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Dynamic Causal Relationships among the Greater China Stock markets

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Abstract--This study examines the dynamic causal relationships among the Great China stock markets. In addition, we find the Asian financial crisis is a breakpoint during the whole sample period, so we examine the return and volatility effect with three different sample periods, namely, the whole sample period, the pre-crisis period, and the post-crisis period. We find that there were no return spillover effects between any pair of these three stock markets in the pre-crisis period. Return changes of the Mainland China spills over into Hong Kong, which in turn affects the return in the Taiwan market after the crisis. The bivariate GARCH framework of the BEKK is estimated to examine the volatility spillover effects. Before the crisis, there existed volatility spillover effects from Hong Kong to Mainland China and Taiwan, but no volatility feedback existed between Mainland China and Taiwan. Unidirectional volatility spillover from Mainland China to Hong Kong was found after the crisis, and a bidirectional volatility spillover effect between Hong Kong and Taiwan was also presented, however, there was no spillover effect between Mainland China and Taiwan.

Keywords: Great China stock markets; Asian financial crisis; Spillover effects; Bivariate GARCH

I. INTRODUCTION

Nowadays, the trend of globalization enables world capital markets more and more integrated. The major financial markets seem to be affected by common factors. For instance, Campbell and Hamao (1992) find integration between the US and Japanese financial markets and suggest that a common force may drive economic activities across borders and reductions in barriers facilitate a more closely integrated global market. On the other hand, the emerging markets may not sensitive to the impact from other markets. Bekaert (1995) indicates that returns in emerging markets exhibit a higher level of autocorrelation compared to returns in developed countries. Harvey (1995) finds that emerging markets may be more likely to be influenced by local events and information than the developed ones.

Owing to the geographical proximity, close economic relationships and political interdependence, the three markets in the Greater China area have strong linkages with each other. Since the early fifties, Hong Kong has been acted as an intermediary for China's international trade through re-exports. The linkages have been reinforced since the handover of Hong Kong to China in 1997. In addition, as an important channel, a large amount of capital has been raised through Hong Kong to finance China's economic expansion. During recent years, more and more Chinese enterprises have sought listings on the Hong Kong Stock Exchange (which are called H-shares). On the other hand, due to the problems left over by history, the economic linkage between China and Taiwan has been indirect for a long time. However, as the relation between them has been continuing to improve in the past few years, many Taiwan investors are actively exploring investment opportunities in Mainland China. Along with the surge in trade, investment and people flows, financial links of Hong Kong, Taiwan and the Mainland have also been on a rapid increase, and their stock markets are more attractive to the international investors. Therefore, it is of great interest to investigate that whether the three stock markets are affected by one another in this region. Specially, as an emerging stock market, whether the Mainland China stock market responds mainly to domestic news and shocks is also a focus.

In this paper, we will employ the the VAR framework and bivariate BEKK GARCH method together which enable us to understand the interdependence among the three stock markets not only in mean returns, but also in volatility spillover effect. The rest of the paper proceeds as follows: Section 2 offers a brief overview of literature related to the Greater China stock markets. Section 3 discusses the methodology. Section 4 introduces data description and characteristics. Section 5 provides the empirical results, and Section 6 summarizes the conclusions.

II. METHODOLOGY

The principal task in this paper is to examine the mean and volatility spillover effects among the Mainland China stock market, the Hong Kong stock market, and the Taiwan stock market. In this section, we will first implement the unit root test and the cointegration test with the log-level data. If the three series are cointegrated, we will use a vector error correction (VECM) model to examine the long-run and short-run relationships among these stock markets. If they are not cointegrated, we will examine the information transmission among them by exploring the vector-autoregressive framework as well as Granger causality, impulse response function and variance decomposition using daily returns. Finally, a bivariate GARCH model (BEKK model) will be estimated to examine the volatility spillover effects.

