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International Transmission of Stock Price Movements: Evidence from the U.S. and Five Asian-Pacific Markets

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ABSTRACT

Using a vector autoregressive analysis, this paper examines the structure of international transmissions in daily returns for six national stock markets—the U.S., Japan, Hong Kong, Singapore, Taiwan, and Thailand. Our results generally indicate that (1) the degree of interdependence among national stock markets has increased substantially after the 1987 stock market crash, (2) the U.S. market plays a dominant role of influencing the Pacific-Basin markets, (3) Japan and Singapore together have a significant persistent impact on the other Asian markets, and (4) the markets in Taiwan and Thailand are not efficient in processing international news.

Introduction

Portfolio theory suggests that investing in less correlated assets will result in greater diversification effects. Over the past decade, the search for diversification gains has been aggressively extended into investing internationally. In the mean time, the ongoing relaxation of foreign investment restrictions and foreign exchange controls in many countries has led to the speculation that world equity markets have become more integrated than ever, and that the diversification gain from investing internationally might have reduced significantly.

Considerable amount of work has been devoted into examining the integration of world stock markets. Earlier studies (e.g., Aqmon 1972, Ripley 1973, Lessard 1976, Panton, Lessig, and Joy 1976, Finnerty and Schneeweis 1979, and Hilliard 1979, among many others) generally find low correlations between national stock markets, supporting the benefits of international diversification. Recently, studies have a focus on investigating either the short-run dynamic structure of interactions (e.g., Schollhammer and Sand 1985 and Eun and Shim 1989), or the long-run comovements between markets (e.g., Arshanapalli and Doukas 1993 and Chung and Liu 1994). The results from these studies generally show that the interdependence among international stock markets increases substantially after the October 1987 crash.

Although the subject of international stock market integration has been studied extensively, the endeavor does not seem enough for two reasons. First, most earlier studies focus mainly on the extent of interdependence between national markets, and neglect the short-run dynamic interactions. Second, most prior studies have their main focus on well-developed equity markets in the U.S., Japan, and Europe, and pay much less attention to other stock markets.[1]

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The objective of this paper is to examine the short-run dynamic interactions among the U.S. and Asian-Pacific stock markets. For the past decade, many Asian-Pacific countries have been enjoying remarkably rapid economic growth. In particular, the equity markets in Asia are gaining increasing influence on world capital markets and attracting investors throughout the world. A study of dynamic interactions of world equity markets including Asian-Pacific markets would provide valuable information to the investment public as to what extent the world equity markets are integrated. We include five Asian stock markets—namely Japan, Hong Kong, Singapore, Taiwan, and Thailand—in this study. These five Asian markets represent different stages of development, capitalization size, and trading volume. The Japanese market is one of the well-established, large stock markets in the world. The markets in Singapore and Hong Kong are not as large as that of Japan, but play a significant role in international investing for having almost no investment barriers to foreigners. Finally, the Taiwanese and Thai markets are more stringent in terms of restrictions on foreign ownerships and capital flow controls.[2]

In this paper, we examine the dynamic structure of interactions among national stock markets in three aspects. First, we examine causality relationships among the six stock markets. Second, we test to what extent and how rapid of shocks induced by innovations in one market are borne by other markets. Third, we explore whether the structure of transmissions changes after the October 1987 crash, since the international transmission in stock returns may change after some turbulences in world equity markets (King and Wadhwani 1990).

The main testing method employed is a six-market vector-autoregressive (VAR) system. The VAR analysis permits us to disclose the degree of interdependence across markets as well as the relative importance of these markets in explaining unexpected variations of returns in other markets. Further, one can utilize the impulse responses estimated from the VAR system to infer how soon shocks in one market are transmitted to other markets.

The organization of the rest of the paper is as follows. Section II describes the data and the testing methodology. Section III presents the empirical results. The final section concludes the paper.

