Mean and Volatility Spillover Effects in the U.S. and Pacific–Basin Stock Markets*

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This paper investigates the mean return and volatility spillover effects from the U.S. and Japan to four Asian stock markets, including Hong Kong, Singapore, Taiwan, and Thailand. The empirical results from examining the data for the period of 1984 to 1991 suggest that the U.S. market is more influential than the Japanese market in transmitting returns and volatilities to the four Asian markets. In addition, the observed spillover effects are unstable over time in the sense that the spillovers increase substantially after the October 1987 stock market crash. Furthermore, the evidence indicates that while the cross–country stock investing hypothesis cannot by itself explain the international transmissions of return and volatility, the market contagion also plays an important role in the transmission mechanism.

I. Introduction

Interests in the integration of international financial markets have generated a considerable amount of work in this area. Studies such as Hilliard (1979), Errunza and Losq (1985), and Malliaris and Urrutia (1992) focus on the degree of interdependence and causality among national stock markets. While many studies find low correlations among national stock index returns, results from recent studies (e.g., Eun and Shim [1989] and Arshanapalli and Doukas [1993]) seem to indicate that the interdependence between international stock markets has increased, particularly after the October 1987 stock market crash.

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* We are grateful to three anonymous referees for their helpful comments. A version of this paper was presented at the 1994 Financial Management Association annual meeting. Helpful comments from conference participants are gratefully acknowledged.

(*Multinational Finance Journal*, 1997, vol. 1, no. 1, pp. 47–62)

DOI: 10.17578/1-1-3

Since the information transmission between markets might be related through not only mean returns but also volatility (e.g., Tauchen and Pitts [1983] and Ross [1989]), recent research efforts (e.g., Hamao, Masulis, and Ng [1990], King and Wadhwani [1990], Hamao, Masulis, and Ng [1991], Ng, Chang, and Chou [1991], Cheung and Ng [1992], Theodossiou and Lee [1993], and Susmel and Engle [1994]) have a focus on examining the volatility transmission in addition to the mean spillover effect. The findings from previous studies can be generally summarized as: (1) volatility of stock returns is time–varying; (2) significant mean and volatility spillovers are found from the U.S. market to other national stock markets; and (3) structures of information transmission seem to have changed since the 1987 stock market crash.

The purpose of this study is to explore stock return and volatility spillover effects from the U.S. and Japanese markets to four Asian emerging stock markets, including Hong Kong, Singapore, Taiwan, and Thailand. All the four emerging stock markets included in the study have the U.S. and Japan as one of their major trading partners. As a result, it is expected that there is a fairly high degrees of economic integration between the U.S., Japan, and these Asian markets.[1] In addition, since the five Pacific–Basin markets have different degree of market openness in terms of restrictions on foreign ownerships and capital flow controls (see Rhee and Chang [1993] for a detailed survey), a comparison between these Asian markets allows us to examine whether the openness of a financial market impacts spillover effects.

The paper is primarily motivated by several reasons. First, most studies that examine the mean and volatility spillover effects across international stock markets focus mainly on markets in the U.S., Japan, and Europe, with little attention paid to emerging markets.[2] The four emerging Asian markets included in the study have enjoyed remarkably rapid economic growth in the past decade and are gaining increasing influence in the world capital markets. Thus, the linkages of these emerging markets with other markets deserve closer attention. Second, since a number of studies (e.g., Brady [1988], Hamao, Masulis, and Ng [1991], Cheung and Ng [1992], and Arshanapalli and Doukas [1993]) have documented that international stock market interactions change

1. For example, Chinn and Frankel (1995) document that both the U.S. and Japan have an influence on real interest rates around the Pacific Rim. Bailey (1990) examines the effect of U.S. money supply surprises on Pacific Rim stock markets. His result shows that the stock indexes of countries with relatively few barriers to investment flows exhibit stronger reactions to U.S. money shocks than those countries with significant capital flow controls.

2. Ng, Chang, and Chou (1991) and Wei et al. (1995) have included several Pacific–Basin markets in their studies. However, Ng, Chang, and Chou use daily data from January 1985 to December 1987 and Wei et al. employ about one year's intra-daily data over the period August 1991 to December 1992. Our study covers a longer sample period from January 1984 to December 1991, than both studies.