1 .Unit root test

It is well known that most financial time series have deterministic trend which means that they are non-stationary and should be treated differently from those that are stationary. The augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979) , which is specified in Equation (1), is the most common unit root test . It has a null hypothesis of series contains a unit root. If we fail to reject the null hypothesis, the series is said to be non-stationary. Phillips and Perron have developed a more comprehensive theory of unit root non-stationarity that is described in Equation (2). The tests are similar to ADF tests, but they incorporate an automatic correction to the DF procedure to allow for autocorrelated resideals. Here we conduct both unit root tests on the three time series with an intercept, or an intercept and trend, or neither. The test regressions are as follow:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta y_{t-i} + \varepsilon_t \ , \quad (1)$$

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \varepsilon_t \ , \quad (2)$$

2 .Cointegration test

In general, if y_t and x_t are nonstationary $I(d)$ series, then we would expect that their difference, or any linear combination of them to be $I(d)$ as well. However, if a vector exist such that the linear combination is $I(d-b)$ where $b>0$, then y_t and x_t are said to be cointegrated. A cointegrating relationship can be seen as a long-term or equilibrium phenomenon, since it is possible that cointegrating variables may deviate from their relationship in the short run, but their association would return in the long run. Here we use the Johansen technique based on VAR (p) to test that if there is long run relationship between these three series. A VAR with k lags containing these variables could be set up:

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t-2} + \ldots \beta_k y_{t-k} + \varepsilon_t \ , \quad (3)$$

In order to use the Johansen test, the VAR modeled in Equation (3) needs to be turned into a vector error correction model (VECM) of the form

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t \ , \quad (4)$$

The Johansen test centers around an examination of the Π which can be interpreted as a long-run coefficient matrix. The test for cointegration between the y is calculated by looking at the rank of the Π matrix via its eigenvalues. There are two test statistics for cointegration under the Johansen approach, which are formulated as

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{g} \ln(1-\hat{\lambda}_i) \ , \quad (5)$$

and

$$\lambda_{max}(r, r+1) = -T \ln(1-\hat{\lambda}_{r+1}) \ , \quad (6)$$

Where r is the number of cointegrating vectors under the null hypothesis and $\hat{\lambda}_i$ is the estimated value for the i th ordered eigenvalue from the Π matrix. λ_{trace} is a joint test where the null is that the number of cointegrating vectors is less than or equal to r against an unspecified or general alternative that there are more than r. λ_{max} conducts separate tests on each eigenvalue, and has as its null hypothesis that the number of cointegrating vectors is r against an alternative of $r+1$.

3.Chow test and VAR model

3.1. Chow breakpoint test and regression equation

$$DJ88_t = \alpha_1 + \beta_1 HangSeng_t + \gamma_1 Taiwan_t + \varepsilon_t \ , \quad \text{where } t = 1, \ldots 567 \ , \quad (7)$$

$$DJ88_t = \alpha_2 + \beta_2 HangSeng_t + \gamma_2 Taiwan_t + \varepsilon_t \ , \quad \text{where } t = 568, \ldots, 3112 \ , \quad (8)$$

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3.2. Granger causality test

Here we use a VAR model with three variables to examine the information transmission between these stock markets, and each of those three current values depend on different combinations of the previous p values of these variables, and error terms as follows :

$$\begin{pmatrix} DJ88_t \\ HangSeng_t \\ Taiwan_t \end{pmatrix} = \begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} + \begin{pmatrix} a_{11} & b_{11} & c_{11} \\ a_{21} & b_{21} & c_{21} \\ a_{31} & b_{31} & c_{31} \end{pmatrix} \begin{pmatrix} DJ88_{t-1} \\ HangSeng_{t-1} \\ Taiwan_{t-1} \end{pmatrix} + \cdots + \begin{pmatrix} a_{1p} & b_{1p} & c_{1p} \\ a_{2p} & b_{2p} & c_{2p} \\ a_{3p} & b_{3p} & c_{3p} \end{pmatrix} \begin{pmatrix} DJ88_{t-p} \\ HangSeng_{t-p} \\ Taiwan_{t-p} \end{pmatrix} + \begin{pmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \end{pmatrix} \tag{9}$$

Often, financial theory will have little to say on what is an appropriate lag length for a VAR, so here we will use the information criteria of BIC to choose the optimal lag length for the VAR model. Also, this is known as a reduced form VAR. Some researchers have argued that the a-theoretical nature of reduced form VARs leaves them unstructured and their results difficult to interpret theoretically. In order to partially alleviate this problem, three sets of statistics are usually constructed for an estimated VAR model: Granger causality tests, impulse responses and variance decompositions.

