NBER WORKING PAPER SERIES

INTRADAY YEN/DOLLAR EXCHANGE RATE MOVEMENTS: NEWS OR NOISE?

Takatoshi Ito

V. Vance Roley

Working Paper No. 2703

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
September 1988

Takatoshi Ito is Associate Professor of Economics, University of Minnesota, and Research Associate, National Bureau of Economic Research. V. Vance Roley is Rainier National Bank Professor of Banking and Finance, University of Washington, and Research Associate, National Bureau of Economic Research. The authors are grateful to Sean Becketti and Richard Meese for helpful comments and discussions. The authors also benefitted from comments received from seminar participants at the Federal Reserve Bank of Kansas City, the Summer Institute of the National Bureau of Economic Research, the University of British Columbia, and the University of California at Berkeley. Financial assistance from the National Science Foundation (SES-8808828) to the first author and the Center for the Study of Banking and Financial Markets at the University of Washington to the second author is gratefully acknowledged. This research is part of NBER's research program in International Studies. Any opinions expressed are those of the authors not those of the National Bureau of Economic Research.

NBER Working Paper #2703
September 1988

INTRADAY YEN/DOLLAR EXCHANGE RATE MOVEMENTS: NEWS OR NOISE?

ABSTRACT

Intraday movements in the yen/dollar rate are examined over the 1980-86 period using opening and closing quotes in the New York and Tokyo markets. The results indicate that random-walk behavior is violated about half of the time in various subsamples. However, the economic significance of departures from the random-walk model diminshes over time. Large jumps in the exchange rate also are examined, and some evidence on subsequent mean reversion is presented. Finally, the response of Japanese and U.S. stock prices suggests that intraday yen/dollar rate movements do contain at least some relevant information.

Takatoshi Ito
Institute of Economic Research
Hitotsubashi University
Kunitachi, Tokyo 186
JAPAN

V. Vance Roley
Department of Finance DJ-10
University of Washington
Seattle, WA 98195

I. INTRODUCTION

The behavior of asset returns in terms of both their predictability and their relation to economic fundamentals has received considerable attention. For exchange rates, a common efficient markets - rational expectations view is that most rate movements are unpredictable, and these unpredictable movements result from news about economic fundamentals (e.g., Mussa 1979, Dornbusch 1980, and Frenkel 1981). Different aspects of this view, however, have been questioned either empirically or theoretically.

First, while some portion of longer-run movements in exchange rates may potentially be predictable using forward premiums or interest-rate differentials, for example, very short-run movements should approximately follow a random walk. The results of filter rule studies, however, suggest that short-run movements are partially predictable and can be exploited to generate excess returns (e.g., Bilson 1981, Dooley and Shafer 1983, and Sweeney 1986). Based on studies of this type, Meese (1986) hypothesizes that the profitability of filter rules rises as the sampling frequency of the data increases. Alternative hypotheses leading to such predictable movements can be taken from recent studies in U.S. stock returns. Following Fama and French (1988) and Poterba and Summers (1987), one hypothesis is that exchange rates exhibit mean reversion, implying predictable offsetting movements. Another hypothesis is that exchange rate movements have inertia (i.e., positive correlation), which corresponds to the results of Lo and MacKinlay (1987) for weekly stock returns.

Second, a number of studies do not reject the hypothesis that exchange rates sometimes reflect speculative bubbles (e.g., Meese 1986, Evans 1986, and Woo 1987). In these instances, exchange rates supposedly diverge from their fundamental values for significant periods of time before the bubble bursts. The leptokurtic distributions of daily exchange rate changes (e.g., McFarland, Pettit, and Sung 1982, and Friedman and Vandersteel 1982) also are taken as evidence that large jumps occur too frequently, perhaps reflecting sudden shifts back to fundamental values. Large jumps also can potentially be characterized as resulting from over-reaction, a hypothesis analogous to that proposed by Shiller (1981) for U.S. stock returns.

Third, short-run movements in asset prices and returns, including exchange rates, may simply be characterized as noise (e.g., Black 1986, and DeLong, Shleifer, Summers, and Waldman 1987). That is, while noise trading could cause persistent speculative bubbles in exchange rates, such trading also may result in short-run random movements away from fundamental values. These movements, then, would not be expected to have any information content of their own. Announcement studies do, however, indicate that at least some short-run movements in exchange rates can be linked to unanticipated changes in economic fundamentals. Cornell (1982, 1983), Frankel and Hardouvelis (1985), Engel and Frankel (1984), Hardouvelis (1984), and Roley (1987a), among others, find that U.S. money announcements affect daily exchange rate movements. Hakkio and Pearce (1985) and Ito and Roley (1987) consider additional economic announcements and find significant effects on more finely-sampled intraday exchange rate movements.

The purpose of this paper is to examine intraday movements in the yen/dollar exchange rate in terms of their predictability, behavior around large jumps, and information content.[1/] The yen/dollar rate is particularly useful to examine these properties for at least two reasons. One is that New York and Tokyo currency markets are open during nonoverlapping hours. So, with the daily opening and closing quotes collected from each market, the behavior of the New York and Tokyo markets can be compared. A second reason is that during the 1980-1986 sample period considered here, different policy regimes emanating from both the U.S. and Japan were announced. Among these policy changes, Japan made significant moves to liberalize capital market restrictions further. As a result, the daily behavior of the yen/dollar rate over policy regimes may be different, and these potential differences can be analyzed as well.

Following this introductory section, the second section summarizes the data used to investigate the behavior of intraday yen/dollar rate movements. The various subsamples used, corresponding to different policy regimes in both the U.S. and Japan, also are discussed. In the third section, the predictability of intraday yen/dollar rate movements is tested. The null hypothesis in these tests is that intraday movements follow a random walk. An analysis of large jumps in the yen/dollar rate is presented in the fourth section. Hypotheses relating to both bubbles and over-reaction are considered.

In the fifth section, the information content of intraday movements is empirically examined. This is accomplished by estimating the effects of changes in the yen/dollar rate on U.S. and Japanese stock prices. The main conclusions are summarized in the final section.

II. EXCHANGE RATE DATA AND POLICY REGIMES

To examine intraday movements in the yen/dollar exchange rate, four major segments are considered within each business day from January 1, 1980, through September 29, 1986. (The timing of the different segments is explained further in the Appendix.) First, exchange rate movements in the Tokyo market are represented by opening (TKO) and closing (TKC) quotes. These quotes are collected at 9:00 a.m. and 3:30 p.m. each day, the formal opening and closing times in this market. Both the London and New York markets are closed during business hours in Tokyo. As such, this segment is denoted as the "Tokyo" segment of the day. Second, from the close in the Tokyo market to the opening in the New York market, European markets can influence the yen/dollar exchange rate through cross arbitrage with European currencies. This segment is referred to as "Europe." Third, yen/dollar rate quotes at 9:00 a.m. (NYO) to 4:30 p.m. (NYC) in New York are taken as the opening and closing quotes in this market. This is the "New York" segment, although the London market is still open concurrently at the very beginning hours of New York trading. The fourth segment of the day differs from the others. In particular, there is no major market between New York and Tokyo. For 2-1/2 hours (3-1/2 during daylight savings time), most of the Japanese, American, and European market participants are not trading. For convenience, this period is referred to as the "Pacific" market, and it is represented by movements from the closing New York quote (NYC) to the opening Tokyo quote in the next day (TKO_{+1}).

To take into account the effects of changes in policy and deregulation on intraday yen/dollar exchange rate movements, several possible break points are considered within the 1980-86 sample. First, in December 1980, sweeping deregulation occurred with respect to Japanese capital controls both into and out of Japan.[2/] Second, in October 1982, the Federal Reserve announced the abandonment of its previous monetary-control procedure and also indicated that targets for the narrowly-defined money stock (M1) would be de-emphasized. Third, in February 1984, the Federal Reserve adopted a different reserve requirement system, and as a consequence the behavior of money and interest rates in the U.S. may have changed.[3/] Also in 1984, further efforts were made to liberalize Japanese capital markets (Frankel 1984). Because of the closeness of these separate events in 1984, any relative effects cannot be distinguished. Finally, in September 1985, the Group of Five (G5) meeting was held which may have led to a concerted effort to depreciate the dollar (see Ito 1987). However, Feldstein (1986), among others, notes that the dollar had gradually been depreciating for seven months prior to the G5 meeting, and that market forces may have been at least as important in causing the dollar's subsequent slide.