after the October 1987 crash, the inclusion of a longer sample period permits us to investigate the impact of some turbulence in world equity markets on the degree of interactions. Specifically, we intend to examine one possible reason for the change in the international transmission of stock returns and volatility, i.e., market contagion. Such a market contagion effect (see King and Wadhwani [1990]) suggests that stock prices in one country may be affected by the changes in another country beyond what is conceivable by connections through economic fundamentals. In other words, price movements driven by speculative and noise trading may move across borders. Third, as the five Asian markets have a wide range of market openness and currency controls, a comparison between these markets would allow us to gauge the impact of currency controls and the openness of a market on the spillover effects. Particularly, Japan, Hong Kong, and Singapore have no currency control and nearly no restrictions on foreign ownerships, while Taiwan and Thailand have significant foreign exchange and stock ownership controls. It would be reasonable to imagine that a market with fewer restrictions would show greater influence from foreign markets. That is, we expect to observe a stronger spillover effect for Japan, Hong Kong, and Singapore than that for Taiwan and Thailand. Furthermore, the actions taken by both Taiwan and Thailand to open their market during our testing sample period permit us to further investigate whether the openness of a market facilitates the transmission of return and volatility among national stock markets.[3]

The remainder of the paper is organized as follows. Section II describes the empirical methods and the data. Section III reports the test results on mean and volatility spillover effects. Section IV concludes the paper.

II. Empirical Methods and Data

A. Empirical Methods

It is well-documented that the distribution of stock returns is characterized with higher peakedness and fat tails relative to a normal distribution. A number of distributions have been proposed and used to model stock returns. Among them, GARCH models proposed by Engle (1982) and Bollerslev (1986) are appealing because they can capture the fat–tailed nature of the distribution and

3. 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. In Thailand, the Securities Exchange of Thailand inaugurated its Alien Board in September 9, 1987, to facilitate foreigners' trading in the Thai market. See Bailey and Jagtiani (1994) and Harvey (1994), respectively, for a summary of restrictions on foreign equity investments in the Thai and Taiwanese markets.

presence of time–varying volatility. Empirical evidence has shown that GARCH models are useful in modeling the dynamic behavior of security returns, e.g., Bollerslev, Chou and Kroner (1992) for a survey.

TABLE 1. Exchange Trading Hours

Country	Trading hours (Eastern Standard Time)
US	9:30 a.m.–4:00 p.m.
Japan	7:00 p.m.–1:00 a.m.
Hong Kong	9:00 p.m.–2:30 a.m.
Singapore	8:00 p.m.–2:00 a.m.
Taiwan	8:00 p.m.–11:00 p.m.
Thailand	10:00 p.m.–4:30 a.m.

In this study, we employ a two–stage GARCH approach to examine the international transmission of stock return and volatility. In particular, in the first stage, we model each stock index return series through an ARMA(1)–GARCH(1,1)–in–mean model (or its variants) as follows:

$$r_{i,j} = \varphi_{i,0} + \varphi_{i,1} r_{i,t-1} + \varphi_{i,2} v_{i,t} + \varphi_{i,3}\varepsilon_{i,t-1} + \sum_{j=1}^{4} d_{i,j} DM_{i,j,t} + \varepsilon_{i,t} \quad (1)$$

$$v_{i,t} = \alpha_{i,0} + \alpha_{i,1} v_{i,t-1} + \alpha_{i,2}\varepsilon_{i,t-1}^{2} \quad (2)$$

where $r_{i,t}$ is the daily return of stock index i at day t, $DM_{i,j,t}$ are dummy variables for Monday through Thursday for capturing the day–of–the–week effect in daily returns, and ε_t is the residual (or unexpected return) which is normally distributed with mean zero and time–varying variance $v_{i,t}$. Each stock index return series is modeled as an ARMA(1,1) (or a MA(1)) model in the mean equation to adjust for possible serial correlation in the data.

In the second stage, mean return and volatility spillover effects across markets are estimated by obtaining the standardized residual and its square in the fist stage and substituting them into the mean and volatility equations of other markets as follows:

$$\begin{aligned} r_{i,t} = {} & \varphi_{i,0} + \varphi_{i,1} r_{i,t-1} + \varphi_{i,2} v_{i,t} + \varphi_{i,3}\varepsilon_{i,t-1} + \sum_{j=1}^{4} d_{i,j} DM_{i,j,t} \\ & + \lambda_{i,1} e_{t-1,US} + \lambda_{i,2} e_{t,JP} + \varepsilon_{i,t} \end{aligned} \quad (3)$$

$$v_{i,t} = \alpha_{i,0} + \alpha_{i,1} v_{i,t-1} + \alpha_{i,2}\varepsilon_{i,t-1}^{2} + \gamma_{i,1} e_{t-1,US}^{2} + \gamma_{i,1} e_{t-1,JP}^{2} \quad (4)$$

where $e_{t-1,US}$ and $e_{t,JP}$ are the standardized residual series for the U.S. and

Japanese markets, respectively, and are for capturing the mean return spillover effect from these two markets.[4] In order to examine the volatility spillover, the exogenous variables $e^2_{t-1,US}$ and $e^2_{t,JP}$, the square of the standardized residual series, are included in the conditional volatility equation.

