PRIVATE INFORMATION, TRADING VOLUME, AND STOCK RETURN VARIANCES

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Abstract

The institutional features of the Tokyo Stock Exchange allow tests that provide new insights into the determinants of stock return variances. When the Exchange is open on Saturday, the weekend variance is roughly 60% higher than when it is closed. However, weekly variances are not increased by Saturday trading. The increase in weekend volume and variance caused by Saturday trading is offset by lower volume and variance on surrounding days. These results are consistent with the view that Saturday trading changes the timing of trades, and that variance is caused by private information revealed through trading. U.S. stocks traded on Tokyo or Japanese stocks traded on the NYSE have increased trading hours, but trading of stock on a foreign exchange is typically light relative to domestic volume. The increased trading hours are not associated with an increase in stock return variance. This suggests that substantial volume is required for private information to be incorporated into stock prices and that there is no causal relation between trading hours and stock return variance.

1. Introduction and Summary

Stock returns on organized exchanges have higher variance during trading than nontrading hours (Fama (1965), Granger and Morgenstern (1970), Oldfield and Rogalski (1980), Christie (1981)). The higher variance is not fully explained by increased public information release during trading hours (French and Roll (1986)). This paper provides new evidence on the determinants of stock return variance, and in particular on the relation between private information, trading volume, and stock return variance.

The Tokyo Stock Exchange is the largest in the world,[1] and has two institutional features which provide an almost ideal experiment for our study. First, the Tokyo Stock Exchange is open for half a normal trading day approximately three Saturdays per month, and closed on other Saturdays. By examining the variance of stock returns over weekends with and without Saturday trading, it is possible to analyze the effects of trading on stock return variance, holding constant the normal flow of public information. This Tokyo weekend analysis is similar to French and Roll (1986), who examine how the variance of New York Stock Exchange (NYSE) returns was affected when the NYSE closed on 24 Wednesdays in 1968 to clear a paperwork backlog. The present study, however, examines Tokyo trading volume as well as return variances, and is based on a much longer time series of data. The volume data are important to disentangle the effects of trading volume and trading hours on stock return variance.

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[1]The total market value of equities listed on the Tokyo Stock Exchange as of December, 1987 was $2,515 billion, 13% larger than on the New York Stock Exchange. See *Nomura Fact Book*, 1988, p. 21.

A second feature of the Tokyo Stock Exchange is that trading takes place when the U.S. exchanges are closed, and vice versa.[2] Thus, U.S. stocks traded on the Tokyo Stock Exchange or Japanese stocks traded on U.S. exchanges have increased trading hours. Trading of stock on a foreign exchange is light, however, relative to the volume of these stocks on their domestic markets. Internationally listed firms therefore permit study of the effects of increasing the number of available trading hours, holding constant total trading volume.

When the Tokyo Stock Exchange is open on Saturday, the weekend (Friday close to Monday close) variance of Japanese stock returns is roughly 60% higher than when the exchange is closed. Saturday trading and the number of trading hours during a week do not, however, increase the weekly variance of stock returns or weekly share volume. The increase in volume and variance over weekends with Saturday trading is offset by lower volume and variance on surrounding days.

The higher weekend but unchanged weekly variance is consistent with the analyses of Kyle (1985) and Admati and Pfleiderer (1988), who provide a structural link between the volume of trading and stock return variance. These authors model the trading strategy of uninformed liquidity traders and traders with private information, and show that variance is caused by private information revealed through trades. An alternative explanation for the higher weekend variance is that it is not due to private information, but occurs because traders overreact to each other's trades. This view has little

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[2]On weekdays, the Tokyo Stock Exchange is open from 9 to 11 a.m. and from 1 to 3 p.m. local time. Since Tokyo is 14 hours ahead of New York, this corresponds to 7 to 9 p.m. and 11 p.m. to 1 a.m. Eastern Standard Time. Saturday trading hours on the Tokyo Stock Exchange are from 9 to 11 a.m. local time.

explanatory power in our tests. Weeks with Saturday trading do not have increased variance, and there is little evidence of pricing errors generated during Saturday trading that are reversed in the following week. In addition, the higher weekend variance when the exchange is open on Saturday cannot be attributed to increased public information release.

Previous work on the relation between private information and stock return variance does not specify the nature of informed investors' private information. Results on variance changes associated with Saturday trading are similar using the Tokyo Composite Index, various industry indexes, or data on individual stocks. This indicates that private information revealed through trading has market wide, industry, and firm specific components.

Secondary listing on a foreign stock exchange does not affect the pattern or increase the level of stock return variance. Moreover, U.S. firms traded on the Tokyo Exchange do not have a higher weekend variance when the Tokyo Exchange is open on Saturday. Both pieces of evidence suggest that there is no causal relation between trading hours and stock return variance. A significant volume of trading is required for private information to be incorporated into stock prices. This is consistent with the analysis of Admati and Pfleiderer (1988), who conclude that it is optimal for traders with private information to execute their trades during periods when uninformed liquidity traders are normally most active.

