Interactions Between the U.S. and Japan Stock Market Indices

Yin-Wong Cheung
Lilian K. Ng

ABSTRACT. In this study we evaluate the importance of one country's news in generating the stock market volatility of another. In the analysis of the interactions between the S&P 500 and the Nikkei 225 indices in the pre- and post-crash periods, we find that the contribution of the U.S. news in generating the stock volatility of the Tokyo market decreases from 56% prior to the October 1987 crash to only 25% after the crash. On the other hand, during the post-crash period, about 58% of the volatility of the New York Stock Exchange is attributable to the impact of Tokyo news. This evidence is consistent with the observed growing significance of the Japanese economic involvement in the U.S.

INTRODUCTION

Recent empirical studies (for example, Eun and Shim (1989), Becker, Finnerty and Gupta (1990), Hamao, Masulis and Ng (1990,

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Yin-Wong Cheung and Lilian K. Ng are affiliated with Economics Board, University of California at Santa Cruz, and Department of Finance, University of Texas at Austin, respectively.

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1991), Kato (1990), Koch and Koch (1990), Cheung and Ng (1991), and Becker, Finnerty and Tucker (1992))[1] have shown that developments in the U.S. market have a significant influence on the Tokyo stock market the next day, but not Tokyo on the U.S. market. Given the U.S.'s dominant economic and political strength in the world market, this finding seems not surprising. However, the recent leading role of Japan in the world equity market[2] and her active participation in the U.S. may possibly signal a reversal of the widely-held notion that the spillover stock market effect is solely from the U.S. to Japan.

This paper studies the economic visibility of Japan in the U.S. via information revealed in the correlations of price changes and volatility across the two national stock markets. We investigate the extent of one national stock market's influence on the other by examining the decompositions of the mean and volatility of the latter's stock returns. Evidence on the cross correlation in stock market movements allows us to infer the direction of information flow between the two markets and hence the investors' perceptions of the Japanese economic involvement in the U.S. Further, the paper examines the relative importance of foreign variables in generating the first two moments of domestic stock returns, providing a measure of the foreign news contributions to domestic stock movements. The pre- and post-crash sampled equity returns will be examined separately to account for possible structural changes occurring after the 1987 crash reported in, for example, Von Furstenberg and Jeon (1989).

In the next section, we describe the tests for causality in mean and variance. In the third section, we describe the data and present the test results. The decompositions of the mean and volatility are also presented in this section. The final section summarizes the paper.

STATISTICAL TESTS

We employ tests for causality in the first two moments that were developed in Haugh (1976) and Cheung and Ng (1991). The tests

entail fitting a univariate model to each time series and calculating the cross correlations in the levels and squares of the resulting innovation series. The initial stage is designed "to remove the effect of the pasts of each individual series before investigating cross relationships between series" (Granger (1977, p. 23)). If one time series is simply regressed on past observations of another, Granger (1977) argues that this generally leads to residuals that are serially correlated and hence misleading inferences. In the second stage, the resulting prewhitened series of innovations standardized by their conditional standard deviations are constructed. Sample cross correlations in the levels and squares of these standardized residuals are used to test the null hypothesis of no correlation in the mean and variance, respectively.

Suppose the rates of return on the S&P 500 Index $\{R_t\}$, $t = 1, \ldots, T$, assume the following conditional heteroskedastic process:

$$R_t = \mu_t + \sqrt{h_t}\,\varepsilon_t \tag{1}$$

where μ_t is the time-dependent conditional mean, h_t is the conditional variance, and ε_t is the random error term with variance equals one. Let $\hat{\varepsilon}_t$ be the estimated error computed from consistent estimates of μ_t and h_t. Suppose the rates of return on the Japan Nikkei 225 Index also follow the conditional heteroskedastic process as in (1) above, except that the corresponding variables are indicated by an "*." In this case, $\hat{\varepsilon}_t^*$, denotes the standardized residual of the return on the Nikkei 225 Index calculated from the consistent estimates of μ_t^* and h_t^*.

