

Intraday Pricing Errors at the Tokyo Stock Exchange

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This paper focused on the market index (TOPIX), not individual stocks, and investigated recent intraday pattern of the pricing errors at the Tokyo Stock Exchange. Contrary to Amihud and Mendelson (*Journal of Finance* 42, 1987), we found that pricing errors at the open are not always larger than those at the close.

I. INTRODUCTION

Following the influential paper by Amihud and Mendelson [1], which constructed the ratio of the open-to-open return variance to the close-to-close return variance, many studies empirically measured the magnitude of pricing errors. Most previous studies (e.g., Amihud and Mendelson [1, 2, 3]) found that pricing errors at the open are likely larger than those at the close. These studies are important because they

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have several implications for market microstructures. For example, based on their findings, Amihud and Mendelson maintained that a long non-trading period is the main causal factor of larger pricing errors at the open.

In this paper, using intraday data, we provide new evidence on pricing errors at the Tokyo Stock Exchange (TSE). Our study is pertinent for the following reasons. First, previous studies did not reach conclusive results about the magnitude of pricing errors at the TSE. While Amihud and Mendelson [2, 3] found larger pricing errors at the open at the TSE, Chang et al. [4], which investigated not individual stock returns but the index returns, found that pricing errors at the open are not always larger than those at the close. Thus, further evidence is needed.

Second, most previous studies dealt with the situation during the 1980's. It is interesting to investigate the effects of recent developments of financial markets on the pricing errors regarding the market index. Particularly, the development of index futures and options trading makes investigating the movement of the index itself more important than ever.

This paper consists of four sections. In Section 2, we review previous studies and explain how to measure pricing errors. In Section 3, we present the empirical results. Section 4 concludes this paper.

II. PREVIOUS STUDIES

A. How to measure pricing errors

Amihud and Mendelson [1] and Stoll and Whaley [6] developed a measure of pricing errors. Following Stoll and Whaley (1990), the observed transaction price on trading day t , P_t , can be written as $P_t = P_t^* U_t$. Here, P_t^* represents the true price of the stock on day t and U_t is the pricing error on day t . The open-to-open returns and the close-to-close returns of stock i are defined by

$$R_{i,t} = \log(P_{i,t}) - \log(P_{i,t-1}) = [\log(P_{i,t}^*) - \log(P_{i,t-1}^*)] + [\log(U_{i,t}) - \log(U_{i,t-1})], \quad (1)$$

where t indexes the trading day; $j = \text{open, close}$. For simplicity, we define $e_{i,t} = \log(P_{i,t}^*) - \log(P_{i,t-1}^*)$ and $u_{i,t} = \log(U_{i,t})$. Using the return relation in equation (1), the variance of $R_{i,t}$ can be written as,

$$\text{Var}(R_{i,t}) = \text{Var}(e_{i,t}) + \text{Var}(u_{i,t} - u_{i,t-1}) + 2\text{cov}(e_{i,t}, u_{i,t} - u_{i,t-1}). \quad (2)$$

$\text{Var}(R^{\text{open}}_{i,t})$ is a variance of the open-to-open returns and $\text{Var}(R^{\text{close}}_{i,t})$ is a variance of the close-to-close returns.

The equation (2) shows that the volatility of the stock returns consists of three components. The first term in the equation (2) reflects the volatility induced by new public information. The second term in the equation (2) is the effect of trading shocks, and the third term is the effect of any interaction between trading shocks and information.

The two return series cover the very same time period for each stock, and differ only in the time of day at which we observe the prices (e.g., at the open or at the close). Therefore, if $\text{Var}(R^{\text{open}}_{i,t})$ is not equal to $\text{Var}(R^{\text{close}}_{i,t})$, this is because the second and/or the third term in the equation (2) for $\text{Var}(R^{\text{open}}_{i,t})$ differ(s) from those for $\text{Var}(R^{\text{close}}_{i,t})$.