Section 2 discusses the paper's testable propositions. The results are presented in Section 3, and the conclusions are given in Section 4.

2. Theory and Empirical Implications

2.1. *Background*

The issue of why stock prices move is unsettled at both a theoretical and empirical level. New public information is generally incorporated into stock prices quickly (see Jensen (1978) for a review of this literature). Stock prices also move in response to private information revealed by traders (Grossman and Stiglitz (1980), Kyle (1985), Admati and Pfleiderer (1988), French and Roll (1986)). In contrast, Shiller (1981,1986), Black (1986), Summers (1986) and others raise the possibility that variance is primarily induced by uninformed "liquidity" traders (sometimes called "noise" traders). Consistent with this view, recent empirical evidence of mean reversion in stock prices suggests that some stock price movements may be caused by temporary mispricing. Further, French and Roll (1986) present evidence of a positive association between trading hours and stock return variance. Since they do not examine the volume of trade, however, conclusions about a causal relation are limited. Thus, the relation between trading hours, trading volume, and stock return variance remains an open question.

2.2. *Testable propositions*

While this paper cannot fully sort out the extent to which public information, private information, and noise trading cause variance, the institutional features of the Tokyo Stock Exchange permit tests which provide important insights. A useful framework for developing our testable propositions is suggested by the work of Kyle (1985) and Admati and Pfleiderer (1988).

Kyle (1985) models a market with three types of traders: informed investors who

trade strategically to maximize the profits from their private information, random liquidity traders whose buy and sell orders arrive randomly through time, and a specialist who has no private information, but who learns through price and volume changes. In this model, private information is incorporated into prices over time at a constant rate (per trading hour) with the price at the end of the relevant trading interval reflecting all private information. The variance of returns over the entire trading interval reflects only the arrival rate of new information. The variance within the trading interval, however, also reflects the volume of trade by random liquidity traders. Trades of both informed and liquidity traders move prices since uninformed traders who learn from price and volume changes cannot distinguish between the two. Thus, trading noise (i.e., variance in excess of that generated in a fully revealing rational expectations model) arises endogenously in this model because price movements and associated volumes are noisy signals for the information of informed traders. This trading noise is rational since the price established by the specialist is an unbiased estimate of the true price conditional on his information set, and the trading noise does not result in pricing errors that are systematically reversed. The variance generated in this model is associated with trading volume, and trading hours have no role.

In related work, Admati and Pfleiderer (1988) extend Kyle's analysis to include a fourth class of traders called discretionary liquidity traders. Discretionary liquidity traders have no private information. Unlike the random liquidity traders who trade strictly at random, however, these traders have some discretion over the timing of their trades. Admati and Pfleiderer show that in general, trades of both the discretionary liquidity traders and the informed traders will cluster together with each group preferring to trade

when the market is thick. This clustering of trades causes variance to be highest when trading is most active. As in Kyle's model, returns are serially uncorrelated (conditional on the uninformed traders information set), and trading hours have no role.

Saturday trading and private information. The impact of Saturday trading in Tokyo will depend on how traders change their behavior in anticipation of and following a particular Saturday. Although neither Kyle nor Admati and Pfleiderer examine such a situation specifically, their analysis suggests that opening the Exchange on Saturday will not change the variance of weekly returns as long as the total amount of new public and private information is unaltered. Within the week, however, a change in the pattern of daily variances would be expected, reflecting the effects of the new trading hours on the arrival of traders. If the total weekly volume of liquidity trades is unchanged, but the intraweek distribution is spread evenly over the extended trading hours, then the return variance will be larger during weekends when the exchange is open on Saturday because of the increased volume of both informed and liquidity traders during this interval. Variance should be lower on surrounding days because of the lower trading volume and the resulting reduction in the amount of information revealed by informed traders.

Previous work on the relation between private information and stock return variance concentrates on individual securities and does not examine the nature of the private information. Informed investors' private information could contain firm-specific, industry, or market-wide components. The return data used in this paper include a market index, a variety of industry indexes, and data for individual Japanese stocks that are also listed on the NYSE. For these different return series, a similar increase in the weekend

variance induced by Saturday trading would imply proportional increases in the market wide, industry, and firm specific components of variance. On the other hand, significant results for individual stocks but not for industry or market indexes would be expected if the private information revealed through trading is predominantly firm-specific.

Saturday trading, noise, and public information. Although the main focus of our tests is on predictions from the noisy rational expectations models of Kyle (1985) and Admati and Pfleiderer (1988), alternative explanations for the effect of Saturday trading on stock return variances are also investigated. French and Roll (1986) raise the possibility that variance arises because investors overreact to each other's trades. While the model underlying this view is imprecise, it is characterized by several predictions. For example, if irrational trading noise is permanent, French and Roll (1986, p. 14) argue that there will be a positive correlation between variance and the number of trading hours in a week. If the increased variance generated by Saturday trading is attributable to pricing errors that are reversed in the following week, the covariance between the weekend return and the return early in the following week should be negative. While we do not test a detailed model of how trading noise affects the autocorrelation structure of returns, we examine this issue.