As Lin, Engle, and Ito (1994) point out, since $e_{t-1,US}$, $e_{t,JP}$, $e^2_{t-1,US}$, and $e^2_{t,JP}$ are proxies for unobservable innovations, the estimated covariance matrix might not be consistent, though the coefficient estimates remain consistent. In this study, the standard errors are constructed following Newey and West (1987) so that they are robust to serial correlation and heteroskedasticity.

B. Data

Data employed in this study are daily closing stock market indices for the U.S. (the Standard & Poor's 500 Index), Japan (the Tokyo Stock Price Index), Hong Kong (the Hang Seng Index), Singapore (the S.E.T. All Price Index), Taiwan (the Taiwan Market 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 S&P 500 index, which is from CRSP tapes. The sample period is from January 3, 1984, to December 30, 1991. In order to check if there is a structural change in the return and volatility spillover effects due to market contagion, we divide the full sample period into two sub-periods with the October 1987 crash as the cutoff point. The pre–crash period covers from January 3, 1984, through October 15, 1987, and the post–crash period is from November 2, 1987 to December 30, 1991.[5]

Daily stock return is computed as the natural logarithm of the price index relative. For missing data due to holidays in one market while other markets are open, the previous day's closing price is used. Japan and Taiwan have Saturday trading and hence we delete Saturday price data for these two countries. However, return on Monday for Japan and Taiwan is computed as ln(Monday closing price) – ln(Saturday closing price), and it is computed as ln(Monday closing price) – ln(Friday closing price) for other countries.

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4. 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 Pacific–Basin stock markets until day t+1. However, a change in the Pacific–Basin 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. Furthermore, as table 1 shows, the Japanese market closes earlier than the other Asian stock markets, except Taiwan. Therefore, the appropriate pairing is time t–1 for Japan and time t for Taiwan, and it is time t for Japan and time t for Hong Kong, Singapore, and Thailand.

5. The data for the two weeks (10/16/87–10/31/87) surrounding the October 1987 crash are excluded for two reasons: first, the exceptionally strong interdependence among international stock markets during this two–week period (see, for example, Malliaris and Urrutia (1992)), and second, the missing data problem due to the market close in several exchange markets right after the crash (e.g., the Hong Kong stock market was closed from 10/20/87 to 10/25/87).

III. Empirical Results

A. Preliminary Analysis of the Data

Some summary statistics for the six stock index return series are given in table 2. The results show that all the mean daily returns decline after the 1987 crash, except for Singapore. In addition, all the stock markets become more volatile after the crash as evidenced from higher standard deviations.

TABLE 2. Summary Statistics on Daily Stock Index Returns: Period 1984–1991

	U.S.	Japan	Hong Kong	Singapore	Taiwan	Thailand
A. Period 1984–1987						
Mean(%)	.0607	.0774	.1505	.0347	.1323	.1274
Std. Dev.(%)	.8428	.8211	1.3968	1.0392	1.2248	.6663
Skewness	–.2188	–.2066	–.2947	–.1968	.1793	.3081
Kurtosis	2.2381	3.9414	3.3380	4.9938	3.9085	5.8339
LB(12)	13.99	64.22*	18.34	78.44*	94.15*	210.05*
LB(24)	25.86	75.13*	27.74	85.68*	129.61*	246.44*
Squared Daily Returns						
LB(12)	28.41*	161.19*	182.21*	133.90*	1159.30*	343.37*
LB(24)	45.57*	234.35*	233.41*	154.46*	1891.40*	602.41*
B. Period 1988–1991						
Mean(%)	.0462	–.0100	.0597	.0538	–.0006	.0798
Std. Dev.(%)	1.0111	1.1268	1.5656	1.1833	2.5769	1.7558
Skewness	–.6382	.1792	–4.0845	–.9918	–.2934	–.4209
Kurtosis	5.2330	9.0764	62.7853	10.8777	.4320	5.7175
LB(12)	18.89	68.25*	67.16*	44.20*	26.48*	40.32*
LB(24)	25.31	88.38*	80.31*	55.31*	41.27*	52.89*
Squared Daily Returns						
LB(12)	44.48*	225.31*	82.98*	106.85*	1011.90*	481.83*
LB(24)	83.35*	284.17*	83.88*	121.23*	1691.54*	730.70*

Note: Kurtosis is excess kurtosis. LB(k) is the Ljung–Box Q statistic for k order serial correlation, which distributes as a chi–square variate with k degree of freedom. *Statistically significant at the 5% level.