Data and Testing Methodology

Data

The data employed in this study are daily closing stock market indices for the U.S. (Dow Jones Industrial Average), Japan (Nikkei Average), Hong Kong (Hang Seng Index), Singapore (Straits Times Index), Taiwan (Taipei Weighted Index), and Thailand (the SET Index). The data were retrieved from the Pacific Basin Capital Markets Research Center (PACAP) of the University of Rhode Island, except for the Dow Jones Industrial Average, which is from CRSP tapes. Daily rates of return are calculated by taking the natural logarithms of the stock index relatives. The sample, which covers the period from January 2, 1985 through December 31, 1990, is divided into two subperiods—the pre-crash period (January 2, 1985 to October 16, 1987) and post-crash period (October 19, 1987 to December 31, 1990).

Since all the Pacific-Basin stock exchanges are closed when the U.S. market opens for the day, all the analyses are conducted with returns at time t for the Pacific-Basin markets versus returns at time t-1 for the U.S.[3] For missing data due to holidays in one market while other markets are open, previous day's closing price is used—a procedure that follows Cheung and Ng (1992). Japan and Taiwan have Saturday trading and hence we delete Saturday price data for these two countries. However, for Japan and Taiwan, return on Monday is computed as log(Monday closing index) - log(Saturday closing index), while it is computed as log(Monday closing index) - log(Friday closing index) for other countries.

Granger Causality Test

The Granger causality test is first employed to investigate the directions of Granger causality between the stock indices of the six markets. A time series Y_t causes another time series X_t in the Granger sense if series X_t can be predicted better by using past values of series Y_t than by using only the historical values of series X_t. To test whether series Y_t Granger causes series X_t, Granger (1969) proposes the following regression equation:

$$\Delta X_t = c_0 + \sum_{i=1}^{m} c_i \, \Delta Y_{t-i} + \sum_{j=1}^{m} d_j \, \Delta x_{t-j} + v_t \tag{1}$$

where Δ is the first difference operator, m is a particular autoregressive lag length, and v_t is a white noise. The test for causality (i.e., $C_i = 0$ for $i = 1, ..., m$) is based on an F test as follows:

$$F = \frac{(SSE_r - SSE_u) \; / \; m}{SSE_u / (T-2m-1)} \tag{2}$$

where SSE_r is the sum of squared residuals from a restricted regression equation (i.e., no lagged Y_t in equation (1)), SSE_u is the sum of squared residuals from equation (1), and T is the number of observations. If the F-statistic is greater than the critical value of a given significance level for an $F(m, T\text{-}2m\text{-}1)$ distribution, then we would reject the null hypothesis that Y_t does not Granger-cause X_t.

Vector Autoregressive Analysis

The analysis of the structure of interactions among the six stock markets is based on the vector-autoregressive analysis (VAR) developed by Sims (1980). The VAR analysis is applied onto an unrestricted reduced form equation system instead of a large-scale structural model that tends to be easily misspecified. In specific, the VAR model employed in this study encompasses the six daily return series and is expressed as:

$$R_t = C + \sum_{s=1}^{L} \beta_s R_{t-s} + e_t \tag{3}$$

where R_t is a 6 x 1 column vector of daily stock index returns, C and β_s are, respectively, 6 x 1 and 6 x 6 matrices of coefficients, L is the lag length, and e_t is a 6 x 1 column vector of serially uncorrelated error terms. The i, j-th component of β_s measures the direct effect on the i-th market of a change in the return to the j-th market in s periods. In particular, i-th component of e_t is the innovation of the i-th market which can not be predicted from past returns of other markets in the system. Namely, $e_t = R_t - E[R_t \mid R_s, s < t]$, where E denotes the expectation of R_t conditioning on $[R_s, s < t]$.