Our tests also provide insights into whether the higher variance during trading hours is caused by public information releases. Saturday is not a normal business day in Japan. Although a number of Japanese companies are open on some Saturdays, the Saturdays that non-financial firms are open appears to be independent of the Saturdays

that the exchange is open.[3] Japanese corporations infrequently release information on a Saturday. This reduces the likelihood that any discretionary public information releases will occur or be timed to whether the Exchange is open or closed on Saturday.[4] Thus, if variance is caused primarily by public information, there should be no difference between the weekend return variance with or without Saturday trading.

The effect of listing on a foreign exchange. Trading on Tokyo takes place when U.S. exchanges are closed, and vice versa. Thus, U.S. stocks traded on the Tokyo Stock Exchange and Japanese stocks traded in the U.S. have increased trading hours. These extended trading hours provided the basis for several additional tests.

If a stock is traded on more than one market, liquidity traders will concentrate their activity in the market with the lowest transaction costs. For stocks that are internationally listed, the transaction costs of liquidity traders are likely to be lower on the domestic exchange than on the foreign exchange.[5] Since liquidity traders in rational trading models prefer to cluster their trades, most liquidity trading would be expected to

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[3]The Japanese Ministry of Labor compiles detailed statistics on the number of businesses open on Saturday. For firms with over 1,000 employees, only 7.9% had just 1 day off per week every week in 1985. Some financial institutions, including banks and foreign exchange traders, are open on the same Saturdays as the Exchange. In addition, the financial wire service is operating whenever the exchange is open.

[4]This summary is based on informal interviews with individuals at Japanese banks, brokerage firms, and the Tokyo Stock Exchange.

[5]For example, in a speech delivered to the Brookings Institute, Mr. Kurokawa, Chairman of Nomura Securities International, stated that "Although stocks of 93 foreign companies are listed on the [Tokyo Stock Exchange], their trading volume in Tokyo is not very heavy. The reason for this is that large institutional investors tend to trade foreign stocks in each mother country, where there is greater liquidity. A major portion of the orders from non-residents is directed to each stock's home market..."

occur on the lower cost, domestic market. Since informed traders attempt to conceal their identity by trading during periods when liquidity trading is normally high, informed traders will also concentrate their trades in the domestic market. Thus, the model of Admati and Pfleiderer suggests that there will be low volume on the foreign market relative to the domestic market and that international listing of a common stock will have little impact on either the level or the pattern of the stock return variance. Without informed traders on the foreign exchange, the extended trading hours will have no effect.

The impact of increasing the number of available trading hours is tested in several ways. The daily and overnight pattern of variance and trading volume of U.S. companies listed on Tokyo is compared with a matched sample of U.S. companies not listed in either Tokyo or London. The impact of new international listing on stock return variance and trading volume is also examined. Finally, the effect of Tokyo Saturday trading on the weekend variance of U.S. stocks listed on Tokyo is analyzed. Because the trading volume for stocks on a foreign exchange is light relative to the domestic market, each of these tests helps to disentangle the effects of increased trading hours from increased trading volume.

3. Empirical Results

3.1. General characteristics of returns on the Tokyo Stock Exchange Composite Index

Table 1 shows the pattern of daily trading volume on the Tokyo Stock Exchange and the pattern of daily return variance for the Tokyo Composite Index.[6] The variance of the return on the Tokyo Composite index is not significantly higher over a typical weekend than over a single trading day even though the weekend is two or three times as long.[7] The variance of returns is also lower over holidays when the Tokyo Exchange is closed than when it is open. For example, the variance of two day returns including a one day holiday is only 42 percent higher than the variance over a normal trading day, and the variance of seven day returns including a six day year-end holiday is slightly less than the variance over a normal trading day. This evidence suggests that stock returns in Japan have higher variance during exchange trading hours than during nontrading hours and that a similar relation between variance and exchange trading hours exists in both the U.S. and Japan.

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[6]The Tokyo Stock Exchange Composite Index (TOPIX) is a value weighted portfolio of all stocks listed on the First Section of the Exchange. The First Section includes most active issues traded in Japan (1,055 issues in 1986). The index is not adjusted for dividend payments. See the *Tokyo Stock Exchange Fact Book*, 1987.

[7]The Monday return variance is calculated using two day returns (measured from Saturday close to Monday close) for weekends when the exchange is open on Saturday and three day returns (measured from Friday close to Monday close) for weekends when the exchange is closed on Saturday.

3.2.   Saturday Trading on the Tokyo Stock Exchange

Effects on trading volume. Since 1973, Tokyo Stock Exchange has opened for half

a normal trading day approximately three Saturdays per month. From January 1973

through July 1987, the Tokyo Stock Exchange was open on 545 Saturdays and was closed

on 204.[8] From table 1, both the average volume and the return variance are lower on

trading Saturdays than on any of the five weekdays. However, the return variance as a

fraction of the normal weekday return variance, .57, and the trading volume as a fraction

of the normal weekday trading volume, .63, are both similar to the relative number of

trading hours, .50. Thus, although Saturday is not a normal business day, the trading

activity per hour of trading on Saturday is no lower than during the rest of the week.