Any of the above policy changes may have not only affected onshore credit markets, but also the stochastic behavior of exchange rates. Indeed, Roley (1987a) and Ito and Roley (1987) find significant differences across regimes for the response of the yen/dollar rate to economic news. As a consequence, the behavior of the yen/dollar rate will be considered for both the entire 1980-86 sample and the subsamples implied by potential changes in policy regimes.

Summary statistics of yen/dollar exchange rate movements for each market and subsample are presented in Table 1. Exchange rate movements are in percent, calculated as changes in natural logarithms multiplied by 100. For the 1980-86 sample as a whole, the dollar tended to appreciate in Tokyo and New York markets, and depreciate in the European and Pacific segments. The volatility of the yen/dollar rate, measured by either the standard deviation or mean absolute change, was highest in the New York market. The Tokyo market exhibited lower volatility than both the European and New York segments. As expected, the volatility in the Pacific segment was the lowest, reflecting the relative lack of trading and news during this part of the day.[4/]

Summary statistics for the five subsamples suggest different behavior over time both within and across markets. During the January 1980-November 1980 period, the Tokyo market exhibited the most voltaility. In the remaining four subsamples, however, the New York market was the most volatile. Moreover, with the exception of the September 1985-September 1986 period, the dollar on average appreciated in New York. In contrast, the dollar depreciated in Tokyo in three of the five subsamples.

Some of the properties of intraday yen/dollar movements acorss subsamples and markets are tested in Table 2. The first row in the table, for example, tests whether the variances in the first two subsamples are significantly different in each market. The results indicate that the null hypothesis of equal variances across periods can be rejected in the New York and Pacific markets. Similarly, the null hypothesis of equal variances in the second and third periods can be rejected in two of the four markets. In the remaining tests across periods, the null hypothesis can be rejected for all markets at low significance levels. The last test in the table examines whether the variances in the Tokyo and New York markets are significantly different. In all subsamples except the first, the hypothesis of equal variances can be rejected. As a whole, these results support the notion that changes in policy regimes altered the stochastic behavior or the yen/dollar rate. Moreover, the stochastic behavior appears to differ across markets. These data are examined in much more detail in the sections that follow.

III. PREDICTABILITY OF INTRADAY YEN/DOLLAR RATE MOVEMENTS

In this section, the predictability of intraday yen/dollar rate movements is examined. Predictability is considered with respect to the three previous intraday movements, day-of-week effects, and previous large jumps of one percentage point or more. The magnitude of the predicted changes also is considered.

A plausible null hypothesis for intraday exchange rate movements is that they follow a random walk. Consider, for example, the expected change in the exchange rate implied by uncovered interest parity:[5/]

$$100 \cdot [E_t(s_{t+1}) - s_t] = \theta(i_t - i_t^*), \tag{3.1}$$

where s_t = natural logarithm of the yen/dollar rate in period t,

i_t, i_t^* = annualized one-period interest rates, in percent, in Japan and the U.S., respectively,

$E_t(.)$ = expectations operator using all public information at time t,

θ = parameter to adjust the differences in units between percentage changes in exchange rates and changes in annualized interest rates.

For nonzero values of the interest-rate differential, equation (3.1) implies that some portion of future exchange rate movements is predictable. The predictability decreases, however, as the length of time between t and t+1 shortens. In particular, if the frequency of measured exchange rate movements is one year, θ takes a value of unity. If quarterly observations are used, θ falls to 1/4. For daily data, θ equals 1/365. Finally, with the four intraday segments considered here, θ is approximately 1/4 of the daily value, or 1/1460. As a consequence, for any plausible value of the Japanese - U.S. interest-rate differential, the intraday predictive ability of the interest differential is approximately zero. Over the 1980-86 period, for example, 3-month dollar-denominated and yen-denominated interest rates were most disparate in mid-1981, at about 12 percentage points. Assuming that the daily interest-rate differential also peaked at about 12 percentage points, the implied daily dollar depreciation was 0.03 percent. At a level of 230 yen/dollar, which was the case then, the interest differential predicted dollar depreciation of about 0.07 yen each day. With four intraday segments, the implied dollar depreciation was only about 0.008 percent per segment, or 0.018 yen. The magnitude of this movement is well below the bid-ask spread, which had a minimum value of 0.05 yen in the New York market over the 1980-86 sample.

Other representations of exchange rates also should imply random-walk behavior over very short time periods, although not necessarily over longer periods (e.g., Hakkio 1986). In particular, even if uncovered interest parity does not hold because of a time-varying risk premium, movements in this risk premium are likely to be unpredictable, or at least small, over an intraday period. Moreover, standard models of spot exchange rates involving a vector of fundamentals plus expected exchange rate movements (e.g., Frenkel and Mussa 1980) also can approximately lead to random walks over very short horizons. In this case, because expected exchange rate movements can be assumed to be small, movements in the spot rate primarily reflect innovations in the variables reflecting economic fundamentals.

To test the random walk hypothesis, several alternative hypotheses are considered. The most general specification estimated is

$$(3.2) \qquad \Delta s_i = c + b_1 \Delta s_{i-1} + b_2 \Delta s_{i-2} + b_3 \Delta s_{i-3} + c_1 \mathrm{Tu} + c_2 \mathrm{Wed} + c_3 \mathrm{Th} + c_4 \mathrm{Fri} + d_1 \Delta s^*_{i-1} + d_2 \Delta s^*_{i-2} + d_3 \Delta s^*_{i-3} + e_i,$$

where Δs_i = change in the natural logarithm of the yen/dollar rate, multiplied by 100, in intraday segment i,

Tu,Wed,Th,Fri = day-of-week dummies,

Δs^*_i = Δs_i if $\Delta s_i \geqq 1.0$ percent, zero otherwise,

e_i = random error term,

c, b_j, c_j, d_j = estimated coefficients (j=1,2,3,4).

A constant term is included in the specification to capture a variety of possible effects from either systematic measurement errors in the variables across markets, small average predictable movements, or small average predictable changes in the risk premium. The next three terms, Δs_{i-1}, Δs_{i-2}, and Δs_{i-3}, are included to test the predictability of intraday yen/dollar rate movements based on the three most recent intraday movements. The movement in European markets, for example, may have an inertia effect on the within-the-market change in New York. Alternatively, the yen/dollar rate may over-react to news in the Tokyo market, and such movements may be partially offset in the subsequent European segment of the day. Positive values for the b_j imply inertia effects, while negative values reflect mean reversion.

The remaining variables in equation (3.2) allow fixed day-of-week effects and separate effects from large jumps in the yen/dollar rate of 1 percent or more in previous segments. Several studies have estimated significant day-of-week effects for exchange rates as well as other assets (e.g., Levi 1978, French 1980, Gibbons and Hess 1981, and McFarland, Pettit, and Sung 1982). Equation (3.2) allows effects different from Monday effects, which are embedded in the constant term. Previous large jumps are included to allow any special inertia or mean reversion effects associated with such unusual events. Large jumps are examined more closely in the next section.