According to Sims (1980), a better way to provide insights on the dynamic interactions among the variables in a VAR system is to trace out the system's moving average representation. The VAR system of equation (3) can be expressed as the moving average model of innovations shown below:

$$R_t = \sum_{s=0}^{\infty} A_s e_{t-s} \tag{4}$$

Equation (4) indicates that R_t is a linear combination of current and past one-step ahead forecast errors (i.e., innovations, e_t). The i, j-th component of A_s reveals the response of the i-th market to a unit random shock in the j-th market in s periods.

Given the moving average model of innovations as equation (4), the k-step ahead forecast error of R_t at time $t - k + 1$ is given as

$$\sum_{s=0}^{k-1} A_s e_{t-s}.$$

The variance of the k-step ahead forecast errors can be decomposed into each innovation. Particularly, this variance decomposition of the forecast errors captures the percentage of unexpected variation in one stock market's return accounted for by shocks from other markets in the system.[4]

Although innovations, e_t, in equation (4) are serially uncorrelated, they may be contemporaneously correlated across equations. To correct this problem, equation (4) can be transformed further through an orthogonalization procedure into an equation as follows:

$$R_t = \sum_{s=0}^{\infty} A_s V u_{t-s} = \sum_{s=0}^{\infty} C_s u_{t-s} \tag{5}$$

where $C_s = A_s V$, V is a lower triangular matrix, u_t is the obtained orthogonalized innovation from $e_t = V_{u_t}$, and u_t is an identity covariance matrix.[5] The orthogonalization transformation results in serially and contemporaneously uncorrelated innovations and has two advantages in the analysis. First, we can incorporate the co-movement between stock index returns into the computation of the impulse responses. Second, it is easier to compute the variances of innovations if they are uncorrelated.

In summary, the VAR analysis provides insightful information on two important aspects of the structure of interactions among the national stock markets: (1) if innovations in a particular market explain a substantial amount of return variations in other markets and cannot be accounted for by innovations in other markets, then the market is relatively influential to other markets; and (2) if the impulse response of a market to a shock in another market tapers off quickly, then the transmission of information between these markets is relatively efficient.

Empirical Results

Granger Causality Among Markets

We first conduct the Granger causality test to investigate the interdependence among the six stock markets. A lag order of ten (i.e., $m = 10$) in equation (1) is used. It is expected that ten lags (i.e., two weeks) should be long enough to complete the transmission process, as similar results are obtained for higher-order lags used.

The Granger-causality test results are reported in Table 1. The results show that in the pre-crash period, there is virtually no significant causal relationship observed among these six markets, except that Japan leads the U.S.

TABLE 1

Granger Causality Tests

The Granger causality regression model:

For the U.S. —> Asia:

$$R_{ASIA,t+1} = a_0 + \sum_{i=1}^{m} a_i R_{ASIA,t-i} + \sum_{j=1}^{m} b_j R_{US,t-j} + u_t$$

For Asia —> the U.S.:

$$R_{US,t} = c_0 + \sum_{i=1}^{m} c_i R_{ASIA,t-i} + \sum_{j=1}^{m} d_j R_{US,t-j} + v_t$$

For Asia —> Asia:

$$R_{x,t} = h_0 + \sum_{i=1}^{m} h_i R_{x,t-i} + \sum_{j=1}^{m} k_j R_{y,t-j} + z_t$$

	Dependent Variable					
	US	JP	HK	SG	TW	TI
Pre-Crash: 850102-871016						
U.S. (US)	2.51*	1.19	0.74	1.56	0.34	0.34
Japan (JP)	1.97*	3.86*	0.54	1.27	0.45	0.33
Hong Kong (HK)	0.64	1.17	0.77	1.30	1.56	1.39
Singapore (SG)	0.71	0.23	1.58	2.04*	0.52	0.37
Taiwan (TW)	0.97	0.40	1.34	0.21	9.54*	0.57
Thailand (TI)	0.76	0.41	0.79	0.41	0.16	16.01*
Post-Crash: 871019-901231						
U.S. (US)	1.98*	1.09	0.70	1.14	2.25*	1.64
Japan (JP)	0.78	5.28*	1.66	1.27	0.97	1.87*
Hong Kong (HK)	2.51*	0.47	8.85*	2.08*	5.57*	1.80
Singapore (SG)	5.02*	1.58	1.24	2.59*	3.15*	4.23*
Taiwan (TW)	1.16	1.99*	4.65*	2.21*	0.98	0.95
Thailand (TI)	1.15	1.56	2.25*	2.00*	1.37	2.11*