Table 2 compares share volume for weeks with Saturday trading to volume for

weeks with no Saturday trading. The average trading volume on the Tokyo Stock

Exchange is from 5% to 7% lower for each weekday near a Saturday when the exchange

is open than for the corresponding weekday near a Saturday when the exchange is closed.

Even though the average combined Saturday and Monday volume when there is Saturday

trading exceeds the average Monday volume when there is no Saturday trading by 71%,

using a standard t-test for the difference of means, the average weekly volume (measured

Wednesday close through Wednesday close) centered on a trading Saturday is not

statistically significantly higher than the average weekly volume centered on a non-trading

Saturday. Saturday trading does not significantly affect the total weekly volume; it simply

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[8]The Tokyo Stock Exchange was closed on the third Saturday of the month from
January 1973 to July 1983, on the second Saturday of the month from August 1983 to
July 1986, and on the second and third Saturdays of the month thereafter.

spreads the same volume more or less evenly over the extended trading hours.

Effects on return variance. From table 2, the weekend return variance for the Tokyo Composite Index, measured from Friday close to Monday close, is 63% higher for weekends with Saturday trading than for weekends without Saturday trading over the January, 1973 through July, 1987 period. Using a standard F-test, the variance ratio of 1.63 is statistically significantly greater than 1.0 at the .01 level. This evidence is inconsistent with the hypothesis that the higher variance during trading hours is caused by a greater flow of public information, since the likelihood of a public information release on a Saturday when the exchange is open does not differ from the corresponding likelihood on a Saturday when the exchange is closed.

Our conclusion about the significance of the increase in the weekend variance does not appear to be sensitive to the distributional assumptions of the F-test. To examine the robustness of the results, we use a bootstrap algorithm to calculate significance levels for all results in table 2.[9] The qualitative results are unchanged using this procedure, although the standard F-test appears to overstate the true significance level. The bootstrap probability for the test that the weekend variance ratio is less than or equal to 1.0 is .008 and the corresponding p-value based on a standard F-test is less than .001.

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[9]The bootstrap probability values are calculated with the following algorithm. Let N_1 be the number of returns for periods including Saturdays with trading and let N_2 be the number of returns for periods including Saturdays with no trading. First, sample with replacement N_1 times from the set of returns for periods with Saturday trading and calculate the sample variance. Next, sample with replacement N_2 times from the set of returns for periods with no Saturday trading, calculate that sample variance and then calculate the variance ratio. Repeat this procedure 1,000 times to estimate the empirical distribution of the variance ratio. The fraction of these variance ratios that exceed 1.0 is the bootstrap probability that the population variance ratio exceeds 1.0.

Despite the increased weekend variance, there is no evidence that the weekly return variance on the Tokyo Stock Exchange Composite Index is higher for weeks with Saturday trading than for weeks without Saturday trading. The ratio of weekly return variances (measured Wednesday close to Wednesday close) for weeks with and without Saturday trading is .78. If anything, this suggests that the weekly variance is slightly lower for weeks when the exchange is open on Saturday, although the case for a lower weekly variance is not strong. First, none of the underlying theories predict a lower weekly variance. Second, while the variance ratio of .78 is at the .005 fractile of the central F-distribution with the appropriate degrees of freedom, this again seems to overstate the true significance. The bootstrap probability that the weekly variance ratio is greater than or equal to 1.0 is .093.

The dissipation of the variance generated during Saturday trading is explained by reduced variance for the weekdays immediately following Saturdays when the Exchange is open. From Monday close to Wednesday close, the ratio of the variance with Saturday trading to the variance without Saturday trading is only .65, which is below the .001 fractile of the central F distribution and has a bootstrap p-value of .016. Individually, the Tuesday and Wednesday variance ratios are .67, and .75, respectively both of which fall below the .001 fractile of the F distribution. Both the variance and volume ratios suggest that informed traders accelerate some of their trades from Tuesday and Wednesday to the preceding Saturday when there is Saturday trading. In contrast, the Wednesday through Friday variance ratio is 1.26. Although trading volume is also lower on Thursday and Friday preceding Saturdays when the exchange is open, there is no evidence from the variance ratios that informed traders postpone their trades from Thursday or Friday

until Saturday.

The rational trading models of Kyle and Admati and Pfleiderer predict that the increase in the weekend variance with Saturday trading can be attributed to greater dissemination of private information due to the increase in the volume of informed trades. These models also predict that the total amount of information released during a week would be unaffected if there were no increase in the normal volume of trade during weeks with Saturday trading and if there were no change in the arrival of private information. Our tests indicate that neither the weekly volume nor the weekly return variance is increased by the number of trading hours, and thus support these predictions.