The causal relationships in the first two moments are investigated by examining the sample cross-correlation coefficients of the standardized residuals and squared standardized residuals. Let $\hat{r}_1(k)$ measures the cross correlation of $\hat{\varepsilon}_t$ and $\hat{\varepsilon}_{t-k}^*$ and $\hat{r}_2(k)$ measures the cross correlation of $\hat{\varepsilon}_k^2$ and $\hat{\varepsilon}_{t-k}^{*2}$. It can be shown that under the null hypothesis of no causal relation between R_t^* and R_t both $\sqrt{T}(\hat{r}_1(k_1),$

$\ldots, \hat{r}_1(k_m))$ and $\sqrt{T}(\hat{r}_2(k_1), \ldots, \hat{r}_2(k_m))$ converge asymptotically to $N(0, I_m)$, where $k_1, \ldots, k_m$ are m different integers and I_m is the $m \times m$ identity matrix (Haugh (1976) and Cheung and Ng (1991)). This asymptotic result does not depend on the underlying distributions of $\hat{\varepsilon}_t^*$ and ε_t.

Given the asymptotic behavior of $\hat{r}_1(k)$ and $\hat{r}_2(k)$, a normal test statistic or a chi-square test statistic can be used to test the null hypothesis that there is no causality between R_t and R_t^*. Specifically, we can compare, say, $\sqrt{T}\hat{r}_2(k)$ ($\sqrt{T}\hat{r}_1(k)$) with the standard normal distribution to test for causality in the second (first) moment at the k-th lag. Alternatively, the causal relationship in variance can be tested using a chi-square test statistic, which is defined as,

$$S = T\Sigma_{i=-j}^{k}\hat{r}_1(i)^2. \tag{2}$$

The S statistic has an asymptotic $\chi^2(k + j + 1)$ distribution. The choice of j and k depends on the specification of alternative hypotheses. With no *a priori* information on the causal relation, we may set $j = k = m$, where m is selected large enough to include all cross correlations that are expected to be significantly nonzero. When the alternative hypothesis, say, the return on the Nikkei 225 Index R_t^* does not cause R_t in the variance is considered, we can set $j = 1$ and $k = m$. A similar chi-square test statistic can also be constructed to test for causality in the mean using sample cross correlation of standardized residuals, $\hat{r}_1(k)$, instead.

This residual-based procedure has two advantages when compared with the widely-used vector-autoregressive approach. It allows the explicit modeling of conditional heteroskedasticity. This is important because empirical evidence suggests that both the U.S. and Japanese stock market indices follow a conditional heteroskedastic process. The method also provides a unified framework in which the causality in both the mean and variance can be determined and hence the information flow between the two national stock markets.

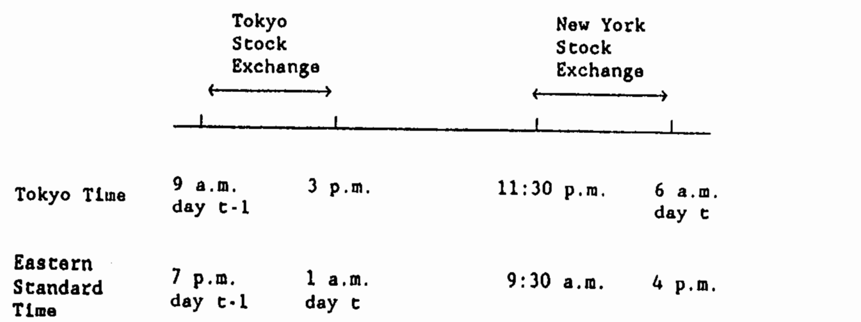
DATA AND EMPIRICAL RESULTS

Data

The data used in this study were daily close-to-close data on the Nikkei 225 Stock Index and the S&P 500 Composite Index from January 1985 to December 1989. The Nikkei 225 Index is a stock index of 225 stocks on the Tokyo Stock Exchange (TSE), and the index data were obtained from Datastream, Inc. Data on the S&P 500 Index were obtained from the Center for Research in Security Prices at the University of Chicago.

While the trading hours of TSE are between 7:00 pm. and 1:00 a.m. Eastern Standard Time (EST), the New York Stock Exchange opens at 9:30 a.m. EST (10:00 a.m. EST before September 30, 1985) and closes at 4:00 p.m. EST. The trading hours of the two exchanges are depicted in Figure 1. The nonoverlapping trading hours between the two stock markets allow informational effects to be separated, and thus make them an attractive candidate for this study. In this case, any new global information released after New York's close but before the subsequent Tokyo's close will first

Figure 1: Trading times on the Tokyo and New York Stock Exchanges



Note: There is no common trading hour in which both the Tokyo and the New York stock markets are open.

affect Tokyo and then New York (8.5 hours difference in real time from Tokyo's close to New York's open) in a sequential manner, and not concurrently, on a given calendar day. If there is a release of information after Tokyo's close, however, this new information will arrive first in New York and then in Tokyo, seven hours later the next calendar day.