As a preliminary test of the random walk hypothesis, the intraday yen/dollar rate data also are tested for the presence of a single unit root (e.g., Meese and Singleton 1982). The specification used for this test is

$$s_i = c + b \cdot t + b' s_{i-1} + b_1 \Delta s_{i-1} + b_2 \Delta s_{i-2} + b_3 \Delta s_{i-3} + e_i, \tag{3.3}$$

where t is a time trend and the other variables are as defined previously. The null hypothesis examined is $H_0 : b{=}0,\ b'{=}1$, and the marginal significance levels are taken from Dickey and Fuller (1981), Table VI.[6/]

A. Estimation and Test Results

The estimation results for a restricted version of equation (3.2) along with various test results are summarized in Tables 3, 4, 5, and 6 for the Tokyo, European, New York, and Pacific markets, respectively. The results are reported for the entire sample and selected subsamples corresponding to possible policy regimes.[7/] The middle of each of these tables gives the results for the unit root test. The reported statistics indicate that the hypothesis that a single unit root is present can be rejected at the 5 percent level in only two of 20 cases for the four markets across the five subsamples. The rejections occur in the last subsample in the European market and in the first subsample in the Pacific market. This hypothesis also can be rejected for the overall sample in the Pacific market. As a whole, however, the first-differenced specification (3.2) appears to be justified.[8/]

The top halves of each of the tables report estimation results for equation (3.2) with the restriction $c_j = d_j = 0$ (j=1,2,3,4). That is, the effects of only the three previous intraday segments are considered.[9/] For the Tokyo market, significant mean reversion relative to the Pacific segment is estimated in three of five subsamples. In the first period, for example, the estimated coefficient indicates that about 41 percent of the movement during the Pacific segment is offset in the Tokyo market. Again, the Pacific segment is represented by the difference in the opening Tokyo quote in day t and the 4:30 p.m. quote in New York in day t-1. Because there are not formal opening and closing times in the New York market, most of the observed movements during the Pacific segment most likely reflect movements in New York after the 4:30 p.m. quote.[10/] Consistent with this view, significant mean reversion in the Tokyo market relative to the New York market also is estimated in two of the five subsamples. In constrast, a significant inertia effect is estimated with respect to the previous

European segment in the fourth period. Tests of the significance of the three previous segments as a group in predicting subsequent movements in the Tokyo market are reported in the second row of tests in Table 3. These tests are performed using the heteroscedasticity-consistent covariance matrix proposed by White (1980).[11/] The test results indicate that the three previous segments are significant at the 5 percent level in three of the five periods and for the overall sample. Thus, the hypothesis that the yen/dollar rate follows a random walk in the Tokyo market can generally be rejected.

In contrast to the results for the Tokyo market, the results for the European segment of the day in Table 4 do not indicate mean-reverting behavior. Instead, significant inertia effects from the New York market are estimated in three subsamples. Moreover, inertia with respect to the Tokyo market is statistically significant in period I. The hypothesis that the effects of the three previous segments as a group equal zero can be rejected in the first two periods as well as in the overall sample.

The results for the New York market in Table 5 are similar to those of the European market in that the random walk model can be rejected in the first two periods and in the overall sample. They differ, however, in that the results once again suggest statistically significant mean-reverting behavior, this time with respect to the previous movement in the European market in periods I and II. During period I, a large and significant inertia effect with respect to the Tokyo market also is estimated.

Finally, the results for the Pacific segment of the day suggest a mixture of mean reversion and inertia with respect to movements during previous segments. For this segment, the random walk hypothesis can be rejected in three periods and in the overall sample. In contrast to the other three markets, the random walk model is rejected in the last subsample, which begins in September 1985.

As indicated in Tables 3, 4, 5, and 6, day-of-week dummies are statistically significant in only two instances other than in the Pacific segment.[12/] This also is the only segment that spans weekends, which may account for the significance of day-of-week effects in two subsamples as well as the overall sample in the Pacific market. The results in the tables additionally indicate that large jumps in the yen/dollar rate only have effects significantly different from the other movements of less than 1 percent in three of the 20 possible cases for the five subsamples. Because of the relatively small number of such large jumps, however, it may not be possible to isolate their effects in this particular specification.

Several other issues relating to the results in Tables 3, 4, 5, and 6 also deserve mention. First, the inclusion of both day-of-week dummies and possible separate effects of large jumps do not eliminate the excess kurtosis found in previous studies (e.g., McFarland, Pettit, and Sung 1982, and Friedman and Vandersteel 1982). This departure from the normal distribution, however, should not significantly bias the reported test statistics (e.g., Miller 1986). Second, the presence of large jumps of 1 percent or more in both the current and lagged segments have little effect on the estimation and test results. That is, outliers are not responsible for the significant departures from the random walk model reported in the tables.[13/]

Third, the rejection of the random walk hypothesis does not necessarily imply an unexploited profit opportunity. In fact, most of the implied predicted changes are smaller than the typical bid-ask spread of 0.10 yen, especially during later subsamples. The last rows of the tables give an indication of the absolute sizes of the fitted values from the estimated equations. The fitted values used to calculate the numbers reported in the tables are taken from the following:

(3.4) $$\Delta S_i = |\Delta \hat{s}_i| \cdot S_{i-1},$$

where $\Delta \hat{s}_i$ = the fitted value for segment i of the version of equation (3.2) reported in Tables 3, 4, 5, and 6, excluding the constant term,

$\Delta S_i = S_i - S_{i-1}$,

S_i = spot yen/dollar rate at the end of segment i.

The cutoff point in the tables is taken as 0.10 yen, the typical bid-ask spread. The results for the New York market in Table 5, for example, show that 148 of the 208 observations in period I have absolute predicted changes greater than 0.10 yen. By the fifth period, however, no fitted values are greater than 0.10 yen. This same pattern is generally repeated in the Tokyo and European markets, but not in the Pacific segment. For the other three markets, however, the results may be interpreted as support for the assertion that as the market becomes large and more traders (speculators) participate in it, the predictable portion of future price movements diminishes.[14/]

IV. LARGE JUMPS IN THE EXCHANGE RATE

The behavior of the yen/dollar rate around large intraday jumps of at least 1 percent is examined more closely in this section. Large jumps in asset prices often capture the attention of the news media, and several common stories are encountered about movements following a jump. One is that the price (exchange rate) declined, for example, because of "profit-taking" after a sharp rise. Another is that the large jump itself represents over-reaction to relevant news, and the subsequent decline merely moves the price back toward its equilibrium level. In any event, there seems to be a view, at least in the news media, that any large change in an asset's price is followed by a movement in the opposite direction. There also is a view, which is not mutually exclusive, that sharp changes in the price reflect the last stage of a bubble (or a bandwagon effect) in which the bubble bursts. A large change by itself, however, is not evidence of a bubble. It may simply be reflecting some major news in the world, such as the sudden death of a political leader, initiation of war in the Middle East, or a major change in economic policy. Nevertheless, the profit-taking, over-reaction, and bubble views suggest that days around and including large price changes should be treated separately from other days.

The top part of Table 7 lists the number of times in which the yen/dollar rate jumped by more than 1 percent in each market. From Table 1, a change of 1 percent is more than two standard deviations. By selecting the infrequent days with jumps of more than 1 percent, special characteristics can be examined.

To examine large jumps initially, suppose that the exchange rate could deviate from an otherwise stationary stochastic process for some period of time in the manner considered by Blanchard and Watson (1982). A rational bubble could then emerge and burst occasionally. That is, this bubble hypothesis for a large change within a day is that the jump is caused by the final stage of a bubble or a bandwagon effect. A large jump can then be interpreted as a sudden correction to the natural (equilibrium) level from an exploding bubble process. This interpretation predicts that the large jump is preceded by a significant change in the opposite direction. Formally, (4.1) $\quad$ Jump = a + b(previous change) + e, b < 0.

The previous change is alternatively represented by either the change in the previous segment or the cumulative change in the previous two segments, three segments, or week. Because this specification only includes values of large jumps for the dependent variable, a sample selection bias exists that most likely biases the results in favor of the bubble hypothesis.

The other specification considered involves the hypothesis that large jumps are partially offset in the subsequent segment because of either profit-taking or mean-reversion following over-reaction. Under this hypothesis, the subsequent movement is not necessarily large, but it is in the opposite direction regardless of the reason for the jump. This behavior can be represented as

(4.2) $\quad$ (Change in subsequent segment) = a + b(Jump) + e, b < 0.

Different magnitudes of jumps over 1 percent also are considered separately in estimating this equation.

The empirical results for intraday segments with large jumps are summarized in the bottom part of Table 7. The results for equation (4.1) indicate that there is very little evidence that large jumps are preceded by cumulative changes in the opposite direction. While the estimated coefficients are negative, they are not statistically significant at high marginal significance levels. Large jumps, therefore, cannot be identified as the popping of a bubble. In contrast, there is some evidence that a portion of a large jump is offset in the subsequent segment. The first row of results for this specification indicates that a positive jump of 1 percent, for example, is partially offset by a 0.13 percent decline in the yen/dollar rate during the next segment of the day. For jumps greater than 1.25 and 1.5 percent, however, the next two rows in the table do not report statistically significant effects. Thus, the segments following the 27 largest jumps in the sample do not exhibit significant mean-reverting behavior.