The lower return variance on individual weekdays following Saturday trading indicates that a shift in the daily variance pattern, rather than negative serial correlation, is mainly responsible for dissipating the higher weekend variance caused by Saturday trading. To illustrate this further, if instead of using the actual Friday to Wednesday return variance in our analysis we use the sum of the Friday to Monday return variance plus the Monday to Wednesday return variance,[10] the ratio of the Friday close to Wednesday close return variance with Saturday trading to the Friday close to Wednesday close return variance without Saturday trading is .84. This indicates that the reduction in Monday through Wednesday variance is sufficient to wholly offset the higher weekend variance caused by Saturday trading.

There is little evidence suggesting that Saturday trading causes pricing errors that are reversed in the following week. For weeks with Saturday trading, the correlation

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[10]Under the assumption of zero serial correlation, the return variance over any interval will equal the sum of the variances over the corresponding sub-intervals.

between the Friday close to Saturday close return and the Saturday close to Wednesday close return on the Tokyo Composite Index is .02, and is not significantly different from zero.[11] The correlation is similar if the Saturday close to Friday close return is substituted for the Saturday close to Wednesday close return.

Results for industry indexes and individual stocks. In addition to daily return data for the Tokyo Stock Exchange Composite Index, our tests also use daily return data from July 1, 1982 through July 29, 1987 for 28 Japanese industry indexes and 8 Japanese stocks that are also listed on the NYSE. This time period includes 175 Saturdays when the Tokyo exchange is open and 74 Saturdays when it is closed.

From table 3, the average weekend return variance with Saturday trading is 62% higher for the 28 industry indexes and 50% higher for the 8 Japanese stocks than the weekend return variance with no Saturday trading. From table 3, the weekend return variance is greater when there is Saturday trading for 27 of the 28 industry indexes (significantly greater at the .05 level for 19 of the 28) and for all 8 of the 8 internationally traded Japanese stocks (significantly greater at the .05 level for 6 of 8). The ratios for these industry indexes and the individual stocks are strikingly similar to the results for the composite index. This suggests that the private information revealed through trading has roughly proportional market wide, industry, and firm specific components.

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[11]Stock indexes typically exhibit positive serial correlation caused by the nonsynchronous trading of the stocks in the index. As discussed later, we have return data for 8 Japanese stocks. The average correlation between the Friday close to Saturday close return and the Saturday close to Wednesday close return is -.09 and only 1 is individually significant at the .05 level.

3.3. *Internationally Listed Firms*

Under the private information hypothesis, trading hours when liquidity traders are normally inactive should have little impact on the rate of dissemination of private information because informed traders will postpone their trades to periods when liquidity traders are more active. Thus, the listing of a NYSE stock on the Tokyo exchange accompanied by inactive trading on the Tokyo exchange should not significantly affect the stock's overnight variance.

Tests using a Matched Sample. The ratios of trading day (open to close) to 24 hour (close to close) NYSE return variance are examined for 21 stocks with a primary listing on the NYSE and a secondary listing on the Tokyo Stock Exchange, and compared with a matched sample of firms that are not listed in either Tokyo or London.[12] The matched sample is chosen on the basis of both industry and size.[13] Although many of the 21 internationally listed U.S. firms have large international operations, the trading volume in Tokyo is small relative to the NYSE. The average trading volume per issue of foreign (non-Japanese) stocks listed on the Tokyo Stock Exchange increased dramatically from approximately 150 shares per day in 1980 to about 30,000 shares per day in 1986. Even in the latter period, however, table 4 indicates that the Tokyo volume is less than 10%

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[12]The sample of internationally listed U.S. firms includes all U.S. firms that were listed on both the NYSE and the Tokyo Stock Exchange for at least 40 trading days between 1980 and 1986.

[13]For each of the 21 internationally listed U.S. firms, we choose the firm in the same Value Line industry classification with the closest match in line of business and market value. The results are similar using matched pairs that have the closest market value within 2 or 4 digit SIC categories.

of the average NYSE volume for US stocks having secondary listings on the Tokyo exchange.

The private information hypothesis predicts that the ratio of trading day to 24 hour variance will not be affected by listing in Tokyo and will be the same for internationally listed firms and their matched pairs. From table 5, the average ratio of within day (open to close) to 24 hour (close to close) return variance for the internationally traded U.S. stocks is .83 which is actually higher than the corresponding average ratio for the matched non-internationally traded stocks, .82. Further, results for individual firms yield no evidence that international listing causes a greater fraction of a firm's total variance to occur overnight during the period of foreign trading hours. For each internationally traded firm and its match, we examine the ratio of the trading day to 24 hour variance. The statistical significance of the difference is assessed using an asymptotic test statistic based on a general convergence result for the distribution of a function of random variables.[14] Only one of the 21 internationally traded stocks has a trading day to 24 hour variance ratio that is significantly different from its matched pair at the .05 level.