The high excess kurtosis in these markets suggests that their daily return series have a fat–tailed distribution. The Ljung–Box (LB) Q statistics for the raw returns are highly significant at the five-percent level for all the markets, indicating the presence of serial correlations. Furthermore, the Ljung–Box Q statistics for the squared returns are much larger than those of the raw returns, suggesting the presence of time–varying volatility. Thus, the preliminary analysis of the data suggests the use of a GARCH model in capturing the fat–tails and time–varying volatility found in these stock return series.

TABLE 3a. An ARMA(1,1)–GARCH(1,1)–in–Mean Model Estimation on Daily Stock Index Return for the Period 1984–1987

	U.S.	Japan	Hong Kong	Singapore	Taiwan	Thailand
φ_0	.3242	.1161	.2144	–.0289	–.0302	.0370
	(.89)	(.76)	(.47)	(–.14)	(–.14)	(.35)
φ_1				.3724	.9145*	.3790
				(.52)	(6.80)	(.59)
φ_2	–.3450	.0622	.0157	.0558	–.0003	.1536
	(–.71)	(.35)	(.09)	(.35)	(–.01)	(1.04)
φ_3	.0908	.2422*	.0918	–.1285	–.8609*	–.1866
	(.92)	(2.04)	(.77)	(–.16)	(–5.42)	(–.33)
d_1	–.1235	–.0545	–.0746	–.0803	–.0168	–.1628
	(–.66)	(–.38)	(–.19)	(–.26)	(–.05)	(–1.16)
d_2	.0068	–.1949	–.1742	–.0243	.0840	–.0602
	(.04)	(–.95)	(–.38)	(–.11)	(.30)	(–.53)
d_3	–.0544	.0668	.0263	.0761	.1030	–.0603
	(–.32)	(.45)	(.06)	(.32)	(.41)	(–.51)
d_4	.0769	–.0581	–.0024	.0927	.0244	–.0616
	(.23)	(–.35)	(–.01)	(.19)	(.06)	(–.39)
α_0	.0667	.0338	.1823	.0721	.0485	.0159
	(1.11)	(1.29)	(1.13)	(.66)	(1.57)	(1.58)
α_1	.8619*	.7185*	.7784*	.8034*	.8411*	.7054*
	(7.07)	(5.88)	(5.43)	(4.15)	(11.25)	(6.23)
α_2	.0451	.2572*	.1293	.1331	.1212	.2958
	(.70)	(2.02)	(1.17)	(1.66)	(1.63)	(1.63)
Skewness	–.1317	–.2159	–.2074	–.3286	–.2153	–.1868
Kurtosis	1.9705	1.8564	1.8735	4.2508	.8013	3.7092
LB(12)	4.97	14.28	12.28	18.22	18.25	23.88
LB(24)	16.49	18.43	20.38	30.70	25.14	35.57
Squared Standardized Residuals						
LB(12)	9.92	16.07	19.47	8.55	11.50	9.11
LB(24)	20.57	34.52	30.65	14.87	17.13	17.15

Note: Parentheses include the robust *t*–statistics. LB(*k*) is the Ljung–Box *Q* statistic for *k* order serial correlation, which distributes as a chi–square variate with *k* degree of freedom. *Statistically significant at the 5% level. The empirical model is: $r_t = \varphi_0 + \varphi_1 r_{t-1} + \varphi_2 v_t + \varphi_3 \varepsilon_{t-1} + \Sigma d_i DM_{t,i} + \varepsilon_t$, $v_t = \alpha_0 + \alpha_1 v_{t-1} + \alpha_2 \varepsilon^2_{t-1}$, where $DM_{t,i}$ (for i = 1 to 4) are the dummy variables for Monday through Thursday.

TABLE 3b. An ARMA(1,1)–GARCH(1,1)–in–Mean Model Estimation on Daily Stock Index Return for the Period 1988–1991