4. Bivariate GARCH(1,1)-BEKK model

We employ the multivariate GARCH(1,1)-BEKK representation (Baba, Engle, Kraft and Kroner, 1990; Engle and Kroner, 1995) to examine the volatility spillover effects between each of the following two pairs of stock markets: China-Hong Kong and China-Taiwan. This model facilitates the interaction between the conditional variances and covariances thus allow us to observe the impact of information on two different markets. To capture the heteroskedasticity in the return series and to ensure that the variance matrix of error term is positive definite, we apply the following bivariate BEKK(1,1) model:

$$\varepsilon_t \mid \Omega_{t-1} \sim N(0, H_t), \quad \text{for } t = 1, 2, \ldots T;$$
$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1}B, \tag{10}$$

The spectral decomposition follows:

$$H_t = \begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11} & \\ c_{21} & c_{22} \end{bmatrix}' \begin{bmatrix} c_{11} & \\ c_{21} & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon^2_{1,t-1} & \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon^2_{2,t-1} \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}' \begin{bmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \tag{11}$$

Where εt is assumed to follow a bivariate normal distribution conditional on the past information set $\Omega t - 1$, Ht denotes the variance-covariance matrix of εt, C is a lower triangular matrix; A and B are unrestricted square matrices. The elements of A capture the effects of shocks or events on volatility, while B shows the extent to which current levels of conditional variances are related to past conditional variances.

The conditional variance of the bivariate GARCH(1,1) model can be expressed as:

$$h_{11,t} = c_{11}^2 + c_{21}^2 + a_{11}^2\varepsilon_{1,t-1}^2 + 2a_{11}a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}^2\varepsilon_{2,t-1}^2 + b_{11}^2 h_{11,t-1} + 2b_{11}b_{21}h_{12,t-1} + b_{21}^2 h_{22,t-1}, \tag{12}$$

$$h_{22,t} = c_{22}^2 + a_{12}^2\varepsilon_{1,t-1}^2 + 2a_{12}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{22}^2\varepsilon_{2,t-1}^2 + b_{12}^2 h_{11,t-1} + 2b_{12}b_{22}h_{12,t-1} + b_{22}^2 h_{22,t-1}. \quad (13)$$

On the basis of this framework, the volatility spillover effects across return series indicated by the off-diagonal entries of coefficient matrices A and B are estimated. In Equations (12) and (13), a_{12} and a_{21} indicate the effect of the historical shocks or innovations happened in one market on the current volatility of the other market. b_{12} and b_{21} indicate the effect of the historical volatility happened in one market on the current volatility of the other market.

Given a sample of T observations, the parameters, θ of the model are obtained from the log-likelihood function optimized with the Berndt, Hall, Hall and Hausman (BHHH) algorithm as

$$L(\theta) = -T\log 2\pi - 0.5\sum_{t=1}^{T}\log\left|H_t(\theta)\right| - 0.5\sum_{t=1}^{T}\varepsilon_t(\theta)' H_t^{-1}\varepsilon_t(\theta), \quad (14)$$

III. DATA DESCRIPTION AND CHARACTERISTICS

1. Sample

This study include price indices of Dow Jones China 88（Mainland China, an index that represents the largest and most liquid stocks traded on the Shanghai and Shenzhen stock exchanges, Hang Seng Index (Hong Kong) and the Taiwan Weighted Index (Taiwan). The data of Dow Jones China 88 is taken from Dow Jones indexes, and two other price indices are taken from Econstats Economic Data.[1] We collected daily data covering January 5, 1995 through March 13, 2009.

2. Data characteristics

Most financial series are non-stationary. Therefore, we consider daily total stock returns. The rate of change in the data is calculated as continuously compounded returns, or $R_{i,t} = \ln(P_{i,t} / P_{i,t-1}) * 100$, where $R_{i,t}$ denotes the continuously compounded return for index i at time t, and $P_{i,t}$ denotes the price level of index i at time t.