Note: The numbers report the F-statistics for testing the null hypothesis that all ten lags of the left column do not Granger-cause the dependent variable. * Significant at the 5% level.

For the post-crash period, the results show a substantial increase in interactions among these markets, particularly among the non-Japanese Asian markets. However, it is interesting to note that neither the U.S. nor Japan significantly lead the non-Japanese Asian markets, except that the U.S. leads Taiwan and Japan leads Thailand. Further, there is no significant lead-lag relationship between the U.S. and Japan. Thus, the results seem to suggest that there is a regional co-movement factor within the Asian stock markets.

Furthermore, in the post-crash period, the causal relationships from Hong Kong and Singapore to the U.S. (coefficients 2.51 and 5.02, respectively) are much stronger than those from the U.S. to Hong Kong and Singapore (coefficients 0.70 and 1.14, respectively). Also, Hong Kong appears to lead Singapore, but not vice versa. Such a result is consistent with the finding of Malliaris and Urrutia (1992, p. 362) that indicates that 'Hong Kong played a leading role among the Asian markets by leading Tokyo and Singapore'. Nevertheless, the result that both Hong Kong and Singapore lead the U.S. is somewhat puzzling, given that a one-way direction of causality from emerging markets such as Hong Kong to developed markets such as the U.S. is generally not expected.

Correlations of Residual Returns

The analysis of pairwise correlations of the residual returns (i.e., innovations) from the VAR model provides further insights on the degree of interdependence among the six stock markets, and the results are presented in Table 2. The residual returns are the unexpected stock market returns which are not predicted based on information already impounded in past returns. Thus, the pairwise correlation coefficient of the residual returns represents the extent to which the effect of new information in one market is received by the other market.

TABLE 2

Correlation Matrix for the Residual Return Series

	US	JP	HK	SG	TW	TI
Pre-Crash: 850102-871016						
U.S. (US)	1.000					
Japan (JP)	0.216	1.000				
Hong Kong (HK)	0.115	-0.021	1.000			
Singapore (SG)	0.050	0.022	0.111	1.000		
Taiwan (TW)	0.021	0.030	0.000	0.014	1.000	
Thailand (TI)	-0.034	-0.017	-0.051	0.039	0.009	1.000
Post-Crash: 871019-901231						
U.S. (US)	1.000					
Japan (JP)	0.249	1.000				
Hong Kong (HK)	0.337	0.319	1.000			
Singapore (SG)	0.417	0.397	0.486	1.000		
Taiwan (TW)	0.068	0.161	0.055	0.107	1.000	
Thailand (TI)	0.317	0.307	0.282	0.384	0.090	1.000

Table 2 shows that the degree of interdependence between any pair of residual returns increases substantially after the 1987 stock market crash. For example, the U.S./Singapore exhibits correlation coefficients of 0.050 and 0.417 in the pre- and post-crash periods, respectively. Also, Singapore shows high correlations with other markets after the crash, while the relationships between Taiwan and other markets are very weak. The observed difference could be due to the fact that Singapore is more liberal in terms of the market openness and hence interacts at a larger degree with foreign markets, whereas Taiwan is on the other extreme.[6] It is also worth mentioning that the correlation coefficient estimates for Thailand have increased substantially after the crash, which could be due to its inauguration of the Alien Board in September 9, 1987, to facilitate foreigners' trading in the Thai market. Further, all the non-Japanese Asian markets, except Taiwan, exhibit relatively higher correlations with the U.S. than with Japan, especially for the post-crash period.