	U.S.	Japan	Hong Kong	Singapore	Taiwan	Thailand
φ_0	–.1974	–.0037	.1286	.2440	.5463	.2023
	(–.34)	(–.02)	(.28)	(.61)	(1.15)	(.30)
φ_1						.6449
						(1.07)
φ_2	.2642	.0841	.0823	.0222	–.0655	.0013
	(.48)	(.46)	(.62)	(.14)	(–1.09)	(.03)
φ_3	.0251	.1839	.1945	.2739	.1018	–.4912
	(.15)	(1.20)	(.61)	(1.00)	(1.25)	(–.71)
d_1	–.0363	–.0575	–.3533	–.3241	.0117	–.4062
	(–.09)	(–.21)	(–.50)	(–1.12)	(.02)	(–.40)
d_2	.0163	.0242	–.0059	–.3035	.0079	–.0558
	(.03)	(.10)	(–.01)	(–.57)	(.01)	(–.07)
d_3	.0298	.0627	–.0146	–.0641	–.1881	.0332
	(.04)	(.19)	(–.02)	(–.13)	(–.37)	(.06)
d_4	–.0992	.0011	–.0223	–.2145	–.0752	–.3231
	(–.16)	(.01)	(–.06)	(–.31)	(–.17)	(–.30)
α_0	.2128	.0554	.1745	.2724	.3205	.2160
	(1.09)	(1.19)	(.98)	(1.35)	(1.24)	(1.22)
α_1	.7065*	.7385*	.6771*	.4248*	.8025*	.6712*
	(3.45)	(6.62)	(3.27)	(1.78)	(7.83)	(4.44)
α_2	.0869	.2293	.2746	.4616	.1450	.2780
	(.58)	(1.48)	(.88)	(1.43)	(1.46)	(1.21)
Skewness	–.8117	–.1906	–1.3952	–1.2825	–.2070	–.2809
Kurtosis	5.4120	2.5500	11.0591	15.1528	.2045	5.1829
LB(12)	11.47	16.02	18.84	12.87	15.75	14.86
LB(24)	17.43	28.44	26.38	15.78	22.04	27.31
Squared Standardized Residuals						
LB(12)	6.65	8.99	5.08	.98	16.23	3.90
LB(24)	12.65	18.06	6.80	2.02	34.85	17.35

Note: Parentheses include the robust *t*–statistics. LB(*k*) is the Ljung–Box *Q* statistic for *k* order serial correlation, which distributes as a chi–square variate with *k* degree of freedom. *Statistically significant at the 5% level. The empirical model is: $r_t = \varphi_0 + \varphi_1 r_{t-1} + \varphi_2 v_t + \varphi_3 \varepsilon_{t-1} + \Sigma\ d_i DM_{t,i} + \varepsilon_t$, $v_t = \alpha_0 + \alpha_1 v_{t-1} + \alpha_2 \varepsilon^2_{t-1}$, where $DM_{t,i}$ (for i = 1 to 4) are the dummy variables for Monday through Thursday.

The estimation results of modeling each stock index return series as an ARMA(1,1)–GARCH(1,1)–in–mean process (or its variants) are provided in tables 3a and 3b, respectively, for the pre– and post–crash periods. The parameter estimates are obtained by maximizing the log–likelihood function of the model using the Berndt et al. (1974) algorithm.[6] Diagnostic tests for the

6. The program is written in RATS code and uses the MAXIMIZE instruction to maximize the log–likelihood function.

appropriateness of the model are based on the Ljung–Box *Q* statistics for checking serial correlation in both normalized raw and squared residuals. The results show that a MA(1)–GARCH(1,1)–in–mean model, specified as in Equations 1 and 2, fits the data generally well, except for the pre–crash return series for Singapore, Taiwan, and Thailand, and the post–crash return series for Thailand. For these four return series, an additional AR term in the mean equation is needed to yield insignificant serial correlation in the residuals. In short, none of the Ljung–Box *Q* statistics in tables 3a and 3b are significant at the five-percent level, suggesting that the ARMA(1,1)–GARCH(1,1)–in– mean model has taken care of most of the fat–tails and time–varying volatility in the data.[7]

B. Mean and Volatility Spillover Effects

The mean return and volatility spillover effects are then examined from the U.S. and Japan to the other four stock markets of interest. Table 4 contains the estimates of the spillover effects for the pre–crash period. The results indicate that the conditional mean returns of all Asian stock markets, except Taiwan, are influenced by the U.S.; suggested by the significant *t* statistics of λ_1. The results also show that the mean spillover effect from the U.S. market is positive for Japan, Hong Kong, and Singapore, while it is negative for Thailand. However, there are no significant mean spillover effects present from Japan to other Asian markets. Thus, the results seem to suggest that the influence is substantially greater from the U.S. to the Asian markets than that from the Japanese market. Nevertheless, we find that the impact of the U.S. return on the Asian markets, except Japan, becomes insignificant when the robust standard error is used.

For the volatility spillover effects, most of the γ coefficients are not significant at the five-percent level except for the cases of the U.S. to Hong Kong and Japan to Taiwan. However, there is no evidence of the volatility spillover effect from either the U.S. or Japan to the Asian markets when the robust standard errors are used.