The sample mean, standard deviation, skewness, kurtosis, Jarque-Bera statistics and Ljung-Box Q test statistic for all five indices are presented in Table Ⅰ. The means range from -0.034% to 0.014%, making them all close to zero. Index of China experienced positive mean daily returns whereas the other two stock markets of Hong Kong and Taiwan had negative mean daily returns during the sample period. The Mainland China show a maximum negative return of over 18% whereas the Hong Kong stock market show a maximum positive return of over 30%. However, the maximum return of China and Hong Kong stock markets are much higher than the Taiwan stock market. The volatility level for the Mainland China market is also higher than the other markets, with a standard deviation of 1.969. The measures for skewness indicate that the return series are skewed but in different directions: the Taiwan stock markets are negatively skewed, while Mainland China and Hong Kong markets have the positive skewness indicating that large positive stock returns were more common than large negative returns. On the other hand, the Mainland China and Hong Kong stock markets shows signs of significantly higher levels of excess kurtosis with the respect to the normal distribution. According to the Jarque-Bera statistic, we have to reject the assumption of normal distribution of these stock returns. Furthermore, the Ljung-Box tests clearly indicate some presence of serial correlation in some of the return series at different lag lengths and also reveal a significant serial correlation in squared returns, indicating the presence of GARCH effects.

TABLE Ⅰ
SUMMARY STATISTICS FOR STOCK MARKET RETURNS

	DJ China88	**Hang Seng**	**Taiwan**
Mean	0.014	-0.007	-0.034
Min	-18.131	-14.735	-6.976
Max	25.467	30.375	8.058
Std.dev.	1.969	1.885	1.580
Skewness	0.436	1.344	-0.082
Kurtosis	18.222	32.787	5.126
Jarque-Bera	28961.3	115949.3	589.5
LB(8)	14.935	18.323	26.761
	(0.060)	(0.019)	(0.001)
LB(12)	16.529	23.371	32.436

[1] http:// www.econstats.com

	(0.168)	(0.025)	(0.001)
$LB^2(8)$	444.53	161.90	432.06
	(0.000)	(0.000)	(0.000)
$LB^2(12)$	456.02	192.22	538.40
	(0.000)	(0.000)	(0.000)

Note: Data summary statistics for daily returns data. Ljung-Box Q-statistics are computed for returns (LB) and squared returns (LB^2). The P-values are given in parenthesis.

IV. EMPIRICAL RESULTS

1. Unit root test and Johansen cointegration test

Table Ⅱ shows the results of ADF test and PP test with the three different specifications, respectively. Clearly, the null hypothesis of a unit root in each of the three log-level series cannot be rejected at a 1% significance level, and implies that all of them are nonstationary series. When the two tests are implemented on the first difference of the three series, the null hypothesis of a unit root in the first differences is convincingly rejected. These results tell us that all three series are integrated of order one, that is *I(1)*.

TABLE Ⅱ
UNIT ROOT TESTS

	Augmented Dickey-Fuller		
	No intercept or trend	**Intercept**	**Intercept and trend**
Log-level			
Dow Jones China 88	0.777	-2.036	-2.015
Hang Seng	0.363	-2.482	-2.483
Taiwan	-0.449	-2.032	-2.078
First difference			
Dow Jones China 88	-58.308***	-58.314***	-58.31***
Hang Seng	-60.239***	-60.233***	-60.236***
Taiwan	-58.008***	-58.002***	-57.995***

	Phillips-Perron		
	No intercept or trend	**Intercept**	**Intercept and trend**
Log-level			
Dow Jones China 88	0.743	-2.084	-2.084
Hang Seng	0.384	-2.426	-2.409
Taiwan	-0.437	-2.121	-2.167
First difference			
Dow Jones China 88	-58.339***	-58.345***	-58.341***
Hang Seng	-60.284***	-60.279***	-60.285***
Taiwan	-58.045***	-58.053***	-58.046***

Note: Numbers are ADF and PP t-statistics for testing the null hypothesis of non-stationarity. The Schwarz Bayesian information criterion is used to choose the optimal numbers of lags for ADF test. Critical values are found in Mackinnon (1996).

2. Johansen cointegration test

Table Ⅲ shows the results of Johansen cointegration test. Both the Trace test and Max-eigenvalue test indicate no cointegration at the 5% level which implies that the three series are not cointegrated, so there is no long-run equilibrium relationship among the three stock markets and we need not to use the vector error correction model to analyze them.