Decomposition of Forecast Error Variance

The orthogonalization procedure of the VAR system decomposes the forecast error variance, the component that measures the fraction of fluctuations in stock returns of a particular market explained by innovations in each of the six markets. Table 3 provides the variance decompositions of the 2-day, 5-day, and 10-day ahead forecast errors for each stock return series.

TABLE 3

Forecast Error Variance Decomposition for the Return Series

Market Explained	Horizon (in days)	US	JP	HK	SG	TW	TI	FM
Pre-Crash: 850102-871016								
U.S. (US)	2	98.36	1.08	0.05	0.10	0.19	0.23	1.64
	5	97.09	1.26	0.38	0.18	0.53	0.55	2.91
	10	93.65	2.64	0.79	0.79	1.17	0.94	6.35
Japan (JP)	2	4.85	94.61	0.08	0.11	0.31	0.05	5.39
	5	5.06	93.91	0.29	0.14	0.39	0.21	6.09
	10	5.63	91.68	1.49	0.27	0.48	0.44	8.32
Hong Kong (HK)	2	1.37	0.31	97.63	0.18	0.22	0.28	2.37
	5	2.37	0.76	95.40	0.43	0.51	0.53	4.60
	10	2.56	1.29	91.23	2.13	1.93	0.87	8.77
Singapore (SG)	2	1.27	0.08	1.11	97.49	0.00	0.04	2.51
	5	2.95	0.26	2.21	94.35	0.09	0.14	5.65
	10	3.43	1.33	2.89	91.47	0.44	0.44	8.53
Taiwan (TW)	2	0.04	0.10	0.08	0.03	99.64	0.11	0.36
	5	0.08	0.11	0.20	0.21	99.24	0.16	0.76
	10	0.72	0.37	1.62	0.68	96.42	0.19	3.58
Thailand (TI)	2	0.09	0.07	1.03	0.17	0.03	98.61	1.39
	5	0.11	0.38	2.11	0.23	0.09	97.09	2.91
	10	0.40	0.61	2.63	0.54	0.40	95.42	4.58
Post-Crash: 871019-901231								
U.S. (US)	2	94.25	0.55	0.72	4.29	0.16	0.03	5.75
	5	92.26	0.88	1.35	4.18	1.00	0.34	7.74
	10	88.20	1.70	2.27	5.53	1.29	1.01	11.80
Japan (JP)	2	6.27	92.68	0.07	0.96	0.00	0.01	7.32
	5	6.39	90.24	0.25	1.38	1.40	0.34	9.76
	10	6.84	87.77	0.68	1.61	2.12	0.98	12.23
Hong Kong (HK)	2	11.35	5.93	81.92	0.11	0.20	0.50	18.08
	5	10.89	6.39	78.81	0.59	2.75	0.57	21.19
	10	9.90	6.68	75.19	1.46	4.85	1.92	24.81
Singapore (SG)	2	17.41	8.76	10.81	62.94	0.00	0.09	37.06
	5	18.11	8.77	10.77	60.93	1.15	0.28	39.07
	10	17.69	8.97	11.09	58.30	2.92	1.01	41.70
Taiwan (TW)	2	0.55	2.39	0.06	2.47	94.52	0.00	5.48
	5	0.72	2.90	0.34	2.58	92.97	0.50	7.03
	10	2.01	3.12	1.13	4.01	88.78	0.95	11.22
Thailand (TI)	2	9.58	6.79	2.64	6.18	0.61	74.20	25.80
	5	9.65	7.42	2.83	6.78	1.05	72.26	27.74
	10	10.73	7.69	3.42	7.33	1.35	69.49	30.51

Note: The column headed by FM captures the percentage of the forecast error variance of each national stock market explained by the collective innovations from the other five markets.