The absolute level of both the 24 hour return variance and the within day return variance is lower for the internationally traded stocks than for their matched pairs. This is likely to occur because the internationally listed firms tend to be the largest firms in

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[14]Let s_1^2 be sample variance of the open-to-close returns and s_2^2 be the sample variance of the close-to-close returns for the internationally traded firm and let s_3^2 and s_4^2 be the corresponding sample return variances for the matched firm. Finally, let $R_1 = s_1^2/s_2^2$ and let $R_2 = s_3^2/s_4^2$. Then $\sqrt{T}(R_1 - R_2)$ is asymptotically normally distributed with mean 0 and variance $\Lambda'\gamma\Lambda$ where T is the number of observations per firm, γ is the four by four covariance matrix for the squared returns, and $\Lambda' = [1/s_2^2, -s_1^2/(s_2^2)^2, -1/s_4^2, s_3^2/(s_4^2)^2]$. For the general convergence result, see Dhrymes (1974, pp. 112–113). The number of observations per firm ranges from 40 to 1,366.

their industry, making it difficult to match by size. Nevertheless, there is no evidence that international listing increases the total level of variance.

Table 5 also indicates that on average the trading day return variance on the New York Stock Exchange for Japanese stocks is only about one fourth of the average 24 hour return variance.[15] This contrasts sharply with U.S. stocks listed on the NYSE for which on average approximately 80% of the 24 hour variance occurs during the trading day. While this is consistent with the view that significant trading volume is necessary for stock prices to reflect private information, it is also consistent with the hypothesis that variance is mainly generated by increased public information releases during trading hours on the primary exchange.

Variance changes following Tokyo listing. Sixteen of the 21 internationally listed U.S. stocks used in the matched pairs tests were first listed on the Tokyo Stock Exchange between 1980 and 1986. In table 6, we examine the ratio of trading day to 24 hour variance for these 16 U.S. 16 NYSE firms before and after they were listed on the Tokyo Stock Exchange. The average of the 16 variance ratios before Tokyo listing is .84, lower than the corresponding average ratio after Tokyo listing of .85. No firm has a statistically significantly higher trading day to 24 hour variance ratio following Tokyo listing. There is also no evidence that the overall level of the 24 hour variance increases following Tokyo listing. The mean and median of the 16 individual 24 hour return variance estimates are lower after Tokyo listing than before. As in the tests involving matched

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[15]We had an insufficient number of New York prices to calculate meaningful statistics for Kubota Corp. Thus, when using New York data, results are presented for only 7 Japanese stocks.

pairs, the results indicate that stock return variance is more closely related to the level of normal trading volume than to the number of hours that a stock is traded on the world markets.

Weekend variances for internationally listed firms. Since trading on a foreign exchange is light relative to domestic volume, if trading volume (rather than simply increased trading hours) is necessary for private information to be revealed through trading, Tokyo Saturday trading should have a different effect for U.S. companies than for Japanese firms. The paper's earlier tests for the effects of Saturday trading are repeated for the 17 U.S. firms traded on Tokyo with sufficient available data.[16] As table 7 indicates, the average New York Friday close to Monday open variance ratio with and without Saturday trading is only 1.15 (median=1.09). Of the 17 stocks, 11 have ratios in excess of 1, but only 2 are statistically significant. Similar results are obtained using Tokyo Friday close to Monday close prices. The unchanged weekend variance for the Tokyo-listed U.S. stocks when there is Tokyo Saturday trading again indicates that longer trading hours do not themselves increase variance.[17]

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[16]All U.S. firms were included in this analysis if they were listed on both the NYSE and the Tokyo Stock Exchange for at least 10 weeks with Saturday trading in Tokyo and at least 10 weeks with no Saturday trading in Tokyo between 1980 and 1988. Four firms included in the matched pairs test did not meet this criterion and thus were not included in this analysis.

[17]For Japanese companies listed on the NYSE, Tokyo Saturday trading is also associated with statistically significant additional variance on the NYSE in the following week, although the impact on 24 hour variance is small. The average open to close return variance ratio for Monday following Saturdays with Tokyo trading relative to Mondays without Saturday Tokyo trading is 1.52, and the average volume ratio is 1.25. Similar results apply to Tuesday. This suggests that New York traders react to the additional private information revealed through price changes during Tokyo Saturday trading.

4. Conclusions

When the Tokyo exchange is open on Saturday, the variance from Friday close to Monday close increases by roughly 60%. The increase in both volume and variance over weekends with Saturday trading is offset, however, by lower volume and variance on surrounding days. These results are consistent with the view that Saturday trading changes the strategy of traders, and that variance is caused by private information revealed through trades. The increased return variance during weekends when the Tokyo exchange is open occurs regardless of whether individual stocks, industry indexes, or the composite market index are examined. Thus, the private information revealed through trades has market-wide, industry, and firm-specific components.

Secondary listing of U.S. stocks on the Tokyo Exchange or Japanese stocks on the New York Stock Exchange does not increase the overall level of variance or affect its pattern, despite a substantial increase in trading hours. This result is confirmed using both time-series and matched-pair tests. Further, the higher weekend variance associated with Saturday trading does not occur for stocks of U.S. firms listed on Tokyo. Since the volume of foreign trading is light, this evidence suggests that substantial normal trading volume is required to affect return variance.