In examining the correlations in stock market movements across two international markets, there are two obvious technical problems. The first problem is the difference in currencies. Numerous studies such as Becker, Finnerty and Gupta (1990), Hamao, Masulis and Ng (1990), and Koch and Koch (1990) on international equity returns have documented that the results are maintained even when currencies of different countries are converted to a common denomination. Even if returns are calculated based on the same currency denomination, the choice of a denomination and the choice of a particular trading time exchange rate used for conversion are also difficult to determine. In light of this, stock equity returns are calculated as percentage changes of the stock indices based on the country's own currency.

The second problem pertains to the difference in national holidays. Two possible ways can be implemented to circumvent the problem. When there is a national holiday where the stock market is closed, we can substitute the previous trading day's index level for the missing national holiday's observation. Alternatively, we can remove the returns for days in which either one of the stock markets is closed for a national holiday. Since relatively little or no new information is released during a holiday as compared to a trading day (see French and Roll (1986)), we chose to adopt the former approach.

Data on both stock index return series are then split into two subsamples:[3] the first subsample includes 728 observations up to October 18, 1987, and the second includes 574 observations from October 20, 1987 onwards. Our way of splitting the data is consistent with evidence suggesting that the dynamic properties of national stock price movements are different before and after the October '87 crash (see Von Furstenberg and Jeon (1989), Jeon and Von Furstenberg (1990) and King and Wadhwani (1990)). For notational convenience, the first subsample is called the "pre-crash" sample and the second is the "post-crash" sample.

Empirical Results

Our preliminary data analysis shows that an MA(1)-GARCH (1,1) model,

$$R_t = \phi_0 + u_t + \phi_2 u_{t-1}, \quad u_t \sim N(0, h_t)$$
$$h_t = \varphi_0 + \varphi_1 h_{t-1} + \varphi_2 u_{t-1}^2, \tag{3}$$

and a GARCH(1,1) model,

$$R_t = \phi_0 + u_t, \quad u_t \sim N(0, h_t)$$
$$h_t = \varphi_0 + \varphi_1 h_{t-1} + \varphi_2 u_{t-1}^2, \tag{4}$$

provide adequate descriptions of the pre- and post-crash daily returns on the S&P 500 Index, respectively,[4] where u_t is the unexpected return, and h_t is the conditional variance. Unlike the S&P 500 Index, diagnostic tests lend support to an MA(1)-GARCH(1,1) model

$$R_t^* = \phi_0^* + u_t^* + \phi_2^* u_{t-1}^*, \quad u_t^* \sim N(0, h_t^*)$$

$$h_t^* = \phi_0^* + \varphi_1^* h_{t-1}^* + \phi_2^* u_{t-1}^{*2} \tag{5}$$

for both the pre- and post-crash Nikkei 225 Index series.

Maximum likelihood estimates and diagnostic statistics of the models (3)-(5) are presented in Table I.[5] The parameter estimates are all significant at conventional levels. The portmanteau test statistics, denoted by $Q(q)$ and $Q^2(q)$, q = 10 and 20, are computed from the first q autocorrelations of the levels and squares of resulting standardized residuals, respectively. None of the Q or Q^2 statistics are significant at the 5 percent level, indicating no evidence of serial

Table I: Maximum likelihood estimates of the GARCH(1,1)-type models using daily data from 1/2/85 - 10/18/87 (pre-crash), and from 10/20/87-12/29/89 (post-crash).

Parameter	S&P 500 Index	Nikkei 225 Index	S&P 500 Index	Nikkei 225 Index
	Pre-Crash		Post-Crash	
ϕ_0, ϕ_0^*	0.1012 (0.0223)	0.1148 (0.0200)	0.0622 (0.0280)	0.1132 (0.0202)
ϕ_2, ϕ_2^*	0.1033 (0.0296)	0.1088 (0.0275)		0.0703 (0.0315)
φ_0, φ_0^*	0.0250 (0.0092)	0.0209 (0.0048)	0.0905 (0.0199)	0.0314 (0.0069)
φ_1, φ_1^*	0.8992 (0.0167)	0.8879 (0.0192)	0.8138 (0.0280)	0.8180 (0.0291)
φ_2, φ_2^*	0.0762 (0.0119)	0.0862 (0.0162)	0.1150 (0.0174)	0.1030 (0.0210)
Q(10)	2.9523	12.1121	5.7738	8.2592
Q(20)	10.5794	17.5003	13.1281	19.0839
$Q^2(10)$	4.8865	10.6346	1.6888	11.1227
$Q^2(20)$	11.1465	16.6426	2.1256	15.8190
Log-likelihood	-911.98	-848.47	-833.50	-579.41