V. INFORMATION CONTENT OF EXCHANGE RATE MOVEMENTS

The information content of the intraday movements in the yen/dollar rate is examined in this section. In this respect, the information content of short-run movements is interpreted as the degree to which such movements reflect changes in fundamental factors. In turn, changes in fundamental factors might be expected to affect not only exchange rates, but other asset prices as well. Given the results in previous sections, where intraday yen/dollar rate movements both sometimes failed to follow the predicted random walk model and indicated offsetting movements following large jumps, the information content of yen/dollar rate movements may be questioned.

To estimate the information content of yen/dollar rate movements, the responses of both U.S. and Japanese stock prices are considered.[15/] One advantage in using stock prices for this purpose is that equity markets are often characterized as being efficient in terms of processing new information quickly. So, if intraday movements in the yen/dollar rate reflect relevant information, stock prices would be expected to respond within a day.

The effects of exchange rate movements in three of the four intraday segments on stock prices are considered for both the U.S. and Japanese stock markets. All four segments cannot be examined for each stock market because of contemporaneous trading in the foreign exchange and stock markets. Nevertheless, the formal opening and closing times of the New York Stock Exchange are ideal in capturing the effects of three of the segments since New York stock trading begins at 9:30 a.m. and ends at 4:00 p.m.[16/] In contrast, the yen/dollar rate quotes in New York are collected at 9:00 a.m. and 4:30 p.m. Thus, it is possible to construct movements in stock prices that capture the information content of the exchange rate. In particular, exchange rate movements are measured from 4:30 p.m. on the previous business day to 9:00 a.m. on the current business day. This time interval includes the Pacific, Tokyo, and European exchange rate segments. Stock prices are measured from the previous day's close at 4:00 p.m. to the current day's close. Exchange rate movements are therefore measured when the New York stock market is closed. This new information should be reflected in stock prices when the market opens at 9:30 a.m., and continue to be reflected at the 4:00 p.m. close. This procedure nevertheless omits a relevant segment from 9:00 a.m. to 4:30 p.m. in New York. However, a variety of major U.S. economic announcements, including those for the consumer price index, producer price index, industrial production, and the unemployment rate, are made at 9:00 a.m. or earlier. Moreover, the information content of this segment is considered for the Tokyo stock market.

For the Tokyo stock market, the opening time is 9:00 a.m. and the market closes at 3:00 p.m.

Analogous to the measured change in the New York stock market, daily changes from the 3:00 p.m. close are used to examine the information content of three exchange rate segments. In this case, however, the three segments represent the Pacific, New York, and European currency markets. As before, currency trading in the three segments occurs when the Tokyo stock market is closed.

The specifications used to estimate the response of stock prices to intraday movements in the yen/dollar rate can be represented as

(5.1) $$NYSP_t - NYSP_{t-1} = a + b_1(NYO_t\text{-}TKC_t) + b_2(TKC_t\text{-}TKO_t) + b_3(TKO_t\text{-}NYC_{t-1}) + e_t,$$

(5.2) $$TKSP_t - TKSP_{t-1} = a + b_1(TKO_t\text{-}NYC_{t-1}) + b_2(NYC_{t-1}\text{-}NYO_{t-1}) + b_3(NYO_{t-1}\text{-}TKC_{t-1}) + e_t,$$

where $NYSP_t$ = natural logarithm of the Standard & Poors 500 Index at 4:00 p.m. (New York) on day t, multiplied by 100,

$TKSP_t$ = natural logarithm of the Nikkei-Dow 225 Index at 3:00 p.m. (Tokyo) on day t, multiplied by 100,

and the other variables, which were defined previously, also are in natural logarithms multiplied by 100. In addition to these basic specifications, the separate effects of large intraday jumps in the yen/dollar rate are considered, as well as possible day-of-week effects in the two stock markets, in a manner analogous to equation (3.2).[17/] Finally, the random error terms, e_t, reflect movements in stock prices from the closing quotes on day t-1 to the closing quotes on day t not due to the measured changes in the exchange rate along with the response to new information from the opening of the stock markets to the closing on day t. Under the efficient markets hypothesis, this latter component is orthogonal to the measured changes in the yen/dollar rate in equations (5.1) and (5.2).

The estimation results for equation (5.1) are presented in Table 8. The results indicate that the estimated response of U.S. stock prices is negative with respect to each segment in each subsample.[18/] That is, dollar appreciation over these periods was associated with bad news for the U.S. stock market. The hypothesis that the responses to movements in the three segments as a group equal zero ($b_1 = b_2 = b_3 = 0$), however, can be rejected only for the complete sample and the second subsample. The results also suggest that yen/dollar rate movements in the Tokyo market contain little or no information. The estimated response of U.S. stock prices to these movements is insignificantly different from zero in every subsample. In contrast, for the entire sample, movements in both Europe (NYO - TKC) and Pacific (TKO - NYC_{-1}) segments provide information. In the case of the Pacific segment, the information may simply be the result of trading in New York after the 4:30 p.m. quote used here. The test results in the table also suggest that infrequent large jumps in the yen/dollar rate in recent years had extraordinary effects on U.S. stock prices in three of the subsamples, but not in the overall sample.

Table 9 presents estimation and test results for the response of Japanese stock prices as represented by equation (5.2). With only three exceptions, the response of Japanese stock prices to intraday yen/dollar rate movements again is negative. Moreover, the response to the European segment is significantly negative for every subsample, and the response to the New York segment is significantly negative in two subsamples. Reflecting the estimated responses to the New York segment, the hypothesis that the response to the three segments as a group equals zero can be rejected in periods III, IV, and the overall sample. Also, the responses to jumps in the exchange rate are significantly different from the other estimated responses only in the first period.

As a whole, the results from both the U.S. and Japanese stock markets suggest that short-run movements in the yen/dollar rate contain some relevant information. As a consequence, at least part of these movements can be rationalized in terms of fundamental factors and not simply noise. Moreover, during the 1980-86 sample period, changes in the implied underlying fundamental factors led to a negative relationship between the yen/dollar rate and the stock market in each country. One possible factor consistent with this result is world oil prices. An unanticipated rise in oil prices, for example, adversely affects both economies, but such a rise has a larger negative effect on Japan since it imports 99 percent of its oil. As a consequence, both stock markets could fall, and the dollar might appreciate in value relative to the yen. The significant negative relationship between Tokyo stock prices and yen/dollar rate movements in the European segment would appear to support this hypothesis, as major world oil markets are trading during this part of the day. Another possible factor is U.S. money announcements. In the case of a positive money announcement surprise, for example, empirical evidence suggests that U.S. real interest rates rise, the dollar appreciates in foreign exchange markets, and U.S. stock prices fall.[19/] In response, the Japanese central bank may raise interest rates to moderate dollar appreciation, resulting in a similar decline in Japanese stock prices.

VI. SUMMARY OF CONCLUSIONS

Intraday movements in the yen/dollar exchange rate were examined in this paper. The availability of daily opening and closing quotes in both the New York and Tokyo markets allowed four segments to be considered. These segments corresponded to currency trading in Tokyo, European, New York, and Pacific markets.

Several aspects of the daily movements in the four markets were examined. First, the random walk behavior of intraday movements was tested. Random walk behavior was rejected in about half of the five subsamples considered during the 1980-86 period. The economic significance of the departures from the random walk model declined, however, during the latter part of the sample. Second, the behavior of the yen/dollar rate in segments immediately before and after large jumps was investigated. The empirical results suggested that large jumps themselves could not be characterized as final stages of speculative bubbles. The results did indicate, however, mean reversion in the segment following a large jump. Finally, the information content of the intraday movements was considered in terms of their effect on U.S. and Japanese stock prices. The results suggested that yen/dollar rate movements of less than one day contain relevant information. As a consequence, intraday movements cannot simply be characterized as noise.