The models of Kyle (1985) and Admati and Pfleiderer (1988), in which variance is generated because privately informed traders reveal their information through trading, appear to have considerable explanatory power. Consistent with the evidence in this paper, such models indicate how changes in the timing of trades will affect daily variance patterns. Moreover, these models suggest no direct link between trading hours and stock

return variance.

An alternative view is that variance represents irrational trading noise which occurs because traders overreact to each other's trades. While the model underlying this view is poorly specified, the predictions based on this notion are rejected. For example, if irrational trading noise is permanent and constant per hour of trading, there would be a positive correlation between variance and trading hours in a week. This prediction is inconsistent with evidence from both the Tokyo weekend experiment and from the analysis of internationally listed firms. Moreover, it does not appear that the higher weekend variance when the Tokyo Exchange is open on Saturday is caused by temporary pricing errors which are reversed in the following week.

References

Admati Anat R. and Paul Pfleiderer, 1988, A theory of intraday trading patterns: Volume and price variability, Review of Financial Studies 1, 3-40.

Black, Fisher, 1986, Noise, Journal of Finance 41, 529-543.

Christie, Andrew A., 1981, On the efficient estimation and intra-week behavior of common stock variances, Unpublished working paper.

Dhrymes, Phoebus J., 1974, Econometrics: Statistical Foundations and Applications, Springer-Verlag, New York.

Fama, Eugene F., 1965, The behavior of stock market prices, Journal of Business 38, 34-105.

French, Kenneth R. and Richard Roll, 1986, Stock return variances: The arrival of information and the reaction of traders, Journal of Financial Economics 17, 5-26.

Granger, Clive W. and Oskar Morgenstern, 1970, Predictability of stock market prices (Heath-Lexington, Lexington, MA).

Grossman, Sanford J. and Joseph E. Stiglitz, 1980, On the impossibility of informationally efficient markets, American Economic Review 70, 393-408.

Jensen, Michael C., 1978, Some anomalous evidence regarding market efficiency, Journal of Financial Economics 6, 95-101.

Kurokawa, 1988, On the stock market collapse: A view from Tokyo, Speech to the Brookings Institute, March 8, 1988.

Kyle, Albert S., 1985, Continuous auctions and insider trading, Econometrica 53, 1315-1335.

Nomura Research Institute, 1988, Nomura Fact Book, Tokyo.

Oldfield, George S. and Richard J. Rogalski, 1980, A theory of common stock returns over trading and non-trading periods, Journal of Finance 35, 729-751.

Shiller, Robert J., 1981, Do stock prices move too much to be justified by subsequent changes in dividends?, American Economic Review 71, 421-436.

_____, 1986, Comments on Merton and Kleidon, Journal of Business 59 Supplement, s317-s322.

Summers, Lawrence H., 1986, Does the stock market rationally reflect fundamental values?, Journal of Finance 41, 591–601.

Tokyo Stock Exchange, 1987, Tokyo Stock Exchange Fact Book 1987, Tokyo.

Table 1

Variance of returns and trading volume for the Tokyo Stock Exchange Composite Index by day of week.
1/1/73 to 7/29/87

Day of Week	Ratio of Return Variance to Average Weekday Return Variance	Ratio of Trading Volume to Average Weekday Trading Volume
Monday	1.01	.78
Tuesday	.94	.91
Wednesday	.95	1.04
Thursday	1.04	1.01
Friday	1.02	1.04
Saturday	.57	.63
One day Holiday	1.42	.84
Year-end Six Day Holiday	.75	.56

Monday return is based on Saturday close to Monday close for weeks when the exchange was open on Saturday and Friday close to Monday close on other weeks. Tuesday through Saturday returns are one day close to close returns. The average weekday return variance is .000044. The average weekday volume is 393,129,000 shares.

Table 2

Ratio of return variances and trading volumes for the Tokyo Stock Exchange composite index for periods near Saturdays when the exchange is open relative to periods near Saturdays when the exchange is closed. All returns are calculated with closing prices.
1/1/73 to 7/29/87

	Ratio of Variances	Ratio of Volumes
Periods Including Saturdays		
Friday to Monday	1.63[a]	1.71[a]
Friday to Tuesday	.95	1.30[a]
Friday to Wednesday	.68	1.14[b]
Wednesday to Wednesday	.78	1.06
Periods Preceding Saturdays		
Thursday	1.34	.93
Friday	1.22	.92
Wednesday to Friday	1.26	.95
Periods Following Saturdays		
Tuesday	.67[c]	.93
Wednesday	.75[d]	.94
Monday to Wednesday	.65[c]	.93

[a] One tailed test significantly greater than 1.0 at .01 level
[b] One tailed test significantly greater than 1.0 at .05 level
[c] One tailed test significantly less than 1.0 at .01 level
[d] One tailed test significantly less than 1.0 at .05 level

Number of Observations: 545 Saturdays with trading and 204 Saturdays with no trading.