B. Previous findings regarding the TSE

Amihud and Mendelson [2, 3], George and Hwang [5], and Yamori [7]

calculated the variance ratios for Japanese stocks traded on the Tokyo Stock Exchange. Amihud and Mendelson [2] found that the open-to-open return variance exceeded the close-to-close return variance for 49 out of 50 stocks during the period from June 1, 1985, to August 19, 1988. However, Yamori [7] found that the open-to-open return variance was likely greater than the close-to-close return variance in the 1980's, but it was not necessarily greater than the close-to-close return variance in the 1990's (e.g., for only 17 out of 50 stocks in 1996).

Furthermore, Chang et al. [4] used not individual stock returns but market index returns (i.e., the Tokyo Stock Price Index (TOPIX)) to calculate the variances. They found that the open-to-open index return variance was not necessarily greater than the close-to-close variance, contrary to the results of Amihud and Mendelson, even though they used data from similar periods. Thus, pricing errors regarding the index may be different from those of individual stocks, so we need to investigate the pricing errors by using more recent data regarding the index returns.

III. DATA AND RESULTS

A. Data

The Tokyo Stock Exchange (TSE) opens at 9:00 and closes at 15:00 with a lunch break from 11:00 to 12:30¹. *Nikkei Newspaper* (the most popular economic newspaper in Japan) reports the prices of the Tokyo Stock Price Index (TOPIX) at 9:15, 10:00, 11:00, 12:45, 14:00, and 15:00². The TOPIX at 9:15 can be regarded as the morning open prices because most stocks need some time to be traded after the market open. Also, the TOPIX at 12:45 can be regarded as the afternoon open prices. The TOPIX at 11:00 and 15:00 are, respectively, the morning close and afternoon close prices.

B. Results

We can obtain six variances based on the time of day when the index is observed, that is, $\text{Var}(R_j)$; $j = 9:15, 10:00, 11:00, 12:45, 14:00, \text{ and } 15:00$. For example, $\text{Var}(R^{10:00})$ means the variance of the daily returns computed as the changes in logarithmic value of the TOPIX from 10:00 the previous trading day to 10:00 the current day. The variances for each year from 1993 to 1997 are shown in Table 1.

The 15:00-to-15:00 (or the close-to-close) variance is the greatest for 1994, 1996, and 1997, while it is the smallest for 1995. The 10:00-to-10:00 variance is the smallest for 1993, 1996, and 1997. We found that the 9:15-to-9:15 (or the open-to-open) variances are larger than the close-to-close variances only for 1993 and 1995, but the difference is statistically insignificant for both years. Therefore, contrary to Amihud and Mendelson [2, 3], our result is consistent with Yamori [7] and Chang et al. [4].

If the long non-trading period matters in terms of pricing errors, as Amihud and Mendelson [2, 3] suggested, the variance at 9:15 would tend to be the largest and that at 12:45, the second-largest. However, we have no evidence showing so.

Finally, Amihud and Mendelson [2] examined the variance of the market index returns at the open and close as a function of the day of the week. The paper showed that (1) on every day of the week except for Monday, the variance of the open-to-open returns is greater than that for the close-to-close returns; (2) on Monday, the inequality between the return variances is reversed; and (3) on Monday, the opening volatility is smaller than on any other opening, whereas the closing volatility is

about average.