APPENDIX

Data Definitions and Sources

A. Exchange Rate Quotes

TKO = 9 a.m. quote in the Tokyo foreign exchange market

TKC = 3:30 p.m. quote in the Tokyo foreign exchange market

NYO = 9 a.m. quote in the New York foreign exchange market

NYC = 4:30 p.m. quote in the New York foreign exchange market

All quotes are in yen/dollar. Tokyo quotes were collected from a daily newspaper, Nihon Keizai Shinbun. New York quotes were obtained from the Federal Reserve Bank of New York.

B. Data Timing

Tokyo		New York		
Day	Time	Day	EST	EDT
T	9:00 A.M. (opening), TKO	T-1	7:00 P.M. (closed)	8:00 P.M. (closed)
T	3:30 P.M. (closing), TKC	T	1:30 A.M. (closed)	2:30 A.M. (closed)
T	10:00 P.M. (closed)	T	8:00 A.M. (closed)	9:00 A.M.(opening), NYO
T	11:00 P.M. (closed)	T	9:00 A.M.(opening), NYO	10:00 A.M. (open)
T+1	5:30 A.M. (closed)	T	3:30 P.M. (open)	4:30 P.M.(closing), NYC
T+1	6:30 A.M. (closed)	T	4:30 P.M.(closing), NYC	5:30 P.M. (closed)
T+1	9:00 A.M. (opening), TKO	T	7:00 P.M. (closed)	8:00 P.M. (closed)

The New York foreign exchange market, unlike its Tokyo counterpart, does not have well-defined business hours. Therefore, 9 A.M. and 4:30 P.M. quotes are only approximations of the opening and closing rates for the day.

The number of hours between opening (O) and closing (C) quotes is the following:

Tokyo (O) - Tokyo (C):	6.5 hours (with 1.5 hour lunch break)
Tokyo (C) - N.Y. (O):	7.5 hours (EST)/6.5 hours (EDT)
N.Y. (O) - N.Y. (C):	7.5 hours
N.Y. (C) - Tokyo (O):	2.5 hours (EST)/3.5 hours (EDT)

FOOTNOTES

1. Based on the profitability of filter rules on daily data, Meese (1986, pg. 346) states that "it would appear that a major omission of empirical academic research has been to ignore analysis of intraday exchange rate movements... ." This paper attempts to fill part of this void.

2. See Ito (1986) for an analysis of the effect of the December 1980 changes on covered interest parity.

3. The effects of these changes in Federal Reserve policy are considered in detail by Roley (1986, 1987b). The response of U.S. interest rates to money announcement surprises is found to change significantly over the different regimes.

4. As reported in Ito and Roley (1987), correcting these data for differences in the number of hours in each segment does not alter these qualitative results or the test results reported in Table 2. In Ito and Roley (1987), however, changes in the yen/dollar rate are considered, as opposed to the percentage changes used in Table 1. Corrections for the number of hours are not made here since the actual data used later correspond to those reported in Tables 1 and 2.

5. See Ito (1988) for tests which support uncovered interest parity for the case of the yen/dollar rate.

6. The test results are qualitatively unchanged for the null hypothesis involving only $b' = 1$. Also, s_i and s_{i-1} in equation (3.3) are multiplied by 100.

7. Observations involving national holidays in each country are deleted, but observations spanning weekends are included.

8. While the other tests reported below use White's (1980) heteroscedasticity-consistent covariance matrix in cases where the estimated standard errors increase using this procedure, the reported results for the unit-root tests are not adjusted. In the other tests, the heteroscedasticity correction does not significantly alter the test results, so it seems likely that corrections to the unit-root tests also would not change the results appreciably. If heteroscedasticity was apparent, however, procedures proposed by Phillips (1987) should probably be used.

9. A complete set of estimation and test results for various subcases of equation (3.2) is available as a supplement from the authors. In general, the results are not sensitive to the exclusion or inclusion of a particular set of variables. Specifications excluding the most recent lagged segment also were estimated to consider the effects of possible spurious correlation due to measurement errors, particularly in moving from quotes in the New York market to quotes in the Tokyo market, and vice versa. Tests of the significance of lagged segments changed only slightly in these specifications. In particular, the results in Tables 4 and 5 are the same, while in Table 6 lagged segments are significant in period III at the 5 percent level but not in period I. In Table 3, lagged segments in periods III and IV are no longer significant as a group at the 5 percent level, but they are significant at the 7 percent level.

10. This feature may be important for at least one day each week because of the effects of U.S. money announcements, which were made either at 4:10 p.m., 4:15 p.m., or 4:30 p.m. over different subsamples.

11. White's (1980) correction is used for the same tests in Tables 4, 5, and 6 as well. Moreover, the day-of-week dummies test uses this covariance matrix. However, the jumps test reported in Tables 3, 4, 5, and 6 does not. In general, the test statistics for the jumps test are higher using

White's procedure, so the conservative approach of using the unadjusted covariance matrix was followed.

12. The hypothesis that the effects of day-of-week dummies equal zero is tested in equation (3.2) under the restriction that $d_1 = d_2 = d_3 = 0$. Similarly, the effects of large jumps are tested in equation (3.2) under the restriction that $c_1 = c_2 = c_3 = c_4 = 0$. These tests also were performed in equation (3.2) without any of these restrictions, and the results were qualitatively the same.

13. Both of these results again are reported in the supplement available from the authors.

14. It also should be emphasized that the reported numbers do not necessarily imply anything about the profitability of filter rules. In particular, just fitted values are reported, not the accuracy of the fitted values. The low $\bar{R}^2$'s reported in the tables suggest that the fitted values do not capture much of the variation in actual values.

15. Obstfeld (1985) also uses stock prices to infer the factors affecting exchange rates.

16. During the earlier subsamples considered here, stock trading began at 10:00 a.m. in New York.

17. The estimation and test results are not sensitive to the inclusion or exclusion of day-of-week dummies, so the reported results are for the specification without these dummies.

18. In the last subsample, however, the estimated response to the cumulative change in the three segments was positive, but insignificantly different from zero, after the yen/dollar rate dropped to about 160.

19. For evidence that U.S. money announcement surprises cause dollar appreciation, again see the relevant references in the introduction. For evidence on the negative relationship between U.S. money announcement surprises and U.S. stock prices, see Pearce and Roley (1985).

REFERENCES

Bilson, John F.O., "The 'Speculative Efficiency' Hypothesis," Journal of Business, 54 (July 1981), 435-51.

Black, Fischer, "Noise," Journal of Finance, 41 (July 1986), 529-43.

Blanchard, Olivier J., and Mark W. Watson, "Bubbles, Rational Expectations, and Financial Markets," in P. Wachtel (ed.), Crises in the Economic and Financial Structure. Lexington, Mass.: Lexington Books, 1982.

Cornell, Bradford, "Money Supply Announcements, Interest Rates, and Foreign Exchange," Journal of International Money and Finance, 1 (August 1982), 201-8.

Cornell, Bradford, "The Money Supply Announcements Puzzle: Review and Interpretation," American Economic Review, 73 (September 1983), 644-57.

De Long, J. Bradford, Andrei Shleifer, Lawrence H. Summers, and Robert J. Waldman, "The Economic Consequences of Noise Traders," National Bureau of Economic Research, Working Paper No. 2395, 1987.

Dickey, David A., and Wayne A. Fuller, "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," Econometrica, 49 (July 1981), 1057-72.

Dooley, Michael P., and Jeffrey R. Shafer, "Analysis of Short-Run Exchange Rate Behavior: March 1973 to November 1981," in D. Bigman and T. Taya (eds.), Exchange Rate and Trade Instability: Causes, Consequences, and Remedies. Cambridge, Mass.: Ballinger, 1983.

Dornbusch, Rudiger, "Exchange Rate Economics: Where Do We Stand?" Brookings Papers on Economic Activity, (No. 1, 1980), 143-85.

Engle, Charles, and Jeffrey Frankel, "Why Interest Rates React to Money Announcements: An Explanation from the Foreign Exchange Market," Journal of Monetary Economics, 13 (January 1984), 31-9.

Evans, George W., "A Test for Speculative Bubbles in the Sterling-Dollar Exchange Rate: 1981-84," American Economic Review, 76 (September 1986), 621-36.

Fama, Eugene, and Kenneth French, "Permanent and Temporary Components of Stock Prices," Journal of Political Economy, 96 (April 1988), 246-73.