TABLE Ⅲ
JOHANSEN COINTEGRATION TEST

(A) Trace test			
Hypothesized No. of CE(s)	Trace Statistic	0.05 Critical Value	Prob.**
None	25.84725	29.79707	0.1334
At most 1	12.66893	15.49471	0.1275
At most 2 *	4.763746	3.841466	0.0291
(B) Maximum eigenvalue test			
Hypothesized No. of CE(s)	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	13.17832	21.13162	0.4360
At most 1	7.905187	14.26460	0.3884
At most 2 *	4.763746	3.841466	0.0291

Note: * denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

TABLE Ⅳ
RESULTS OF CHOW TEST

Chow breakpoint test			
F-statistic	9.212462	Prob. F(3,3112)	0.0000
Log likelihood ratio	27.56828	Prob. Chi-Square(3)	0.0000
Wald Statistic	27.63739	Prob. Chi-Square(3)	0.0000

Before we use the vector-autoregressive model to examine the mean spillover effects among the three stock markets, we decide to consider the Asian financial crisis, which became evident on July 2, 1997 as a breakpoint and implemented the chow test. The result of the chow test is shown in Table Ⅳ. The null hypothesis of no breaks at specified breakpoint is strongly rejected by all the three test statistics.

TABLE Ⅴ
GRANGER CAUSALITY TEST

	DJ88	Hang Seng	Taiwan
(A) Whole sample period (5 Jan 1995~13 Mar 2009)			
DJ88	-	0.546	0.742
Hang Seng	13.569***	-	0.616
Taiwan	0.003	38.645***	-
(B) Pre-crisis period (5 Jan 1995~2 July 1997)			
DJ88	-	0.047	0.503
Hang Seng	0.206	-	0.268
Taiwan	0.027	0.549	-
(C) Post-crisis period (3 July 1997~13 Mar 2009)			
DJ88	-	0.827	0.535
Hang Seng	18.855***	-	0.434
Taiwan	0.063	35.182***	-

Note: *** indicates significance at 1% level

Table Ⅴ shows the results of Granger causality test with three different sample periods. During the whole sample period, the null hypothesis of the stock return of DJ88 does not Granger cause the stock return of Hang Seng is rejected at a 1% significant level. Also, the null hypothesis of the stock return of Hang Seng does not Granger cause the stock return of Taiwan is rejected at a 1% significant level. The results show that there exists unidirectional causality from DJ88 to Hang Seng and Hang Seng to Taiwan. However, there is no feedback between DJ88 and Taiwan.

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Then the sample data are divided into two parts. During the pre-crisis period (5 Jan 1995-2 July 1997), neither set of lags are statistically significant in the equation for the other variables, it would be said that the three return series are independent. During the post-crisis period (3 July 1997-13 Mar 2009), both the null hypotheses of DJ88 does not Granger cause Hang Seng and Hang Seng does not Granger cause Taiwan are rejected at a 1% significant level. Therefore, based on the above analysis, we can conclude that there is no feedback among the Greater China stock markets before the Asian financial crisis, but after the crisis, there exists unidirectional causality from DJ88 to Hang Seng and Hang Seng to Taiwan. The causality relationship between Mainland China and Taiwan is still not significant.

Table Ⅵ-Ⅶshows the summary of estimates for bidirectional volatility spillover effect between DJ88~HangSeng, DJ88~Taiwan and HangSeng~Taiwan. The coefficients are estimated from the bivariate GARCH $(1,1)$ -BEKK representation. We will first analyze the results for the total sample period which is showed in Table 10. The first column provides the estimates for the DJ88~HangSeng pair of stock returns.

We find that off-diagonal ARCH$(1,2)$ and GARCH$(1,2)$ terms are significant at the 1% significance level, while those of ARCH$(2,1)$ and GARCH$(2,1)$ are not, indicating the existence of a unidirectional volatility spillover effect from DJ88 to HangSeng. As we inspect the DJ88-Taiwan pair of stock returns, only the GARCH $(1,2)$ term is significant at the 10% level, which indicates that there is only a unidirectional volatility spillover effect from DJ88 to Taiwan. With respect to the estimates of the HangSeng-Taiwan market, the results show that all off-diagonal ARCH terms and GARCH terms are significant and imply a bidirectional volatility spillover effect and strong information transmission between HangSeng and Taiwan index.

