VOLATILITY SPILLOVER EFFECTS IN ASIAN-7 EQUITY MARKETS: EVIDENCE FROM BEKK-GARCH MODEL

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Abstract

The main purpose of this paper is to investigate the international information transmission of return and volatility spillovers from the U.S and Japan and the rest of the Asia-Pacific countries using daily stock market return data covering the last 14 years. A pre-1997 and post-1999 analysis reveals that the linkages between the markets have changed substantially in the more recent era, suggesting that international markets have become more interdependent. In the majority of the countries under scrutiny, we provide evidence of direct volatility spillovers, running mainly from the Japanese and US markets and pointing to more rapid information transmission during the recent years. First, the volatility of the Asia-Pacific markets is influenced more by the Japanese market than by the US market for the pre-crisis sample. Secondly, only the influence of the US is important for the Asia-Pacific markets; there is no influence from Japan for the pre-crisis period, except for the Taiwanese market. Lastly, for the post-crisis period only the US market have a significant return and volatility spillover impact to many of the Asia-Pacific countries.

Keywords: Asia-Pacific; Volatility spillovers; GARCH-BEKK.

JEL Classification Codes: C32; F31; G10.

1. Introduction

Nowadays, with the increasing liberalization and integration of global market activities, with the more growing integration of international financial markets, the study on the co-movement among international asset markets becomes more important. As economic environments and market situations could vary over time, it is not necessary that conditional correlations across different international assets remain constant over time. As a result, evaluating time-varying conditional covariances and volatilities of international assets would be major concerns of market participants in order to obtain an efficiently dynamic allocation of international assets and diversify risk effectively. In this paper we describe a model which can be used to estimate large time-varying covariance matrices and describe the theoretical properties of the (BEKK) Multivariate GARCH model, first introduced in Engle (1995). The first multivariate GARCH (MGARCH) model is proposed by Bollerslev et al. (1988).This model uses the VECH operator and is thus referred to as vech-model. It does not guarantee a positive-definite covariance matrix and the number of parameters is relatively large. The full unrestricted model requires large number of parameters to be estimated by maximum likelihood in each matrix, but many of these parameters are superfluous. A simpler model, the diagonal vech was also proposed which allows for non-zero coefficients only on own lagged effects and cross products, each variance-covariance term is postulated to follow a GARCH-type equation with the lagged variance-covariance term and the product of the corresponding lagged residuals as the right-hand side variables in the conditional-(co)variance equation. The diagonal specification allows for a relatively straightforward interpretation, as each series has a GARCH-like specification.

It is often difficult to verify the condition that the conditional-variance matrix of an estimated MGARCH model is positive definite (Engle et al. 1984). Furthermore, such conditions are often very difficult to impose during the optimization of the log-likelihood function. Bollerslev and Wooldridge (1992) suggested the constant-correlation MGARCH (CC-MGARCH) model that can overcome these difficulties. He pointed out that under the assumption of constant correlations; the maximum likelihood estimate (MLE) of the correlation matrix is equal to the sample correlation matrix. As the sample correlation matrix is always positive definite, the optimization will not fail as long as the conditional variances are positive. In addition, when the correlation matrix is concentrated out of the log-likelihood function further simplification is achieved in the optimization. However, while the constant-correlation

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[Ψ] Corresponding author. Ahmed Shamiri. School of Mathematical Science, Faculty of Science and Technology, Unicveristi Kabangsaan Malaysia, 43600 Bangi , Selangor, Email: Shamiri@ukm.my assumption provides a convenient MGARCH model for estimation, some studies find that this assumption is not supported by some financial data (Tse 2000). Engle and Kroner (1995) proposed a class of MGARCH model called the BEKK (Baba, Engle, Kraft and Kroner) model, developed a general quadratic form for the conditional covariance equation which eliminated the problem of assuring the positive definiteness of the conditional covariance estimate of the original vech model. Engle and Kroner provided some theoretical analysis of the BEKK model and relate it to the vech-representation form.

This paper considers a volatility spillover model by applying a bivariate GARCH model, for which a BEKK representation is adopted (Engle & Kroner 1995), for each of the Asia-Pacific countries against the Japan and US using daily returns for the last-14 years. This BEKK formulation enables us to reveal the existence of any transmission of volatility from one market to another, as well as any increased persistence in market volatility (Engle et al. 1990). Splitting our sample into two non-overlapping sub-samples, we investigate whether the efforts for more economic, monetary and financial integration have fundamentally altered the sources and intensity of volatility spillovers to the individual stock market.