It is interesting to note that there are no significant mean and volatility spillover effects from Japan to other Asian markets despite the existence of a geographical proximity. Nevertheless, the Japanese market's significant influence on Taiwan's conditional volatility might be partly due to the strong trade and geographical relations which exist between Japan and Taiwan.

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7. Since the Ljung–Box *Q*(12) statistic is significant for the pre–crash Thai return series, we have included additional AR terms in the mean equation in order to whiten the residual. The results for higher order ARMA models, however, do not improve; therefore, the ARMA(1,1) model is used in the following analyzes.

TABLE 4. Mean and Volatility Spillovers Estimated from an ARMA(1,1)–GARCH(1,1)–in–Mean Model on Daily Stock Index Return for the Period 1984–1987

	Japan	Hong Kong	Singapore	Taiwan	Thailand
φ_0	.1414	.2128	–.0416	–.0420	.0386
	(1.03)	(.76)	(–.21)	(–.29)	(.40)
φ_1			.4024	.9401*	.2527
			(.99)	(10.67)	(.41)
φ_2	.0533	.0044	.0656	.0005	.1739
	(.26)	(.03)	(.40)	(.04)	(1.14)
φ_3	.2309	.0830	–.1721	–.8920*	–.0621
	(1.79)	(.81)	(–.36)	(–7.66)	(–.12)
d_1	–.0777	–.0591	–.0673	.0219	–.1575
	(–.50)	(–.18)	(–.31)	(.07)	(–1.33)
d_2	–.2259	–.1341	–.0180	.0980	–.0732
	(–1.39)	(–.43)	(–.08)	(.43)	(–.67)
d_3	.0317	.0567	.0812	.1400	–.0656
	(.23)	(.15)	(.32)	(.61)	(–.70)
d_4	–.0723	.0176	.0662	–.0200	–.0537
	(–.43)	(.06)	(.18)	(–.07)	(–.38)
λ_1	.1382*	.1593	.0942	–.0056	–.0264
	(2.70)	(1.18)	(.91)	(–.22)	(–.83)
λ_2		–.0052	.0049	.0159	–.0002
		(–.05)	(.05)	(.58)	(–.01)
α_0	.0157	.0728	.0292	.0006	.0164
	(.50)	(.48)	(.36)	(.02)	(1.18)
α_1	.6976*	.8276*	.8516*	.8537*	.7065*
	(5.90)	(8.34)	(4.86)	(11.45)	(5.99)
α_2	.2674*	.1233	.1055	.1094	.2986
	(2.14)	(1.45)	(1.29)	(1.82)	(1.61)
γ_1	.0237	.0412	.0190	.0179	.0005
	(.76)	(.74)	(.46)	(.97)	(.09)
γ_2		–.0097	.0011	.0298	–.0021
		(–.17)	(.02)	(.81)	(–.26)
Skewness	–.2415	–.3293	–.2895	–.2241	–.1559
Kurtosis	2.1682	1.4532	3.9194	.5674	3.5149
LB(12)	15.88	12.32	16.12	17.13	29.77
LB(24)	21.25	21.07	26.04	21.74	42.02
Squared Standardized Residuals					
LB(12)	15.68	20.68	12.41	12.27	9.51
LB(24)	32.23	31.68	19.31	20.69	18.50

Note: Parentheses include the robust *t*–statistics. LB(k) is the Ljung–Box Q statistic for k order serial correlation, which distributes as a chi–square variate with k degree of freedom. *Statistically significant at the 5% level. The empirical model is: $r_t = \varphi_0 + \varphi_1 r_{t-1} + \varphi_2 v_t + \varphi_3 \varepsilon_{t-1} + \Sigma\ d_i DM_{t,i} + \lambda_1 e_{t-1,US} + \lambda_2 e_{t,JP} + \varepsilon_t$, $v_t = \alpha_0 + \alpha_1 v_{t-1} + \alpha_2 \varepsilon^2_{t-1} + \gamma_1 e^2_{t-1,US} + \gamma_2 e^2_{t,JP}$

TABLE 5. Mean and Volatility Spillovers Estimated from an ARMA(1,1)–GARCH(1,1)–in–Mean Model on Daily Stock Index Return for the Period 1988–1991