Notes: This table reports maximum likelihood estimates of: (i) the MA(1)-GARCH(1,1) model, $R_t=\phi_0 + u_t + \phi_2 u_{t-1}$, using pre-crash S&P 500 index data, (ii) the GARCH (1,1) model, $R_t=\phi_0 + u_t$, using post-crash S&P data, and (iii) the MA(1)-GARCH(1,1) model using the Nikkei 225 Index data, with parameters denoted by "*", where $u_t^*\sim N(0, h_t^*)$ and $h_t^*=\varphi_0^* + \varphi_1^* h_{t-1}^* + \varphi_2^* u_{t-1}^{*2}$. Asymptotic standard errors are in parentheses. Q(q) and $Q^2(q)$, q=10, 20, are the Box-Pierce portmanteau statistics for the first q autocorrelations on the levels and squares of standardized residuals, respectively.

correlations in the first two moments of the estimated residual series. Thus, conditioning on each index's own past observations, the models selected are neither mis-specified nor overfitted.

Sample cross correlations of standardized residuals from these estimated models are reported in Table II. The "lag" refers to the number of periods the Nikkei 225 Index series lags the S&P 500 Index series. The lead is given by a negative lag. Since Tokyo and New York stock markets operate in different time zones, the observed returns at the same time period would not be synchronized. Thus the correlation of the two indices on the same calendar day, defined by the cross correlation at lag 0, should be appropriately interpreted as evidence of the Nikkei 225 Index causing the S&P 500 Index. It is important to note that any causality between these two series cannot be induced by news that has contemporaneous impact on the two international stock markets since there is no common trading hour in which they operate.

Cross correlations of the resulting standardized residuals based on the pre-crash sample, reported in Table II, indicate that the S&P 500 Index causes (or lags) the Japanese index in the mean as well as the variance. The causation pattern is of lag one in the mean and up to lag three in the variance. In contrast, however, there exists some feedback in the rate of informational flow between the Tokyo and New York stock markets after the October '87 crash, rather than a uni-directional causation from New York to Tokyo. Causation patterns are found in both the conditional mean and variance, but are less distinct when using the pre-crash sample. In comparing cross correlations of standardized residual series, we observe that although Tokyo has an influence on New York's same day's stock prices, the impact is not half as large as that of New York on the Japanese next-day's stock prices. Nevertheless, this indicates that new information is not only transmitted from New York to Tokyo, but also from Tokyo to New York within one trading day. However, the volatility spillover effect is stronger from Tokyo to New York than in the other direction. By construction of the correlation test, these results are asymptotically robust to the distributions of both indices.

Table II: Cross correlations of the levels and squares of standardized residuals resulting from the estimated models reported in Table I.

lag k	$\hat{r}_1(k)$	$\hat{r}_2(k)$	$\hat{r}_1(k)$	$\hat{r}_2(k)$
	Pre-Crash		Post-Crash	
-10	.0274	.0372	.0353	-.0302
-9	.0044	.0228	-.0489	-.0278
-8	.0070	-.0231	.0272	-.0172
-7	.0087	-.0124	-.0433	.0525
-6	-.0359	-.0178	-.0994*	-.0303
-5	-.0113	-.0085	.0100	-.0578
-4	.0062	.0558	-.0920*	-.0266
-3	.0184	.0972*	-.0448	-.0265
-2	.0349	-.0234	-.0097	.0792*
-1	.2306*	.1081*	.2384*	.1193*
0	.0285	-.0480	.0920*	.0544
1	.0182	.0065	.0041	.0514
2	.0362	-.0205	-.0270	.1652*
3	.0319	-.0122	-.0254	-.0049
4	-.0111	-.0084	.0519	-.0119
5	-.0558	-.0284	-.0292	.0386
6	-.0458	.0644	-.0365	-.0119
7	-.0043	-.0308	.0161	-.0050
8	-.0236	.0149	.0168	-.0083
9	.0055	.0140	-.0056	.0113
10	.0322	.0184	.0186	.0401

Notes: $\hat{r}_1(k)$ and $\hat{r}_2(k)$ are sample cross correlations of the respective levels and squares of standardized residuals obtained from the estimated models using daily returns on S&P 500 and Nikkei 225 indices, reported in Table I. k is the number of periods the Nikkei 225 Index lags the S&P 500 Index. Cross-correlation coefficients significant at the 5% level are indicated by "*".