TABLE Ⅵ

ESTIMATION RESULTS OF BIVARIATE GARCH $(1,1)$ –BEKK MODEL FOR WHOLE SAMPLE PERIOD (5 JAN 2002~13 MAR 2014)

	DJ88-HangSeng	DJ88-Taiwan	HangSeng-Taiwan
A(1, 1)	0.088(7.40)***	0.063(4.866) ***	0.020(0.135)
A(2, 1)	-0.133(-3.502) ***	0.057(0.683)	-0.081(-0.116)
A(2, 2)	0.002(0.0001)	0.214(8.170) ***	0.296(1.567)
ARCH(1, 1)	0.239 (28.73)***	0.218(29.02) ***	0.223(26.920) ***
ARCH(1, 2)	-0.024(-3.194) ***	0.008(1.039)	0.080(9.076) ***
ARCH(2, 1)	-0.016(-1.433)	0.006(0.439)	-0.039(-2.598) ***
ARCH(2, 2)	0.281(24.79)***	0.288(24.315) ***	0.320(22.314) ***
GARCH(1, 1)	0.976 (697.6)***	0.981(972.08) ***	0.974(479.057) ***
GARCH(1, 2)	0.015 (9.747) ***	-0.002(-1.672) *	-0.020(-6.756) ***
GARCH(2, 1)	0.002(0.538)	-0.002(-0.358)	0.036(6.052) ***
GARCH(2, 2)	0.959(287.0)***	0.948(221.58) ***	0.924(145.229) ***

Note: Numbers in parentheses are t-statistics, *** and * indicate significance at the 1% and 10% levels, respectively.

TABLE Ⅶ

ESTIMATION RESULTS OF BIVARIATE GARCH $(1,1)$ –BEKK MODEL FOR POST-CRISIS PERIOD (3 JULY 1997-13 MAR 2009)

	DJ88-HangSeng	DJ88-Taiwan	HangSeng-Taiwan
A(1, 1)	0.105(3.889)***	0.084(7.601) ***	0.009(0.022)
A(2, 1)	-0.251(-2.712)***	0.052(0.935)	0.047(0.020)
A(2, 2)	0.00003(0.000)	0.178(8.118) ***	0.291(0.817)
ARCH(1, 1)	0.2454(15.91)***	0.213(24.394) ***	0.216(24.123) ***
ARCH(1, 2)	-0.0582(-3.244)***	0.005(0.542)	0.090(9.493) ***
ARCH(2, 1)	-0.0139(-0.703)	0.016(1.234)	-0.048(-2.376) **
ARCH(2, 2)	0.3820(17.35)***	0.269(20.977) ***	0.317(19.069) ***
GARCH(1, 1)	0.9815(287.6)***	0.979(762.4) ***	0.973(385.58) ***
GARCH(1, 2)	0.0332(6.986)***	-0.002(-1.300)	-0.023(-7.011) ***
GARCH(2, 1)	-0.0015(-0.232)	-0.004(-0.990)	0.045(5.486) ***
GARCH(2, 2)	0.9292(119.6)***	0.957(232.49) ***	0.926(127.27) ***

Note: Numbers in parentheses are t-statistics, *** and ** indicate significance at the 1% and 5% levels, respectively.

Table Ⅶ shows the estimated results for bidirectional volatility spillover effect after the Asian financial crisis. In general, we find that relationships among the three markets are very similar to those of the results presented in Table10. For the pair of DJ88-Hang Seng, we find a unidirectional volatility spillover effect from DJ88 to Hang Seng. As we inspect the DJ88-Taiwan pair, we find no volatility spillover effect between them. For the HangSeng-Taiwan pair, the results show that all off-diagonal ARCH terms and GARCH terms are significant and disclose a bidirectional volatility spillover effect between them, implying strong transmission of information between these two stock markets.