Table 3

Ratio of variances for 28 industrial group indexes and 8 individual stocks for periods including Saturdays when the exchange is open and periods including Saturdays when the exchange is closed. All returns are calculated with closing prices.
7/1/82 to 7/29/87

28 Industrial Groups		Friday to Monday	Friday to Tuesday	Friday to Wednesday	Wednesday to Wednesday
Average		**1.62**	**1.14**	**.95**	**.95**
Marine		1.83**	1.01	1.15	.92
Mining		2.30**	2.08**	1.70**	1.91**
Construction		1.42*	1.34	.80	.56
Foods		1.52*	1.13	.86	1.01
Fiber/Textiles		1.67**	1.17	.83	.79
Pulp/Paper		1.66**	1.07	.81	1.16
Chemicals		1.44*	.89	.87	1.09
Oil/Coal		1.61*	1.47*	1.13	1.39
Gum		1.81**	1.18	1.12	.70
Glass/Cement		1.33	.99	.76	.69
Steel		1.91**	1.20	.67	.61
Non/Steel		2.75**	1.48*	1.43*	1.11
Metal		1.28	1.74**	1.02	.76
General Machinery		1.31	1.01	.74	.80
Electrical		1.29	.94	.99	.96
Shipbuilding/Automobile		2.01**	1.25	.98	1.01
Precision Instruments		1.61*	1.14	1.14	1.09
Other Manufacturing		1.34	1.00	.92	.78
Trade/Retail		1.40	.95	.60	.65
Financial		.97	.60	.62	.42
Real Estate		1.30	1.10	.80	1.04
Transportation:	Land	1.40	.66	.54	.64
	Sea	1.85**	1.52*	1.08	1.12
	Air	1.53*	.76	.62	.80
Warehouses		1.44*	1.11	1.47*	1.72**
Communication		2.06**	.86	1.11	.89
Utilities		1.78**	.85	.83	1.11
Leisure		1.50*	1.28	1.11	.89

8 Individual Stocks

		Friday to Monday	Friday to Tuesday	Friday to Wednesday	Wednesday to Wednesday
Average		**1.50**	**1.04**	**1.00**	**.95**
Hitachi		1.88**	.96	.94	1.19
Matsushita		1.90**	1.39	1.31	1.12
Sony		1.15	.81	.54	.39
Honda		1.02	.89	1.06	.99
TDK		1.43*	1.07	1.07	1.11
Pioneer		1.46*	1.13	1.17	1.10
Kubota		1.69**	1.10	1.06	.80
Kyocera		1.43*	.97	.86	.9 3

* One tailed test significant at .05 level
** One tailed test significant at .01 level
Number of observations: 175 Saturdays with trading, 74 Saturdays with no trading.

Table 4

Trading volume of internationally listed stocks on the foreign
market as a percent of their domestic trading volume.
1982–1986

Year	Average volume of U.S. stocks on the Tokyo Stock Exchange as a percent of their volume on the NYSE[a]	Average volume of Japanese stocks on the NYSE as a percent of their volume on the Tokyo Stock Exchange
1982	.17%	4.01%
1983	.59	5.14
1984	.53	6.67
1985	9.36	9.48
1986	7.83	2.74

[a]Volume of U.S. stocks on the Tokyo Stock exchange is estimated as the average share volume of all foreign (non-Japanese) stocks on the Tokyo Stock exchange. Source: Manual of Securities Statistics, Nomura Research Institute, Tokyo, Japan.

Table 5

Variance of Returns on the New York Stock Exchange for
stocks that are also traded on the Tokyo Stock Exchange.
1/1/80 to 12/31/86

	Open to Close Return Variance (x 10,000)	Close to Close Return Variance (x 10,000)	Ratio of Variances
Stocks of 21 U.S. firms also traded on Tokyo			
Mean	2.334	2.883	.833
Median	2.121	2.565	.839
Matched Sample of 21 Stocks Not Internationally Traded			
Mean	3.659	5.351	.819
Median	2.426	3.240	.834
Stocks of 7 Japanese firms also traded on New York			
Mean	1.294	5.058	.261
Median	1.117	4.520	.245

Table 6

Variance of Returns on the New York Stock Exchange before and after listing on the Tokyo Stock Exchange for 16 U.S. firms listed on the Tokyo Stock Exchange between 1/1/80 and 12/31/86.

	Open to Close Return Variance (x 10,000)	Close to Close Return Variance (x 10,000)	Ratio of Variances
Before Tokyo Listing			
Mean	2.188	2.599	.835
Median	2.155	2.547	.841
After Tokyo Listing			
Mean	1.619	1.941	.850
Median	1.700	1.903	.847

Table 7

Average ratios of return variances with and without Saturday trading for 17 U.S. firms that are also traded on the Tokyo Stock Exchange and 7 Japanese firms that are also traded on the New York Stock Exchange.
1980–1986

Period	Japanese Stocks also traded on NYSE	U.S. Stocks also traded on Tokyo
Friday close to Monday open using New York prices	1.93	1.15
Friday close to Monday close using Tokyo prices	1.47	1.14