA RES INC	46253710	236	32.04	0.004157	345430	N	22.0
1	IPW	INTERSTATE PWR CO	46107410	236	23.75	0.003968	233903	N	21.1
1	WPL	WISCONSIN PWR and LT CO	97682610	236	32.21	0.003831	660131	N	39.0
2	CNT	CENTEL CORP	15133410	236	41.61	0.004067	1524205	N	45.0
2	LOU	LOUISVILLE GAS and ELEC CO	54667610	236	43.51	0.003772	710030	N	29.0
2	SNG	SOUTHERN NEW ENGLAND TEL CO	84348510	236	49.64	0.004073	1588952	N	43.0
3	GFD	GUILFORD MLS INC	40179410	236	8.32	0.004040	224672	N	22.5
3	NJR	NEW JERSEY RES CORP	64602510	236	9.58	0.003961	102292	N	25.8
3	WST	WEST INC	95334810	236	7.90	0.003622	231840	N	24.9
4	MDA	MAPCO INC	56509710	236	38.09	0.004131	1432451	N	36.0
4	ORU	ORANGE and ROCKLAND UTILS INC	68406510	236	31.62	0.004445	416818	N	26.3
4	SWX	SOUTHWEST GAS CORP	84489510	236	34.98	0.004571	203265	N	16.6
5	CCB	CAPITAL CITIES COMMUNICATION	13985910	236	58.73	0.004953	3199108	N	208.2
5	IDA	IDAHO PWR CO	45138010	236	58.57	0.004773	891796	N	22.8
5	TEK	TEKTRONIX INC	87913110	236	48.50	0.005020	1180817	N	54.5

[a] These stocks are also listed in London in 1986.

B.2. Japanese Stocks Listed on NYSE / AMEX in 1987

OBS	SYM	NAME	CUSIP	DAYS	NTPD	Std Dev.	SIZE	EX	LOWPRI
1	HIT	HITACHI LTD [a]	43357850	219	32.00	0.005170	22290416	N	59.3
2	HMC	HONDA MTR LTD	43812830	219	33.44	0.005058	8759186	N	78.0
3	KYO	KYOCERA LTD [a]	50155620	219	10.98	0.006708	5248604	N	48.0
4	MC	MATSUSHITA ELEC INDL LTD	57687920	219	19.89	0.007213	24546272	N	93.3
5	SNE	SONY CORP	83569930	219	42.01	0.006136	6236788	N	18.3
American matching stocks in 1987									
1	IOR	IOWA RES INC	46253710	219	23.72	0.004723	476730	N	17.4
1	IPW	INTERSTATE PWR CO	46107410	219	18.06	0.004662	225179	N	19.4
1	WPL	WISCONSIN PWR and LT CO	97682610	219	25.00	0.003975	633860	N	42.5
2	CNT	CENTEL CORP	15133410	219	53.99	0.005091	1616308	N	32.8
2	LOU	LOUISVILLE GAS and ELEC CO	54667610	219	34.82	0.004420	697810	N	30.1
2	SNG	SOUTHERN NEW ENGLAND TEL CO	84348510	219	34.87	0.004862	1590076	N	43.0
3	GFD	GUILFORD MLS INC	40179410	219	11.38	0.004973	307493	N	23.1
3	NJR	NEW JERSEY RES CORP	64602510	219	21.94	0.007241	79346	N	16.1
3	WST	WEST INC	95334810	218	12.73	0.008083	225591	N	12.4
4	MDA	MAPCO INC	56509710	219	32.28	0.004814	1197977	N	39.9
4	ORU	ORANGE and ROCKLAND UTILS INC	68406510	219	27.48	0.005185	389971	N	25.0
4	SWX	SOUTHWEST GAS CORP	84489510	219	41.12	0.006703	304204	N	18.3
5	CCB	CAPITAL CITIES ABC INC	13985910	219	75.95	0.006178	5644920	N	270.0
5	IDA	IDAHO PWR CO	45138010	219	51.77	0.007193	843901	N	19.0
5	TEK	TEKTRONIX INC	87913110	219	56.29	0.009560	753599	N	20.5

[a] These stocks are also listed in London in 1987.

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