Our results, however, contrast those of Cheung and Ng (1991), using daily close-to-close data of the same sample period, and Becker, Finnerty and Tucker (1992), using hourly data from October 1985 to December 1989. Assuming structural stability across their whole sample periods, both these studies show that the spillover effect is only from the U.S. to the Japan market. The difference in the findings is mainly attributed to the change in the dynamics of the two stock indices before and after the crash that is not incorporated in their analysis.

Based on causation patterns revealed in sample cross correlations reported in Table II, we re-construct the time series models by including exogenous variables (that is, the foreign market index's lagged mean return or lagged squared return)[6] in the model for the domestic stock market index. Then, models with possible lagged foreign variables, as implied by the cross correlations reported in Table III, are estimated and evaluated.

For the Japanese Nikkei 225 Index the pre- and post-crash models are specified as follows:

i) Pre-crash

$$R_t^* = \phi_0^* + u_t^* + \phi_2^* u_{t-1}^* + \xi_1^* R_{t-1}, \qquad u_t^* \sim N(0, h_t^*)$$

$$h_t^* = \varphi_0^* + \varphi_1^* h_{t-1}^* + \varphi_2^* u_{t-1}^{*2} + \delta_1^* R_{t-1}^2, \tag{6}$$

ii) Post-crash

$$R_t^* = \phi_0^* + u_t^* + \xi_1^* R_{t-1} + \xi_4^* R_{t-4} + \xi_6^* R_{t-6}, \quad u_t^* \sim N(0, h_t^*)$$

$$h_t^* = \varphi_0^* + \varphi_1^* h_{t-1}^* + \varphi_2^* u_{t-1}^{*2} + \delta_2^* R_{t-2}^2 \tag{7}$$

For the S&P 500 Index we reconstruct only the post-crash model (since the Nikkei 225 Index does not cause the U.S. stock index in the pre-crash period), which is given by:

Table III: Maximum likelihood estimates of the GARCH(1,1)-type models with exogenous variables. Pre-crash period is from 1/2/85 - 10/18/87, and the post-crash period is from 10/20/87 - 12/29/89.

Parameter	Nikkei 225 Index	S&P 500 Index	Nikkei 225 Index
	Pre-Crash	Post-Crash	
ϕ_0, ϕ_0^*	0.1059 (0.0203)	0.0634 (0.0264)	0.0968 (0.0180)
ϕ_2, ϕ_2^*	0.1067 (0.0294)		
ξ_1, ξ_1^*	0.2138 (0.0241)	0.0942 (0.0472)	0.1883 (0.0188)
ξ_4, ξ_4^*			-0.0649 (0.0185)
ξ_6, ξ_6^*			-0.0745 (0.0188)
φ_0, φ_0^*	0.0314 (0.0096)	0.0523 (0.0135)	0.1243 (0.0369)
φ_1, φ_1^*	0.7767 (0.0428)	0.8478 (0.0289)	0.3858 (0.1360)
φ_2, φ_2^*	0.1349 (0.0279)		0.2171 (0.0465)
δ_1, δ_1^*	0.0402 (0.0141)	0.1787 (0.0453)	
δ_2, δ_2^*			0.0484 (0.0171)
Q(10)	12.4262	7.9641	9.7880
Q(20)	17.3461	16.4500	22.0240
$Q^2(10)$	5.8758	2.9223	8.3546
$Q^2(20)$	11.5488	5.3047	14.2690
Log-likelihood	-822.73	-790.40	-556.50
M, M^*	0.1696	0.1298	0.0355
H, H^*	0.5629	0.5814	0.2463

Notes: Maximum likelihood estimates of the models given by (11)-(13), where parameters of the Nikkei 225 Index series are indicated with an "*", while those of the S&P 500 are without. Asymptotic standard errors are in parentheses. Q(q) and $Q^2(q)$, q=10, 20, are the Box-Pierce portmanteau statistics for the first q autocorrelations on the levels and squares of standardized residuals, respectively. The M (M*) and H (H*) are the indices measuring the New York (Tokyo) stock market's contribution in the corresponding unconditional first and second moments of Tokyo (New York) stock returns.

$$R_t = \phi_0 + \xi_1 R_t^* + u_t, \qquad u_t \sim N(0, h_t)$$

$$h_t = \varphi_0 + \varphi_1 h_{t-1}^* + \delta_1 R_t^{*2} \tag{8}$$

Estimates of models (6)-(8) are reported in Table III. The additional explanatory variables are all significantly different from zero. For the pre-crash sample the inclusion of S&P 500 Index's lagged return and lagged squared return in the Nikkei 225 Index conditional mean and variance equations (6) statistically improves the log likelihood value from -848.47 to -822.73. Using the pre-crash sample, the results suggest that the movement in the U.S. stock index, as evidenced by the ξ_1-estimate, has a larger impact on the conditional mean of the Japan stock index than the latter's own moving-average shock ϕ_2. The conditional volatility spillover effect from the U.S. to the Japan market is significant, but small, as measured by δ_1^* of 0.04.