Feldstein, Martin, "New Evidence on the Effects of Exchange Rate Intervention," National Bureau of Economic Research, Working Paper No. 2052, 1986.

Frankel, Jeffrey A., "The Yen/Dollar Agreement: Liberalizing Japanese Capital Markets," Institute for International Economics, mimeo, 1984.

Frankel, Jeffrey A., and Gikas A. Hardouvelis, "Commodity Prices, Money Surprises, and Fed Credibility," Journal of Money, Credit, and Banking, 17 (November 1985), 425-38.

French, Kenneth R., "Stock Returns and the Weekend Effect," Journal of Financial Economics, 8 (March 1980), 55-69.

Frenkel, Jacob A., "Flexible Exchange Rates, Prices and the Role of 'News': Lessons from the 1970s," Journal of Political Economy, 89 (August 1981), 665-705.

Frenkel, Jacob A., and Michael L. Mussa, "The Efficiency of Foreign Exchange Markets and Measures of Turbulence," American Economic Review, 70 (May 1980), 374-81.

Friedman, Daniel, and Stoddard Vandersteel, "Short-Run Fluctuations in Foreign Exchange Rates: Evidence from the Data, 1973-79," Journal of International Economics, 13 (August 1982), 171-86.

Gibbons, Michael R., and Patrick J. Hess, "Day of the Week Effects and Asset Returns," Journal of Business, 54 (October 1981), 579-96.

Hakkio, Craig S., "Does the Exchange Rate Follow a Random Walk? A Monte Carlo Study of Four Tests for a Random Walk," Journal of International Money and Finance, 5 (June 1986), 221-9.

Hakkio, Craig S., and Douglas K. Pearce, "The Reaction of Exchange Rates to Economic News," Economic Inquiry, 23 (October 1985), 621-36.

Hardouvelis, Gikas A., "Market Perceptions of Federal Reserve Policy and the Weekly Monetary Announcements," Journal of Monetary Economics, 14 (September 1984), 225-40.

Ito, Takatoshi, "Capital Controls and Covered Interest Parity Between the Yen and the Dollar," Economic Studies Quarterly, 37 (September 1986), 223-41.

Ito, Takatoshi, "The Intradaily Exchange Rate Dynamics and Monetary Policies after the Group of Five Agreement," Journal of the Japanese and International Economics, 1 (September 1987), 275-98.

Ito, Takatoshi, "Use of (Time Domain) Vector Autoregressions to Test Uncovered Interest Parity," Review of Economics and Statistics, 70 (May 1988), 296-305.

Ito, Takatoshi, and V. Vance Roley, "News from the U.S. and Japan: Which Moves the Yen/Dollar Exchange Rate?" Journal of Monetary Economics, 19 (March 1987), 255-77.

Levi, Maurice D., "The Weekend Game: Clearing House vs Federal Funds," Canadian Journal of Economics, 11 (November 1978), 750-7.

Lo, Andrew W., and A. Craig MacKinlay, "Stock Market Prices Do Not Follow Random Walks: Evidence from a Simple Specification Test," National Bureau of Economic Research, Working Paper No. 2168, 1987.

McFarland, James W., R. Richardson Pettit, and Sam K. Sung, "The Distribution of Foreign Exchange Price Changes: Trading Day Effects and Risk Measurement," Journal of Finance, 37 (June 1982), 693-715.

Meese, Richard A., "Testing for Bubbles in Exchange Markets: A Case of Sparkling Rates?" Journal of Political Economy, 94 (April 1986), 345-73.

Meese, Richard A., and Kenneth J. Singleton, "On Unit Roots and the Empirical Modeling of Exchange Rates," Journal of Finance, 37 (September 1982), 1029-35.

Miller, Rupert G., Jr., Beyond ANOVA, Basics of Applied Statistics. New York: John Wiley & Sons, 1986.

Mussa, Michael, "Empirical Regularities in the Behavior of Exchange Rates and Theories of the Foreign Exchange Market," Carnegie-Rochester Conference Series on Public Policy, 11 (Autumn 1979), 9-57.

Obstfeld, Maurice, "Floating Exchange Rates: Experience and Prospects," Brookings Papers on Economic Activity, (No. 2, 1985), 369-450.

Pearce, Douglas K., and V. Vance Roley, "Stock Prices and Economic News," Journal of Business, 58 (January 1985), 49-67.

Phillips, P.C.B., "Time Series Regression with a Unit Root," Econometrica, 55 (March 1987), 277-301.

Poterba, James M., and Lawrence H. Summers, "Mean Reversion in Stock Prices: Evidence and Implications," National Bureau of Economic Research, Working Paper No. 2343, 1987.

Roley, V. Vance, "Market Perceptions of U.S. Monetary Policy Since 1982," Federal Reserve Bank of Kansas City, Economic Review, 71 (May 1986), 27-40.

Roley, V. Vance, "U.S. Money Announcements and Covered Interest Parity: The Case of Japan," Journal of International Money and Finance, 6 (March 1987a), 57-70.

Roley, V. Vance, "The Effects of Money Announcements Under Alternative Monetary Control Procedures," Journal of Money, Credit, and Banking, 19 (August 1987b), 292-307.

Shiller, Robert J., "Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?" American Economic Review, 71 (June 1981), 421-36.

Sweeney, Richard J., "Beating the Foreign Exchange Market," Journal of Finance, 41 (March 1986), 163-82.

White, Halbert, "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity," Econometrica, 48 (May 1980), 817-38.

Woo, Wing Thye, "Some Evidence on Speculative Bubbles in the Foreign Exchange Market," Journal of Money, Credit, and Banking, 19 (November 1987), 499-514.

TABLE 1

Summary of Yen/Dollar Exchange Rate Movements in Four Markets

Entire Sample: January 1, 1980 - September 29, 1986

	Tokyo	Europe	New York	Pacific
Mean	.0014	-.0256	.0105	-.0098
Standard Deviation	.3448	.3579	.4265	.2014
Mean Absolute Change	.2406	.2538	.3086	.1251
Period I: January 1, 1980 - November 30, 1980				
Mean	-.0057	-.0588	.0039	.0181
Standard Deviation	.4404	.4044	.3988	.1455
Mean Absolute Change	.3147	.2694	.2730	.1025
Period II: December 1, 1980 - October 4, 1982				
Mean	.0180	-.0239	.0570	-.0035
Standard Deviation	.4069	.3974	.4634	.1840
Mean Absolute Change	.3083	.2962	.3646	.1112
Period III: October 5, 1982 - January 31, 1984				
Mean	-.0025	-.0412	.0060	-.0006
Standard Deviation	.2888	.3273	.4461	.1732
Mean Absolute Change	.2054	.2439	.3341	.1106
Period IV: February 1, 1984 - September 22, 1985				
Mean	.0006	.0082	.0052	-.0121
Standard Deviation	.2089	.2868	.3339	.1573
Mean Absolute Change	.1446	.1949	.2317	.1043
Period V: September 23, 1985 - September 29, 1986				
Mean	-.0166	-.0336	-.0537	-.0548
Standard Deviation	.3693	.3776	.4774	.3276
Mean Absolute Change	.2530	.2711	.3289	.2229

NOTES: Exchange rate movements are measured as changes in natural logarithms, multiplied by 100. If one market is closed because of a holiday, then not only that market, but also adjacent markets become missing observations. As a result, the number of observations can differ across markets for the same period.

TABLE 2

Tests of Variances Across Periods and Markets

	Tokyo	Europe	New York	Pacific	
H_0: V(I)=V(II)					
F-statistic	1.172	1.036	1.350*	1.599*	
degrees of freedom	(225,460)	(216,446)	(463,228)	(444,217)	
p-value	.081	.377	.005	.000	
H_0: V(II)=V(III)					
F-statistic	1.985*	1.474*	1.079	1.129	
degrees of freedom	(460,328)	(446,317)	(463,331)	(444,316)	
p-value	.000	.000	.230	.125	
H_0: V(III)=V(IV)					
F-statistic	1.912*	1.303*	1.785*	1.212*	
degrees of freedom	(328,411)	(317,396)	(331,408)	(316,393)	
p-value	.000	.006	.000	.036	
H_0: V(IV)=V(V)					
F-statistic	3.127*	1.733*	2.044*	4.335*	
degrees of freedom	(252,411)	(243,396)	(255,408)	(243,393)	
p-value	.000	.000	.000	.000	
Period:	I	II	III	IV	V
H_0: V(TK)=V(NY)					
F-statistic	1.219	1.297*	2.386*	2.556*	1.671*
degrees of freedom	(225,228)	(463,460)	(331,328)	(408,411)	(255,252)
p-value	.068	.003	.000	.000	.000

NOTES: The alternative hypothesis is that one of the variances is larger, e.g., V(I) > V(II). V(j), j=I, II, III, IV, V, represents the variance in an individual market in period j. V(TK) and V(NY) are the variances in the Tokyo and New York markets, respectively.