The results in Table 3 indicate that prior to the crash, all the markets are pretty exogenous in the sense that a very high percentage of the error variance is accounted for by their own innovations. The percentage of the foreign explanatory power, as indicated by the FM column, is generally below 9 percent, with an average of 4.26 percent. In short, the results support the finding reported in previous sections that negligible interaction exists among the stock markets before the crash.

However, stronger interactions are documented in the post-crash period. Specifically, the percentage of the forecast error explained by the other five markets rises from an average of below 9 percent to about 19 percent. Across the markets, Singapore prevails to be the most interactive (i.e., least exogenous) market, with about 40 percent of the error variance explained by the other markets. Furthermore, Taiwan appears to be the least interactive market, and is somewhat affected more by regional countries such as Japan and Singapore than by the U.S., a result that is mostly consistent with evidence presented by Ko and Lee (1991).

Considering individual innovations and the post-crash period, the U.S. market accounts for the highest percentage of foreign-source variance for all the markets, except Taiwan. At the end of a 5-day horizon, the U.S. market innovations explain as high as 18 percent (for Singapore) of the forecast error variances of the Asian markets, while these Asian markets collectively explain only 7.74 percent of the fluctuations in the U.S. In other words, the results imply that the U.S. is the most influential market, though the degree of the influence differs across national markets.

Impulse Responses of Markets to Shocks

The estimated impulse responses of the VAR system offer an additional way of examining how each of the six markets responds to innovations from other markets. Although the tests are conducted for all six markets, only the results in response to shocks in the U.S., Japan, and Singapore are reported for two reasons. First, the impulse response coefficients for shocks originating in Hong Kong, Taiwan, and Thailand tend to be very small. Second, Singapore shows a strong impact on the non-Japanese Asian markets than the two industrialized countries—the U.S. and Japan.

TABLE 4

Impulse Response to Unit Shocks in the U.S. Market

	Impulse Response in					
ith Day after Shock	US	JP	HK	SG	TW	TI
Pre-Crash: 850102-871016						
1	-0.15	0.02	0.01	0.11	0.01	-0.05
2	0.00	0.02	0.04	0.13	0.01	0.03
3	0.01	0.03	-0.09	0.01	0.04	-0.05
4	-0.01	-0.02	-0.05	-0.03	0.02	0.02
5	-0.08	-0.05	-0.03	0.01	0.03	-0.09
6	0.06	0.04	-0.01	-0.01	-0.06	-0.09
7	0.06	0.04	0.02	-0.01	0.07	0.03
8	0.00	0.05	-0.04	-0.09	0.06	-0.03
9	0.05	0.05	-0.01	-0.05	-0.13	0.07
10	-0.03	-0.04	-0.01	-0.02	0.05	-0.11
Post-Crash: 871019-901231						
1	-0.13	-0.01	0.02	-0.01	-0.31	-0.15
2	-0.07	-0.03	0.04	0.08	0.00	0.07
3	0.02	-0.04	0.01	0.00	0.09	0.07
4	-0.02	0.00	0.04	0.07	-0.10	0.10
5	0.06	-0.10	0.03	-0.02	-0.14	0.15
6	-0.07	-0.03	0.06	-0.02	-0.23	-0.06
7	-0.04	-0.02	-0.08	-0.01	-0.10	-0.05
8	-0.04	-0.05	-0.01	-0.05	-0.26	-0.06
9	-0.04	-0.02	-0.05	-0.02	0.10	0.04
10	0.03	0.06	0.05	0.04	-0.20	-0.12

Note: The symbols of US, JP, HK, SG, TW, and TI represent the U.S., Japan, Hong Kong, Singapore, Taiwan, and Thailand, respectively.