In Table III, the additional explanatory variables in the post-crash models (7) and (8) are all significantly different from zero. The inclusion of these explanatory variables also yields a statistically significant improvement in the log likelihood value. For the S&P 500 Index model the log likelihood increases from -833.50 to -790.40, and that for the Nikkei 225 Index improves from -579.40 to -556.50. The ξ_1 and ξ_1^* estimates suggest that the immediate influence of the U.S. stock index on the conditional mean of the Japan stock index is larger than in the other direction. In comparing the magnitudes of δ estimates, we observe that the volatility spillover effect is stronger from Tokyo to New York than from New York to Tokyo. This phenomenon is consistent with price movements observed in the Tokyo and New York stock markets during the period after the October '87 crash and also with the sample cross correlations reported in Table II.

To test the adequacy of these models, we check again whether the residuals obtained from the reconstructed models are well-behaved; results are reported in Table IV. Unlike those presented in Table II, the results indicate no evidence of cross correlations in the

Table IV: Cross correlations of the levels and squares of standardized residuals resulting from the estimated models reported in Table III.

lag k	$\hat{r}_1(k)$	$\hat{r}_2(k)$	$\hat{r}_1(k)$	$\hat{r}_2(k)$
	Pre-Crash		Post-Crash	
-10	.0176	.0354	.0172	-.0511
-9	.0051	-.0008	-.0648	-.0281
-8	.0045	-.0171	.0209	-.0282
-7	.0066	-.0330	-.0446	.0558
-6	-.0199	-.0247	.0187	-.0264
-5	-.0070	-.0146	.0137	-.0622
-4	-.0089	.0322	.0006	-.0409
-3	.0281	.0668	-.0562	-.0434
-2	.0411	-.0447	.0078	.0056
-1	.0004	.0056	-.0110	-.0318
0	.0279	-.0442	.0068	.0395
1	.0138	.0060	.0024	.0274
2	.0315	-.0359	-.0164	.0352
3	.0290	-.0183	-.0087	-.0316
4	-.0047	-.0259	.0474	-.0383
5	-.0488	-.0198	-.0317	-.0016
6	-.0500	.0543	-.0489	-.0148
7	-.0032	-.0224	.0020	-.0002
8	-.0286	.0196	.0379	.0001
9	-.0074	.0005	-.0252	-.0185
10	.0315	-.0190	-.0039	.0271

Notes: $\hat{r}_1(k)$ and $\hat{r}_2(k)$ are sample cross correlations of the respective levels and squares of standardized residuals obtained from the estimated models using daily returns on S&P 500 and Nikkei 225 indices, reported in Table III. k is the number of periods the Nikkei 225 Index lags the S&P 500 Index. None of the cross-correlation coefficients are significant at the 5% level.

first and second moments. All this indicates that these models provide a reasonable description of the interactions between these two indices.

Relative Importance of News in Mean and Variance

Although the above causation method determines the direction of informational flow, it does not provide a measure of the contribution of the news of one market to the other. The importance of the foreign informational effect can be evaluated by measuring the relative magnitude of the foreign stock component in the first and second moments of the domestic stock returns. The composition of foreign components in the domestic total component is used to infer the amount of foreign information affecting the unconditional mean and volatility of the country's stock returns.

Assuming stationarity and applying the unconditional expectations operator to the conditional mean equations (7) and (8), we have

$$R^* = \phi_0^* + (\xi_1^* + \xi_4^* + \xi_6^*)R, \tag{9}$$

and

$$R = \phi_0 + \xi_1 R^*, \tag{10}$$

where $R^* = E(R_t^*)$, $R = E(R_{t-1}) = E(R_{t-4}) = E(R_{t-6})$ and E is the expectations operator. Essentially, we decompose each unconditional mean into a constant country-own component and a foreign component. From (9) and (10), we can construct a simple index to measure the proportion of foreign components in each country's unconditional stock return.