Table 2
The "day of the week" effect on return variances

		09:15	10:00	11:00	12:45	14:00	15:00	Obs. #
Monday	1993	0.000128	0.000158	0.000205	0.000233	0.000230	0.000243	49
	1994	0.000107	0.000141	0.000176	0.000184	0.000215	0.000274	49
	1995	0.000312	0.000395	0.000417	0.000428	0.000377	0.000286	50
	1996	0.000081	0.000067	0.000059	0.000077	0.000068	0.000087	43
	1997	0.000237	0.000248	0.000251	0.000273	0.000289	0.000391	46
	1993-1997	0.000182	0.000210	0.000229	0.000247	0.000243	0.000260	237
Tuesday	1993	0.000198	0.000114	0.000117	0.000103	0.000139	0.000164	49
	1994	0.000212	0.000152	0.000136	0.000102	0.000083	0.000094	50
	1995	0.000220	0.000167	0.000143	0.000156	0.000112	0.000186	49
	1996	0.000089	0.000083	0.000097	0.000102	0.000096	0.000093	49
	1997	0.000295	0.000269	0.000254	0.000241	0.000276	0.000272	46
	1993-1997	0.000203	0.000157	0.000149	0.000140	0.000140	0.000160	243
Wednesday	1993	0.000192	0.000154	0.000162	0.000147	0.000131	0.000122	48
	1994	0.000085	0.000091	0.000101	0.000090	0.000099	0.000117	49
	1995	0.000238	0.000224	0.000255	0.000259	0.000216	0.000160	50
	1996	0.000058	0.000056	0.000062	0.000077	0.000076	0.000111	50
	1997	0.000211	0.000160	0.000198	0.000211	0.000244	0.000306	50
	1993-1997	0.000159	0.000140	0.000156	0.000158	0.000154	0.000164	247
Thursday	1993	0.000156	0.000164	0.000235	0.000217	0.000135	0.000169	47
	1994	0.000128	0.000118	0.000066	0.000068	0.000074	0.000071	49
	1995	0.000154	0.000127	0.000159	0.000193	0.000121	0.000152	49
	1996	0.000101	0.000077	0.000068	0.000069	0.000068	0.000078	50
	1997	0.000230	0.000220	0.000218	0.000216	0.000211	0.000237	50
	1993-1997	0.000156	0.000145	0.000151	0.000156	0.000124	0.000146	245
Friday	1993	0.000148	0.000157	0.000182	0.000204	0.000184	0.000118	50
	1994	0.000059	0.000058	0.000049	0.000057	0.000065	0.000064	47
	1995	0.000224	0.000207	0.000249	0.000326	0.000297	0.000255	48
	1996	0.000097	0.000108	0.000137	0.000121	0.000091	0.000121	51
	1997	0.000265	0.000166	0.000263	0.000226	0.000292	0.000260	49
	1993-1997	0.000162	0.000143	0.000181	0.000191	0.000190	0.000166	245

To compare the results of Amihud and Mendelson [2], we calculate the return variance for each day of the week³. Table 2 shows the results. First, the variance of the open-to-open returns tends to be greater than that for the close-to-close returns only for Tuesday and Thursday. Second, for Monday, the variance of the open-to-open returns is smaller than that for the close-to-close returns except for 1995. Third, the opening volatility on Monday is not the smallest for the week, but the closing volatility on Monday is the largest. The first and third results are different from those of Amihud and Mendelson [2], while the second is consistent with that of Amihud and Mendelson [2].

IV. CONCLUSIONS

Amihud and Mendelson [1, 2, 3] constructed the ratio of the open-to-open return variance to the close-to-close return variance in order to measure the magnitude of pricing errors at the open and close. Using their methodology, we investigated the pricing errors regarding the market index returns in the 1990's.

We found that the open-to-open return variances are not always greater than the close-to-close return variances regarding the Japanese

stock market in the 1990's. Furthermore, the magnitude of the open-to-open variances are likely similar to those of any other variances in this decade.

Therefore, this result is not consistent with the argument of Amihud and Mendelson [1989, 1991], which maintains that a long non-trading period makes the value discovery process at market open inefficient. If that argument is right, then the trend toward internationalization may have a favorable effect on the value discovery process at the open of the Tokyo Stock Exchange. The effect of internationalization on pricing errors is left for future research.

NOTES

1. On both the first day and the last day of the year, the TSE opens at 9:00 and closes at 11:00. We exclude these two irregular days in the following calculations.
2. The TOPIX consists of all stocks listed on the First Section of the TSE. The TOPIX is weighted by market capitalization.
3. Variance ratios calculated from figures in Table 2 did not necessarily reflect the magnitude of pricing errors because the open-to-open returns and the close-to-close returns for each day of the week are obtained using different time periods. Therefore, we

are not sure if the variance of Monday morning open is smaller than that of Monday afternoon close because (1) the value discovery process at the morning open is more efficient, (2) there is more noise or news Monday daytime, or (3) for some other reasons.

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