	Japan	Hong Kong	Singapore	Taiwan	Thailand
φ_0	.0059	.0750	.1630	.4221	.1705
	(.03)	(.30)	(1.50)	(.87)	(.52)
φ_1					.4248
					(1.95)
φ_2	.0687	.0844	–.0470	–.0459	.0108
	(.43)	(.97)	(–.29)	(–.73)	(.21)
φ_3	.1537	.1094	.1774*	.1001	–.2708
	(1.43)	(.74)	(2.15)	(1.27)	(–1.11)
d_1	–.0518	–.2172	–.1428	.0290	–.2430
	(–.24)	(–.82)	(–.78)	(.06)	(–.42)
d_2	.0452	.0225	–.1454	–.0696	–.1108
	(.24)	(.08)	(–1.03)	(–.13)	(–.27)
d_3	.0784	.0905	.0696	–.1779	.0926
	(.29)	(.27)	(.42)	(–.39)	(.37)
d_4	–.0064	.0150	.0104	–.0365	–.1445
	(–.06)	(.06)	(.06)	(–.09)	(–.27)
λ_1	.1970*	.2576*	.2739*	.2105	.2499*
	(2.29)	(3.46)	(2.86)	(1.32)	(2.46)
λ_2		.2872*	.1729*	.0860	.1114
		(3.35)	(2.41)	(.59)	(.70)
α_0	.0164	.0127	.0023	.1213	–.0035
	(.48)	(.18)	(.03)	(.44)	(–.04)
α_1	.7830*	.6998*	.6212*	.8552*	.7324*
	(9.19)	(5.11)	(4.22)	(9.14)	(4.93)
α_2	.2031	.2295	.1359	.1176	.2122
	(1.48)	(1.22)	(1.51)	(1.35)	(1.44)
γ_1	.0193	.0459	.1217	–.0171	.0539
	(.46)	(.59)	(1.32)	(–.14)	(.51)
γ_2		.0691	.0873	.0664	.1100
		(.86)	(1.24)	(.45)	(.76)
Skewness	–.0101	–.4583	.1265	–.2907	–.1811
Kurtosis	2.0891	4.3663	1.6723	.1368	2.2650
LB(12)	12.71	30.08	14.79	21.40	13.79
LB(24)	23.79	38.46	24.19	27.65	27.44
Squared Standardized Residuals					
LB(12)	8.93	76.37	11.17	15.81	15.32
LB(24)	19.21	83.68	23.23	34.20	24.20

Note: Parentheses include the robust *t*–statistics. LB(*k*) is the Ljung–Box *Q* statistic for *k* order serial correlation, which distributes as a chi–square variate with *k* degree of freedom. *Statistically significant at the 5%. The empirical model is: $r_t = \varphi_0 + \varphi_1 r_{t-1} + \varphi_2 v_t + \varphi_3 \varepsilon_{t-1} + \Sigma d_i DM_{t,i} + \lambda_1 e_{t-1,US} + \lambda_2 e_{t,JP} + \varepsilon_t$, $v_t = \alpha_0 + \alpha_1 v_{t-1} + \alpha_2 \varepsilon^2_{t-1} + \gamma_1 e^2_{t-1,US} + \gamma_2 e^2_{t,JP}$

In addition, while significant spillover effects are observed from the U.S. to the Asian markets, the absence of spillover effects from Japan to other Asian markets seems to suggest that the degree of the openness of a market is not significantly related to finding the spillover effects. Furthermore, such a possible irrelevance of the openness of a market is also evidenced from the existence of the volatility spillover effect from Japan to Taiwan but not from the U.S. to Taiwan—the country with the most severe restriction on cross–country equity investing among these capital markets.

In table 5, we investigate the mean and volatility spillover effects from the U.S. and Japan to the Asian markets after the crash. The empirical results show that when the usual standard errors are used, then the λ_1 coefficients for measuring the mean spillover effect from the U.S. are all statistically significant. These coefficients, except for Taiwan, remain significant even if the robust standard errors are used. The results also reveal a significant influence on conditional mean return from Japan to Hong Kong, Singapore, and Thailand, though the impact on the Thai market becomes insignificant when the robust standard error is used.

Table 5 also shows that the estimated coefficients for the volatility spillover effects from the U.S. and Japan onto the Asian markets, γ_1 and γ_2 respectively, are generally significant when the usual standard errors are used, whereas they are insignificant when the robust standard errors are used. The evidence of volatility spillover effects based on the usual standard errors seems to contrast with the finding of Hamao, Masulis, and Ng (1991). The disagreement is likely due to differences in data as well as the time period covered.