Let M^* be the proportion of information affecting the Tokyo stock movements that is due to news from the New York stock market, and M be the proportion measuring Tokyo's influence on New York. Given (9) and (10), we can express M^* and M as follows:

$$M^* = \dot{\xi}_1 + \dot{\xi}_4 + \dot{\xi}_6)R \,/\, (\dot{\phi}_0 + (\dot{\xi}_1 + \dot{\xi}_4 + \dot{\xi}_6)R) \tag{11}$$

and

$$M = \xi_1 R^* / (\phi_0 + \xi_1 R^*). \tag{12}$$

Thus the larger the M (M^*) index, the more important the foreign stock market's contribution to the domestic stock movements.

Accordingly, the second moment variance can be decomposed to evaluate the contribution of foreign news to the country's total variation in stock returns. Applying the unconditional expectations operator to the conditional variance equations in models (7) and (8) and re-arranging terms, we have

$$h^* = [\dot{\varphi}_0 + \delta_2 E\,(R^2_{t-2)})\,]/(1 - \dot{\varphi}_1 - \dot{\varphi}_2) \tag{13}$$

and

$$h = [\varphi_0 + \delta_1 E\,(R_t^{*2})\,]/(1 - \varphi_1), \tag{14}$$

where h and h^* are unconditional variances defined by $h = E(h_{t-1})$ and $h^* = E\,(h^*_{t-1}) = E\,(u^{*2}_{t-1})$. The proportion of the Tokyo (New York) total stock market volatility which is attributable to information from New York (Tokyo) can be measured by H^* (H):

$$H^* = \delta_2 E\,(R^2_{t-2})/(\dot{\varphi}_0 + \delta_2 E\;(R^2_{t-2})\,) \tag{15}$$

and

$$H = \delta_1 E\,(R_t^{*2})/(\varphi_0 + \delta_1 E\,(R_t^{*2})\,) \tag{16}$$

The M, M^*, H, and H^* ratios are reported in the last two lines of Table III. Both M^* and H^* decrease substantially from 0.17 and 0.56 for the pre-crash period to 0.036 and 0.25, respectively, during the post-crash period. The mean spillover effect from New York to Tokyo has attenuated by more than half after the October '87 crash. Developments in the New York market, which contribute about 56% of the variation in the Nikkei 225 Index for the pre-crash period, only account for 25% of the after-crash Japanese stock market volatility.

On the other hand, the magnitudes of the M and H ratios for the S&P 500 Index in the post-crash period are comparable to those of the Nikkei 225 Index in the pre-crash period. It can be interpreted that during the post-crash period, about 58% of the New York stock volatility is attributable to recent developments in the Tokyo market. These ratios are perhaps a manifestation of investors' reaction towards information revealed in the Tokyo market movements and also, an indication of the growing significance of the Japanese economic involvement in the U.S.

SUMMARY

We investigate the dynamic properties of stock returns in Tokyo and in New York before and after the October 1987 stock market crash, using daily close-to-close market indices from January 1985 to December 1989. GARCH-type models are used to describe the intertemporal behavior of these stock indices. Causations in price changes and volatility are examined using a residual-based test that is asymptotically robust to distributional assumptions. Unlike other studies, this paper evaluates the relative contributions of developments in one market to another by examining the decompositions of the mean and variance of stock market returns.

We find that both the time-series properties of individual stock indices and structures of information transmission between the Japan and the U.S. stock markets are different before and after the crash. In the pre-crash period Tokyo stock price movements can be partially explained by those in New York, but the former has very little impact on the latter. In contrast, however, the spillover market effects in the mean and variance are in both directions after the crash. This evidence is further reinforced by our analysis of the variance and mean decompositions. The impact of New York news on the Tokyo stock market becomes less significant after the market crash and, in fact, during this period a greater effect of Tokyo's news on the New York stock market is found.

Changes in cross correlations between the U.S. and Japan stock indices are in accord with the increased interdependence between the New York and Tokyo stock markets, Japan's growing importance in the world economy, and her increasing participation in the U.S. financial and real markets. Such changes in the correlation structure also have implications for international portfolio diversification as a gain from diversification is usually derived under the assumption of a stable correlation structure.