*Significant at the 5 percent level.

TABLE 3

Predictability of Exchange Rate Movements: Tokyo (TKC - TKO)

	Coefficient Estimates and Summary Statistics					
Period:	I-V	I	II	III	IV	V
Constant	.003 (.009)	.011 (.029)	.029 (.019)	.003 (.016)	-.004 (.010)	-.027 (.025)
Pacific ($TKO-NYC_{-1}$)	$-.192^*$ (.043)	$-.409^*$ (.202)	-.147 (.105)	$-.310^*$ (.092)	$-.257^*$ (.067)	-.142 (.081)
New York ($NYC_{-1}-NYO_{-1}$)	$-.091^*$ (.020)	$-.215^*$ (.074)	$-.140^*$ (.042)	-.058 (.035)	-.057 (.032)	-.036 (.054)
Europe ($NYO_{-1}-TKC_{-1}$)	$.079^*$ (.024)	.077 (.072)	.037 (.049)	.053 (.049)	$.090^*$ (.036)	.133 (.069)
$\bar{R}^2$	.03	.05	.03	.05	.05	.02
SE	.34	.41	.40	.27	.20	.38

	Test Results					
Tests	I-V	I	II	III	IV	V
Dickey-Fuller with time trend						
Φ_3	1.440	1.265	3.436	1.195	1.758	0.855
observations	1547	206	429	303	382	233
p-value	>.10	>.10	>.10	>.10	>.10	>.10
Previous 3 segments=0						
F-statistic	9.861^*	2.348	4.121^*	3.240^*	2.982^*	1.650
degrees of freedom	(3,1549)	(3,202)	(3,425)	(3,299)	(3,378)	(3,229)
p-value	.000	.074	.007	.022	.031	.179
Day-of-Week Dummies=0						
F-statistic	1.716	1.562	0.539	2.536^*	1.314	1.270
degrees of freedom	(4,1545)	(4,198)	(4,421)	(4,295)	(4,374)	(4,225)
p-value	.144	.186	.707	.040	.264	.283
Jumps=0						
F-statistic	0.735	1.728	1.188	3.262	1.916	0.889
degrees of freedom	(3,1546)	(1,201)	(3,422)	(1,298)	(3,375)	(3,226)
p-value	.531	.190	.314	.072	.127	.448
Number of absolute fitted values greater than .10 Yen						
number	592	112	228	119	105	79
total observations	1553	206	429	303	382	233

TABLE 3 -- continued

NOTES: Numbers in parentheses below the estimated coefficients are estimated standard errors. Jumps are absolute 1 percentage point or more changes in a segment. The null hypothesis for the Dickey-Fuller, day-of-week dummies, and jumps tests corresponds to the specification with three previous segments and a constant term in the top half of the table. The test of the significance of the three previous segments also is performed in this specification. Absolute fitted values are additionally taken from this specification, but the estimated constant term is excluded in the computations. Tests of the significance of the day-of-week dummies and the three previous segments use White's (1980) heteroscedasticity-consistent covariance matrix.

*Significant at the 5 percent level.

TABLE 4

Predictability of Exchange Rate Movements: Europe (NYO - TKC)

	Coefficient Estimates and Summary Statistics					
Period:	I-V	I	II	III	IV	V
Constant	-.028*	-.060*	-.034	-.041*	.006	-.038
	(.009)	(.028)	(.019)	(.018)	(.015)	(.026)
Tokyo	.056	.137*	.031	.001	.083	.068
(TKC-TKO)	(.032)	(.066)	(.047)	(.064)	(.073)	(.067)
Pacific	-.077	-.037	-.139	-.156	-.077	-.025
($TKO-NYC_{-1}$)	(.044)	(.195)	(.102)	(.106)	(.099)	(.076)
New York	.121*	.251*	.150*	.168*	.075	-.010
($NYC_{-1}-NYO_{-1}$)	(.025)	(.074)	(.041)	(.041)	(.046)	(.052)
$\bar{R}^2$	.02	.05	.03	.05	.01	-.01
SE	.36	.40	.39	.32	.29	.38

	Test Results					
Tests	I-V	I	II	III	IV	V
Dickey-Fuller with time trend						
Φ_3	2.448	0.646	1.313	3.314	0.447	6.342*
observations	1562	208	432	306	378	235
p-value	>.10	>.10	>.10	>.10	>.10	.05
Previous 3 segments=0						
F-statistic	8.984*	2.575	4.872*	3.878*	0.937	0.379
degrees of freedom	(3,1555)	(3,204)	(3,428)	(3,302)	(3,374)	(3,231)
p-value	.000	.052	.002	.009	.422	.768
Day-of-Week Dummies=0						
F-statistic	2.324	1.761	2.011	0.876	0.682	1.383
degrees of freedom	(4,1551)	(4,200)	(4,424)	(4,298)	(4,370)	(4,227)
p-value	.073	.153	.110	.453	.563	.246
Jumps=0						
F-statistic	1.980	0.247	0.333	3.520*	0.853	1.172
degrees of freedom	(3,1552)	(2,202)	(3,425)	(2,300)	(3,371)	(3,228)
p-value	.115	.864	.801	.015	.465	.319
Number of absolute fitted values greater than .10 Yen						
number	542	126	220	170	55	17
total observations	1559	208	432	306	378	235

NOTES: See the notes in Table 3.

TABLE 5

Predictability of Exchange Rate Movements: New York (NYC - NYO)

	Coefficient Estimates and Summary Statistics					
Period:	I-V	I	II	III	IV	V
Constant	.003 (.011)	.000 (.026)	.043 (.022)	.002 (.025)	.002 (.018)	-.049 (.030)
Europe (NYO-TKC)	-.077* (.030)	-.135* (.063)	-.149* (.055)	-.025 (.077)	-.043 (.060)	.008 (.078)
Tokyo (TKC-TKO)	.121* (.031)	.365* (.060)	.031 (.054)	.122 (.087)	.153 (.085)	-.017 (.079)
Pacific (TKO-NYC_{-1})	-.129* (.053)	-.192 (.179)	-.430* (.119)	-.195 (.146)	-.010 (.112)	.004 (.090)
$\bar{R}^2$	.02	.16	.04	.01	.00	-.01
SE	.42	.37	.45	.44	.34	.45

Tests	Test Results					
	I-V	I	II	III	IV	V
Dickey-Fuller with time trend						
Φ_3	2.493	0.422	2.256	0.837	2.912	2.814
observations	1559	208	432	306	378	235
p-value	>.10	>.99	>.10	>.975	>.10	>.10
Previous 3 segments=0						
F-statistic	6.001*	10.071*	8.342*	0.778	1.523	0.012
degrees of freedom	(3,1555)	(3,204)	(3,428)	(3,302)	(3,374)	(3,231)
p-value	.001	.000	.000	.506	.207	.998
Day-of-Week Dummies=0						
F-statistic	2.502	2.636*	1.911	0.037	0.866	1.584
degrees of freedom	(4,1551)	(4,200)	(4,424)	(4,298)	(4,370)	(4,227)
p-value	.058	.035	.108	.997	.485	.179
Jumps=0						
F-statistic	1.951	1.877	1.308	3.986*	2.039	1.898
degrees of freedom	(3,1552)	(2,202)	(3,425)	(1,301)	(3,371)	(3,228)
p-value	.119	.131	.270	.008	.107	.128
Number of absolute fitted values greater than .10 Yen						
number	530	148	244	88	60	0
total observations	1559	208	432	306	378	235

NOTES: See the notes in Table 3.