It is noteworthy that the mean return and volatility spillovers from the U.S. and Japan to the Asian markets appear to have increased significantly after the crash.[8] For instance, in terms of the magnitude of the coefficient in mean spillovers, the U.S.'s influence on Japan, Hong Kong, Singapore, and Thailand has increased, respectively, from .1382, .1563, .0942, and .0264 (in absolute value term) before the crash to .1970, .2576, .2739, and .2499 after the crash. Moreover, all of these coefficient estimates calculated from the post–crash data are highly significant even when the robust standard errors are used. Similar stronger volatility spillovers from the U.S. and Japan to the four Asian markets after the crash are also observed, though the coefficient estimates are in general significant only when the usual standard errors are used. The stronger mean return and volatility spillover effects after the crash seem to suggest that the market contagion has a significant impact on the international transmission in stock returns and volatility.

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8. Koutmos and Booth (1995) also document similar greater mean and volatility spillovers after the crash across the New York, Tokyo, and London stock markets.

C. Market Openness and Spillover Effects

Although the result suggests that the market contagion effect plays a significant role in the international transmission of stock return, it does not preclude the possibility that the openness of a market may also contribute to the documented stronger spillover effects after the crash. To investigate the possible impact of restrictions on foreign equity investments on spillover effects, we focus on the Taiwanese and Thai markets—the two countries that took the action of opening their equity market to foreigners during our sample period.

For Thailand, the inauguration of its Alien Board in September 9, 1987, roughly corresponds with the cutoff point for our two sub-periods. As mentioned before, the mean and volatility spillover effects from the U.S. and Japan to the Thai market have become stronger in the second sub-period not only in terms of the magnitude of the coefficient but also in terms of the statistical significance of the coefficient. For instance, the influences of the U.S. on the Thai market in conditional mean return and volatility have increased from –.0264 and .0005 for the first sub-period to .2499 and .0539 for the second sub-period. Nevertheless, since the date of the policy change for the Thai market is close to the October 1987 international stock market crash, it is rather difficult to tell whether the stronger spillovers in the second sub-period are mainly due to the market contagion or to less restriction on foreign equity investments.

To estimate the impact on spillover effects when the Taiwanese market was opened to foreigners on January 1, 1991, we modify equations 3 and 4 as follows:

$$r_t = \varphi_0 + \varphi_2 v_t + \varphi_3 \varepsilon_{t-1} + \sum_{j=1}^{4} d_j DM_{j,t} + \lambda_1 e_{t-1,US} + \lambda_2 e_{t-1,JP} + \theta_1 D_t e_{t-1,US} + \theta_2 D_t e_{t-1,JP} + \varepsilon_t \tag{5}$$

$$v_t = \alpha_0 + \alpha_1 v_{t-1} + \alpha_2 \varepsilon_{t-1}^2 + \gamma_1 e_{t-1,US}^2 + \gamma_2 e_{t-1,JP}^2 + \psi_1 D_t e_{t-1,US}^2 + \psi_2 D_t e_{t-1,JP}^2 \tag{6}$$

where D_t is a dummy variable for capturing the effective period of policy change, and is set to equal 1 if t is after January 1, 1991, and 0 otherwise. Accordingly, the parameters θ and ψ measure the net effect of the policy change on the mean return and volatility spillover effects, respectively. If the openness of the Taiwanese market is an essential channel for the international transmissions of return and volatility, then θ and ψ would be significantly different from zero.

The results of coefficient estimates for the impacts on the mean return and volatility spillovers due to the openness of the Taiwanese market on January 1, 1991 are: $\theta_1 = -.133$, $\theta_2 = .064$, $\psi_1 = .423$, and $\psi_2 = -.311$.[9] While the two θ coefficient estimates are insignificant, the two ψ coefficient estimates are significant at the five-percent level when the usual standard errors are used. Therefore, it appears that the liberalization in the Taiwanese market has intensified the volatility spillover effect but not the mean return spillover.

IV. Conclusion

This study uses a GARCH model to examine the mean return and volatility spillover effects from the U.S. and Japan to four Asian stock markets, including Hong Kong, Singapore, Taiwan, and Thailand. In sum, our empirical results from examining the data for period of 1984 to 1991 indicate the following: (1) the ARMA(1,1)–GARCH(1,1)–in–mean model employed fits the data generally well; (2) there is an instability in the international mean return and volatility transmissions, and the spillover effects increase substantially after the October 1987 stock market crash; (3) the U.S. market appears to be more influential than the Japanese market in transmitting return and volatility to the Asian markets; (4) either the cross–country equity investing or the market contagion alone cannot explain the international stock return and volatility transmissions; the two hypotheses together seem to better explain the finding of stronger spillover effects after the October 1987 stock market crash.

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9. Since the results of coefficient estimates and standard errors are qualitatively similar to those in table 5, only the relevant coefficient estimates are reported to save space.

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