2. Methodology and data

The analysis is based on a bivariate VAR(1)-GARCH(1,1) model. Let R= $(R_{1t}, R_{2t})'$ be the return vector. The conditional mean of the process is modeled as follows:

$$R_t = \alpha + \beta R_{t-1} + \varepsilon_t \tag{1}$$

where α is a 2x1 vector of constants and β is a 2x2 coefficient matrix and $\varepsilon_t=(\varepsilon_{1t}, \varepsilon_{2t})'$ is the vector of zero-mean error terms. We allow the error term ε_t to have a time-varying conditional variance that $\varepsilon_t \,|\Im$ (t-1) ~ N (0, H_t), we consider the following BEKK representation, introduced by Engle and Kroner (1995):

$$H_t = C_0' C_0 + \sum_{i=1}^{q} A_i' \varepsilon_{t-1} \varepsilon_{t-1}' A_i + \sum_{i=1}^{p} G_i' H_{t-1} G_i \tag{2}$$

where C_0, A_i and G_i are k × k parameter matrices with C_0 is a lower triangular matrix.

Consider a bivariate GARCH (1,1) model as follows:

$$\begin{aligned} H_t = C_0' C_0 &+ \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \\ &+ \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix}' H_{t-1} \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix} \end{aligned} \tag{3}$$

The model ensures that the conditional variance-covariance matrices, H_t are positive definite under weak assumption (Engle & Kroner 1995).

Engle and Kroner (1995) proved that the BEKK model is second-order stationary if and only if all the eigenvalues of (A⊗A+G⊗G) are less than unity in modulus. To elaborate further, the conditional variance for each equation can be expanded for the bivariate GARCH (1,1) as follows:

$$\begin{aligned} h_{11,t} = {} & c_1 + \alpha_{11}^2 \varepsilon_{1,t-1}^2 + 2\alpha_{11}\alpha_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \alpha_{21}^2 \varepsilon_{2,t-1}^2 \\ & + \beta_{11}^2 h_{11,t-1} + 2\beta_{11}\beta_{21} h_{12,t-1} + \beta_{21}^2 h_{22,t-1} \end{aligned} \tag{4}$$

$$\begin{aligned} h_{12,t} = {} & c_2 + \alpha_{11}\alpha_{12}\varepsilon_{1,t-1}^2 + (\alpha_{21}\alpha_{12} + \alpha_{11}\alpha_{22})\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \alpha_{21}\alpha_{22}\varepsilon_{2,t-1}^2 \\ & + \beta_{11}\beta_{12} h_{11,t-1} + (\beta_{21}\beta_{12} + \beta_{11}\beta_{22}) h_{12,t-1} + \beta_{21}\beta_{22} h_{22,t-1} \end{aligned} \tag{5}$$

$$\begin{aligned} h_{22,t} = {} & c_3 + \alpha_{12}^2 \varepsilon_{1,t-1}^2 + 2\alpha_{12}\alpha_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \alpha_{22}^2 \varepsilon_{2,t-1}^2 \\ & + \beta_{12}^2 h_{11,t-1} + 2\beta_{12}\beta_{22} h_{12,t-1} + \beta_{22}^2 h_{22,t-1} \end{aligned} \tag{6}$$

The bivariate BEKK model is estimated by maximizing the following likelihood function:

$$L(\theta) = \sum_{t=1}^{T} \ln(l_t(\theta)) \qquad (7)$$

with $$l_t = \frac{\Gamma(T+v)/2}{\Gamma(v/2)[\pi(v-2)]^{T/2}} \left|H_t\right|^{-1/2} \left[1 + \frac{1}{v-2}\varepsilon_t' H_t^{-1} \varepsilon_t\right]^{-(T+v)/2}$$

where υ denotes the degrees of freedom of the t-distribution and Γ is the gamma function. This log-likelihood function is maximized using the Berndt et al. (1974), which is also known as the BHHH algorithm. The stock markets investigated in this study are the US, Japan and the Asia-Pacific stock markets. The indices are KLSE composite Index in Malaysia, Strait Times Index in Singapore, Stock Exchange of Thailand Index in Thailand, JSX Composite Index in Indonesia, Hang Seng Index in Hong Kong, Korea Composite Stock Price Index in Korea, Taiwan Stock Exchange Capitalization Weighted Index in Taiwan, NIKKEI225 in Japan and S&P500 in the US. Daily index observations of these markets were obtained from DataStream data base. The indices span a period of approximately 14 years from 1/1/1990 to 31/12/2004. In the database, the daily return r_t consisted of daily closing price P_t, which is measured in local currency.