TABLE 6

Predictability of Exchange Rate Movements: Pacific ($TKO - NYC_{-1}$)

Period:	I-V	I	II	III	IV	V
	Coefficient Estimates and Summary Statistics					
Constant	$-.013^*$	.014	-.006	-.007	-.013	$-.057^*$
	(.005)	(.010)	(.009)	(.010)	(.008)	(.019)
New York ($NYC_{-1}-NYO_{-1}$)	-.010	$-.091^*$	.016	.008	$-.105^*$	.051
	(.012)	(.027)	(.019)	(.022)	(.024)	(.042)
Europe ($NYO_{-1}-TKC_{-1}$)	.012	-.034	$.069^*$	$-.113^*$	-.018	.088
	(.014)	(.025)	(.022)	(.030)	(.028)	(.053)
Tokyo ($TKC_{-1}-TKO_{-1}$)	$.060^*$	$.051^*$	.023	.001	.063	$.223^*$
	(.014)	(.025)	(.022)	(.034)	(.038)	(.051)
$\bar{R}^2$	.01	.04	.02	.04	.04	.09
SE	.20	.14	.18	.17	.16	.29

Tests	I-V	I	II	III	IV	V
	Test Results					
Dickey-Fuller with time trend						
Φ_3	10.618^*	9.498^*	1.597	0.908	2.631	0.265
observations	1553	206	429	303	382	233
p-value	<.01	<.01	>.10	>.975	>.10	>.99
Previous 3 segments=0						
F-statistic	3.666^*	5.081^*	4.892^*	2.272	1.348	6.385^*
degrees of freedom	(3,1549)	(3,202)	(3,425)	(3,299)	(3,378)	(3,229)
p-value	.012	.002	.002	.078	.257	.000
Day-of-Week Dummies=0						
F-statistic	2.660^*	1.469	0.419	0.930	3.594^*	2.587^*
degrees of freedom	(4,1545)	(4,198)	(4,421)	(4,295)	(4,374)	(4,225)
p-value	.047	.213	.795	.447	.007	.038
Jumps=0						
F-statistic	2.269	0.226	0.583	1.387	6.372^*	0.600
degrees of freedom	(3,1546)	(2,200)	(3,422)	(2,297)	(3,375)	(3,226)
p-value	.079	.878	.626	.245	.000	.615
Number of absolute fitted values greater than .10 Yen						
number	84	39	56	68	75	102
total observations	1553	206	429	303	382	233

NOTES: See the notes in Table 3.

TABLE 7

Behavior of the Exchange Rate Around Jumps

	Number of Days with Absolute Changes of 1 Percent or More			
	Tokyo	Europe	New York	Pacific
Jan. 1, 1980 - Sept. 29, 1986	36	22	57	8
Jan. 1, 1980 - Nov. 30, 1980	10	5	7	0
Dec. 1, 1980 - Oct. 4, 1982	13	8	15	2
Oct. 5, 1982 - Jan. 31, 1984	4	2	13	1
Feb. 1, 1984 - Sept. 22, 1985	2	3	6	1
Sept. 23, 1985 - Sept. 29, 1986	7	4	16	4

Estimation Results

Jump = a + b(previous change) + e

Previous Change:	a	b	$\bar{R}^2$	SE
previous segment	-.3570*	-.2470	.00	1.28
	(.1213)	(.2049)		
previous 2 segments	-.3780*	-.1143	-.00	1.28
	(.1230)	(.1614)		
previous 3 segments	-.3590*	-.0002	-.01	1.28
	(.1219)	(.0015)		
previous week	-.3699*	-.0430	-.00	1.29
	(.1297)	(.0509)		

(change in subsequent segment) = a + b(jump) + e

Jump:	N	a	b	$\bar{R}^2$	SE
≥ 1%	121	-.0437	-.1319*	.09	.27
		(.0487)	(.0366)		
≥ 1.25%	21	.4484	-.4493	.02	.40
		(.5663)	(.3789)		
≥ 1.5%	6	-2.1347	.9741	-.16	.52
		(3.1158)	(1.7200)		

NOTES: Numbers in parentheses below coefficient estimates are standard errors. N is the number of observations.

*Significant at the 5 percent level.

TABLE 8

Response of U.S. Stock Prices to Yen/Dollar Exchange Rate Movements (NYSP - $NYSP_{-1}$)

Period:	Coefficient Estimates and Summary Statistics I-V	I	II	III	IV	V
Constant	.022 (.030)	.019 (.120)	-.037 (.072)	.057 (.055)	.028 (.038)	.076 (.065)
Europe (NYO-TKC)	-.268* (.085)	-.119 (.294)	-.499* (.180)	-.304 (.167)	-.010 (.139)	-.144 (.169)
Tokyo (TKC-TKO)	-.137 (.088)	-.205 (.277)	-.086 (.174)	-.289 (.190)	-.076 (.184)	-.086 (.170)
Pacific (TKO-NYC_{-1})	-.423* (.151)	-.065 (.839)	-1.15* (.385)	-.099 (.317)	-.399 (.246)	-.177 (.195)
$\bar{R}^2$	.01	-.01	.03	.01	-.00	-.00
SE	1.19	1.67	1.47	0.94	0.73	0.97

Tests	Tests of Information Content I-V	I	II	III	IV	V
Previous 3 segments=0						
F-statistic	5.233*	0.543	3.761*	1.232	1.046	0.714
degrees of freedom	(3,1530)	(3,199)	(3,419)	(3,298)	(3,371)	(3,227)
p-value	.001	.653	.010	.297	.371	.544
Jumps=0						
F-statistic	0.145	1.089	0.329	3.546*	11.539*	11.906*
degrees of freedom	(3,1527)	(2,197)	(3,416)	(1,297)	(2,369)	(3,224)
p-value	.933	.353	.804	.014	.000	.000

NOTES: The dependent variable in the regressions is the change in the natural logarithm of the Standard & Poors 500 Index, multiplied by 100, from the close in day t-1 to the close in day t. Numbers in parentheses below the estimated coefficients are estimated standard errors. The null hypothesis for the jumps test corresponds to the specification in the top part of the table. The test of the significance of exchange rate movements in the three previous segments also is performed in this specification using White's (1980) heteroscedasticity-consistent covariance matrix.

*Significant at the 5 percent level.

TABLE 9

Response of Japanese Stock Prices to Yen/Dollar Exchange Rate Movements (TKSP - TKSF

Period:	I-V	I	II	III	IV	V
	Coefficient Estimates and Summary Statistics					
Constant	.058* (.024)	.039 (.034)	-.005 (.069)	.110* (.033)	.056 (.037)	.145* (.050)
Pacific ($TKO-NYC_{-1}$)	-.051 (.119)	-.191 (.235)	-.103 (.373)	-.182 (.190)	-.003 (.236)	.077 (.162)
New York ($NYC_{-1}-NYO_{-1}$)	-.170* (.056)	.080 (.086)	-.106 (.149)	-.432* (.073)	-.348* (.113)	.017 (.106)
Europe ($NYO_{-1}-TKC_{-1}$)	-.416* (.067)	-.311* (.084)	-.566* (.179)	-.461* (.102)	-.293* (.127)	-.303* (.135)
$\overline{R}^2$	.03	.06	.02	.15	.03	.01
SE	0.92	0.48	1.41	0.56	0.71	0.74

Tests	I-V	I	II	III	IV	V
	Tests of Information Content					
Previous 3 segments=0						
F-statistic	10.985*	3.825*	2.351	9.768*	4.931*	1.991
degrees of freedom	(3,1535)	(3,202)	(3,419)	(3,294)	(3,378)	(3,226)
p-value	.000	.010	.071	.000	.002	.113
Jumps=0						
F-statistic	0.871	3.695*	0.929	0.671	0.368	0.703
degrees of freedom	(3,1532)	(1,201)	(3,416)	(1,293)	(3,375)	(3,223)
p-value	.455	.011	.426	.570	.776	.550

NOTES: The dependent variable in the regressions is the change in the natural logarithm of the Nikkei-Dow 225 Index, multiplied by 100, from the close in day t-1 to the close in day t. See the notes in Table 8.

*Significant at the 5 percent level.