The impulse responses of each market to shocks in the U.S., Japan, and Singapore are given in Tables 4, 5, and 6, respectively. As can be seen in Table 4, the responses of the Asian markets to a U.S. shock, in general, tapers off rapidly, except for Taiwan and Thailand during the post-crash period. After the crash, the impulse responses of Taiwan and Thailand to a U.S shock remain, respectively, as high as -0.20 and -0.12

at the end of 10 days. Therefore, it appears that a shock in the U.S. has a persistent impact on the Taiwanese and Thai markets.These two markets' slow process in responding to the U.S. shock might be due to their institutional rigidities.

TABLE 5

Impulse Response to Unit Shocks in the Japanese Market

ith Day after Shock	Impulse Response in US	JP	HK	SG	TW	TI
Pre-Crash: 850102-871016						
1	0.13	0.10	0.05	0.03	-0.03	-0.11
2	0.02	0.02	0.02	0.06	-0.00	0.15
3	-0.03	-0.08	-0.04	-0.02	-0.00	-0.00
4	0.03	-0.05	-0.09	0.01	-0.04	-0.15
5	-0.02	0.07	-0.06	-0.06	0.00	-0.01
6	-0.07	-0.11	0.01	-0.06	0.00	-0.03
7	-0.14	-0.06	-0.09	-0.05	0.04	0.14
8	0.00	-0.09	-0.02	0.00	0.15	-0.14
9	-0.03	0.01	0.00	0.12	-0.04	0.07
10	0.03	0.13	0.00	-0.03	-0.13	0.03
Post-Crash: 871019-901231						
1	-0.01	0.02	-0.02	-0.04	-0.02	0.05
2	0.01	-0.15	-0.06	-0.06	0.02	-0.10
3	-0.03	-0.02	-0.10	-0.06	-0.03	-0.15
4	0.03	0.01	0.04	0.05	0.18	0.11
5	0.04	-0.11	0.08	0.02	-0.13	-0.00
6	-0.00	-0.02	-0.05	-0.04	-0.10	-0.02
7	-0.04	0.02	-0.03	-0.00	-0.13	-0.02
8	0.03	0.05	0.05	0.05	-0.09	0.09
9	0.03	0.19	0.12	0.02	-0.06	0.06
10	0.05	0.07	-0.02	0.03	-0.02	0.07

Note: The symbols of US, JP, HK, SG, TW, and TI represent the U.S., Japan, Hong Kong, Singapore, Taiwan, and Thailand, respectively.

Similarly, the impulse responses contained in Table 5 reveal that the markets in Taiwan and Thailand take more time to respond to innovations in Japan. In addition, a shock in Japan has a significant impact on the Hong Kong market (particularly after the crash), given that the impulse response coefficient remains at 0.12 even at the end of a 9-day horizon.

The results in Table 6 indicate that a shock in Singapore has a persistent impact on the other non-Japanese Asian markets. For example, in response to a shock in Singapore after the crash, the impulse response coefficients for Hong Kong, Taiwan, and Thailand, respectively, are still as high as 0.10, 0.19, and 0.20 on day 9.

The large impulse responses of other Asian markets to shocks in Japan and Singapore seem to suggest that a regional comovement factor exists in the Asian stock markets. Furthermore, the markets in Taiwan and Thailand seem not efficient in processing international news, given that both markets have noticeable responses to shocks in the U.S., Japan, and Singapore even a week later.

Conclusions

This study uses a vector autoregressive analysis to examine the dynamic structure of international transmission in stock returns for six countries—the U.S., Japan, Hong Kong, Singapore, Taiwan, and Thailand. We conducted the tests using daily stock index data from January 2, 1985 through December 31, 1990. Our empirical evidence generally suggests the following: (1) the degree of interdependence among national stock markets has increased substantially after the 1987 stock market crash; (2) stronger correlations and feedback effects exist within the Asian-Pacific markets after the crash; (3) the U.S. market plays a dominant role of influencing the Pacific-Basin markets; (4) Japan and Singapore together have a