ENDNOTES

1. Other recent studies such as Hilliard (1979), Dwyer and Hafer (1988), Roll (1988), Von Furstenberg and Jeon (1989), and Neumark, Tinsley and Tosini (1991) also investigate the linkages between the U.S. and the Japan stock markets, with other international stock markets included.
2. According to Morgan Stanley Capital International Perspectives, the U.S. market was the largest in the world in 1985-86. However, it was overtaken by the Japan stock market in 1987-89.
3. The likelihood ratio test indicated that there was a structural break in the dynamics of these indices after the '87 crash. The full sample result and the likelihood ratio test are available upon request.
4. The use of GARCH processes in modeling stock returns is consistent with many previous studies, for example, French, Schwert and Stambaugh (1987). In fact, various GARCH-type specifications that were shown to provide a reasonable approximation of the behavior of these stock indices were also considered. However, based on the log likelihood, the Akaike Information Criterion, and the Bayesian Information Criterion, the models specified in the text were selected. The preliminary analysis results are available from the authors.
5. Weiss (1986) proves the consistency and normality of maximum likelihood estimates without the normality assumption of the error term.
6. There are mainly two approaches to investigate causality in a pair of random variables: 1. the residual-based method; 2. the regression-based method where one observed variable is regressed on the other observable variables (see Pierce and Haugh (1977)). The use of (squared) returns to capture the effect of information flow is therefore motivated by the regression-based approach employed in the standard causality analysis. This also facilitates the comparison of our results with those using the residual-based approach.

REFERENCES

Becker, K.G., J.E. Finnerty and M. Gupta, 1990, The intertemporal relation between the U.S. and Japanese stock markets, *Journal of Finance* 45, 1297-1306.

Becker, K.G., J.E. Finnerty and A.L. Tucker, 1992, The intraday interdependence structure between U.S. and Japanese equity markets, *Journal of Financial Research* XV, 27-37.

Cheung, Y.W. and L. K. Ng, 1991, A causality in variance test and its application to the U.S./Japan stock markets, Working paper, University of California at Santa Cruz and University of Texas at Austin.

Dwyer, G.P. and R.W. Hafer, 1988, Are national stock markets linked? *Federal Reserve Bank of St. Louis Review* 70, 3-14.

Eun, S.E. and S. Shim, 1989, International transmission of stock market movements, *Journal of Financial and Quantitative Analysis* 24, 241-256.

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

French, K.R., G.W. Schwert and R.F. Stambaugh, 1987, Expected stock returns and Volatility, *Journal of Financial Economics* 19, 3-29.

Granger, C.W.J., 1977, Discussion on relationships-and lack thereof-between economic time series, with special reference to money and interest rates, *JASA* 72, 24-25.

Hamao, Y., R.W. Masulis and V. Ng, 1990, Correlations in price changes and volatility across international markets, *Review of Financial Studies* 3, 281-307.

Hamao, Y., R.W. Masulis and V. Ng, 1991, The effect of the 1987 stock crash on international financial integration, in W. Ziemba, W Bailey and Y. Hamao eds., *Japanese Financial Market Research*, forthcoming, North Holland.

Haugh, L. D., 1976, Checking the independence of two covariance-stationary time series: A univariate residual cross-correlation approach, *JASA*, 71, 378-85.

Hilliard, J., 1979, The relationship between equity indices on world exchanges, *Journal of Finance* 34, 103-114.

Jeon, N.J. and G.M. Von Furstenberg, 1990, Growing international co-movement in stock price indexes, *Quarterly Review of Economic and Business* 30, 15-30.

Kato, K., 1990, Weekly patterns in Japanese stock returns, *Management Science* 36, 261-272.

King, M. A. and S. Wadhwani, 1990, Transmission of Volatility between stock markets, *Review of Financial Studies* 3, p. 5-33.

Koch, P.D. and T.W. Koch, 1990, Evolution in dynamic linkages across daily national stock indexes, Working paper, University of Kansas at Lawrence and University of South Carolina at Columbia.

Neumark, D., P.A. Tinsley and S. Tosini, 1991, After-hours stock prices and post-crash hangovers, *Journal of Finance* 46, 159-178.

Pierce, D.A. and L.D. Haugh, 1997, Causality in temporal systems, *Journal of Econometrics* 5, 265-293.

Roll, R., 1988, The international crash of October 1987, in R. Kamphuis, R. Kormendi and H. Watson eds., *Black Monday and the Future of Financial Markets*, Homewood, IL, Irwin.

Von Furstenberg, G.M. and B.N. Jeon, 1989, International stock price movements: Links and messages, *Brookings Papers on Economic Activity* 1, 125-179.

Weiss, A.A., 1986, Asymptotic theory for ARCH models: Estimation and Testing, *Econometric Theory* 2, 107-131.