V. CONCLUSIONS

In this study, we explore the possible linkages among the Greater China stock markets. The results of the unit root test and Johansen cointegration test show that the three stock series are non-stationary and not cointegrated, so the vector-autoregressive model and the GARCH$(1,1)$-BEKK framework are applied to examine the mean and volatility spillover effects among them. According to the chow test, we find the Asian financial crisis, which became evident on July 2, 1997 is a breakpoint, so we examine the return and volatility effect with three different sample periods, namely, the total sample period, period before the Asian financial crisis and period after the crisis.

The results of Granger causality show that during the whole sample period, there exists unidirectional causality from DJ88 to Hang Seng and Hang Seng to Taiwan. However, there is no feedback between DJ88 and Taiwan. There exists no causality between any pair of the three stock markets before the Asian financial crisis. Results of period after the crisis are identical with that of the whole sample period. With respect to impulse responses, we find that during the whole sample period, innovations to the returns of Hong Kong and Taiwan stock index almost have no impact on the return of DJ88. Innovations to the return of DJ88 have a impact on the return of Hang Seng and Taiwan stock indices, whereas innovations to the returns of Hang Seng has a positive impact on the return of Taiwan stock index. But for the pre-crisis sample period, responses of the three stock markets to the shocks are very small, except for the response to their own shocks. Results of the second sample period are similar to the whole period. According to the results of variance decompositions, we find that the forecast of variance in DJ88 can be almost attributed to its own innovation in any sample periods. DJ88 shock increases by a large extent in forecasting variance of Hang Seng after the crisis. Moreover, both the contributions of DJ88 and Hang Seng to the forecast variance of Taiwan are increased after the crisis. We also find that innovation of Taiwan does no contribution to the forecast variances of the Mainland China and Hong Kong stock market, whether before the crisis or after it.

The volatility spillover effect shows that during the total sample period, there are only unidirectional volatility spillover effects from DJ88 to Hang Seng and Taiwan. However, a bidirectional volatility spillover effect between HangSeng and Taiwan is presented. Before the Asian financial crisis, the preceding return shock of DJ88 has an influence on the current volatility of the HangSeng index and the former conditional volatility of the Hong Kong stock market has an influence on the current conditional volatility of the Mainland China stock market. There is no volatility spillover effect exists between DJ88 and Taiwan and the former conditional volatility of Hang Seng has an effect on the current conditional volatility of Taiwan. In general, we find that after the crisis, relationships among the three markets are very similar to those of the results obtained from the whole sample period.

REFERENCES

[1]Anders C. Johansson, Christer Ljungwall (2011). "Spillover Effects among the Greater China Stock Markets." *World Development Vol.37, No.4*, pp.839-851

[2]Bekaert, G. (2012). "Market integration and investment barriers in emerging equity markets." *World Bank Economic Review, 9*, pp.75-107

[3]Campbell, J. Y., Hamao, Y. (1998). "Predictable stock returns in the United States and Japan: A study of long-term capital market integration." *Journal of Finance, 47*, pp.43-70

[4]Chris Brooks (2008). "Introductory Econometrics for Finance." *Cambridge University Press*, pp. 295-365

[5]Harvey, C. R. (1995). "Predictable risk and return in emerging markets." *Review of Financial Studies, 8*, pp.773-816.

[6]In-Moo Kim, Chan-Wung Kim (2001). "International Transmission of Stock Market Movement among the Kosdaq, Nasdaq, and Jasdaq." *Korean Securities Association, 28*, pp.481-513

[7]Laurence, M., Cai, F., Qian, S., (1997). "Weak-form efficiency and causality tests in Chinese stock markets." *Multinational Finance Journal 4*, pp. 291-307

[8]Qian Sun, Wilson H.S. Tong (2000). "The effect of market segmentation on stock prices: The China syndrome." *Journal of Banking and Finance 24*, pp.1875-1902

[9]Suk-Joong Kim (2003). "The spillover effects of US and Japanese public information new in advanced Asia-Pacific stock markets." *Pacific-Basin Finance Journal 11*, pp. 611-630

[10]Zhuo Qiao, Thomas C. Chiang, Wing-Keung Wong (2007). "Long-run equilibrium,short-term adjustment, and spillover effects across Chinese segmented stock markets and the Hong Kong stock market." *Journal of International Financial Markets, Institutions and Money*, 18, pp.425-437