TABLE 6

Impulse Response to Unit Shocks in the Singapore Market

ith Day after Shock	Impulse Response in US	JP	HK	SG	TW	TI
Pre-Crash: 850102-871016						
1	0.03	0.02	-0.04	0.11	-0.02	0.04
2	0.02	-0.00	0.05	0.07	-0.00	-0.06
3	-0.02	-0.00	-0.01	-0.01	-0.04	0.02
4	0.01	0.01	0.01	0.03	0.08	-0.02
5	0.00	-0.01	-0.09	0.05	-0.01	0.04
6	0.01	0.01	-0.11	-0.07	0.07	0.11
7	-0.01	0.01	-0.01	-0.01	-0.01	-0.02
8	-0.06	0.02	-0.00	-0.05	-0.10	-0.06
9	-0.03	-0.01	-0.02	-0.03	0.07	0.09
10	0.00	-0.02	0.02	0.05	0.04	-0.04
Post-Crash: 871019-901231						
1	0.24	0.14	0.03	0.18	0.53	0.34
2	0.00	-0.03	0.04	0.05	-0.13	0.15
3	0.00	0.00	-0.09	-0.02	0.12	0.06
4	0.02	0.09	-0.03	-0.05	0.07	-0.04
5	-0.02	0.02	0.09	-0.00	-0.17	0.01
6	-0.07	-0.06	-0.09	-0.03	-0.19	-0.07
7	-0.11	-0.02	-0.09	-0.05	0.09	0.05
8	0.04	0.03	0.03	0.05	0.29	0.00
9	0.09	0.05	0.10	0.06	0.19	0.20
10	-0.02	-0.01	-0.04	-0.00	0.07	0.00

Note: The symbols of US, JP, HK, SG, TW, and TI represent the U.S., Japan, Hong Kong, Singapore, Taiwan, and Thailand, respectively.

significant persistent impact on the other Asian markets; and (5) the markets in Taiwan and Thailand are not efficient in processing international news. Overall, the results of this study adds to the current literature by presenting evidence that some decrease in the risk reduction benefits of international portfolio diversification have occurred due to increased integration in some of the world equity markets. However, there are markets that exhibit less linkages with other markets, such as Taiwan and Thailand, that might represent a better choice for risk reduction in international portfolio investing.

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NOTES

1. Several recent studies (e.g., Cheung and Mak 1992 and Park and Fatemi 1993) have included East Asian stock markets in the study. In particular, Park and Fatemi use a vector autoregression analysis to examine the dependence structure of equity markets of the U.S., U.K., Japan, and seven Asian-Pacific countries. Despite the use of a similar vector autoregression (VAR) analysis, our study differs from Park and Fatemi in one important aspect in that we not only investigate the dependence structure between developed markets and the individual Asian-Pacific market but also among Asian markets. That is, we include all the variables in the VAR system, while Park and Fatemi use a partial system that excludes the interactions among Asian stock markets.

2. For a detailed description of the development, capitalization size, and trading volume on Asian stock markets, see Rhee and Chang (1992).

3. Because of the time differential between the U.S. and western Pacific-Basin, a shock in the U.S. stock market during day t will not be reflected in the Asian-Pacific stock markets until day t+1. However, a change in the Asian-Pacific markets during day t will be reflected in the U.S. market the same day. Thus, the appropriate pairing is time t-1 for the U.S. and time t for the Pacific-Basin markets.

4. It should be noticed that the *k*-step ahead forecast error variance may be due to the estimation error of β_s in equation (3) in estimating R_t at time $t - k$ or to the effects of the innovations. This study only considers the latter.

5. For a detailed description of the orthogonalization process, see Eun and Shim (1989).

6. Taiwan maintained significant foreign exchange and stock ownership controls until January 1991. The Taiwanese market was opened to foreigners on January 1, 1991, though foreign investors must meet high requirements such as a limitation in total cash inflows and a 10% limit on aggregate foreign ownership.

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