3. Empirical results

Individual market analysis

We conduct our analysis for two non-overlapping sub-periods. The data of the stock price markets exhibit large fluctuations during the whole period. Table 1 reports the descriptive statistics of stock returns for the samples under consideration. Panel A reports the statistics for the full sample, while Panel B and C refer to the two subperiods considered, namely the pre-crisis and post-crisis. The US and Hong Kong market yields the highest daily mean returns over the whole period and pre-crisis period, while Malaysia (0.028%) followed by Indonesia (0.026%) has the highest mean returns for post-crisis period. The higher returns in the Asian markets are, however, accompanied by higher volatility 1.14% and 0.66% for Malaysia and Indonesia respectively. Volatility for the Asia-Pacific markets over the whole sample ranges from 0.55% (Japan) to 0.84% (Taiwan). Notably, in terms of daily returns Japan have the lowest mean returns. It is clear that the Asian markets offer higher average returns than Japan and US markets but these high returns are also characterized by higher volatility, which is common for emerging markets and is consistent with previous studies (Ng 2000). We check the statistical features of the data reported in Table 1 the skewness, kurtosis, and their tests. The Ljung-Box Q-statistics Q(20) and $Q^2(20)$ are reported under the null hypothesis of non-serial correlation tests in daily return and squared returns, respectively. At significance levels of 5%, the null hypotheses (skewness=0 or excess kurtosis=0) and of non-serial correlation are rejected, respectively. These time series have the typical features of stock returns as fat tail, spiked peak, and persistence in variance. Therefore, the ARCH models including such features are appropriate for analyzing these series. Furthermore, these descriptive statistics show that the nature of the data varies significantly between the two sub-samples, justifying our modeling strategy.

Cross-market analysis

The cross-market analysis presents a more comprehensive account of information transmission. We find strong evidence of interaction between the Japanese and US stock market and the Asia-Pacific stock markets. The significant positive coefficients of unidirectional volatility transmission from the U.S. and Japanese markets to Asia-Pacific shown in the tables below are consistent with our proposition. To facilitate the discussion, we focus on comparing the results from the two sub-periods. On the whole, the conditional variance-covariance equations incorporated in the GARCH-BEKK methodology effectively capture the volatility and cross volatility dynamics among the markets under consideration. Therefore, useful insights are provided as far as the changes in volatility linkages among the US, Japanese and the rest of the Asia-Pacific countries are concerned.

Starting with Malaysia, Singapore and Indonesia, we find that volatility (conditional variance) in these countries is directly affected by the US volatility in both periods under examination.

- In the case of Malaysia, there are significant volatility spillovers from both the Japanese and US markets transmitted through the cross product of innovations and volatility as well. During the pre-crisis (Equations (8) & (9)) the effects of Japan and US markets on the Malaysian volatility is shown to be more intense with a significant positive coefficient from Japan than the volatility from US. However, our estimates for the pre-crisis period support the increased integration of

Japanese markets with the Malaysian market, allowing for the bidirectional volatility transmission. Specifically, Malaysian volatility adversely affects the Japan volatility. However, Japanese influences are stronger than the Malaysian. This may be due to a strong economic relationship between Malaysia and Japan through large amounts of portfolio investment during this period. As reported in Equations (10) & (11), during post-crisis, no cross-market dependencies are apparent from the Japanese market, as indicated by the diagonality of the corresponding BEKK models. That the integration of Japanese markets with the Malaysian market had been reduced in the recent years, is due to the strong capital control by the Malaysian government after the crisis in 1997.

Table 1: Summary Statistics for daily returns

Panel A:	**All-Sample**								
	MA	**SI**	**TH**	**IN**	**HK**	**KO**	**TA**	**US**	**JA**
Mean	0.0053	0.0063	-0.0031	0.0102	0.0179	-0.0002	-0.0050	0.0137	-0.0091
Max	9.0409	6.4573	4.9290	5.7013	7.4903	4.3533	5.5745	2.4204	4.5519
Min	-10.4897	-4.2004	-4.3551	-5.5295	-6.3992	-5.5610	-4.4682	-3.0890	-3.1806
Std.	0.6780	0.5634	0.7748	0.6554	0.6974	0.8413	0.8447	0.4412	0.5549
Skewness	0.4716	0.2051	0.2358	0.2852	-0.0307	-0.0286	-0.0552	-0.1031	-0.0106
Kurtosis	42.4407	13.7423	7.6066	13.9469	13.0647	6.7982	6.3460	6.8925	7.2655
J-Bera	253832.5	18846.9	3496.8	19596.0	16520.8	2353.2	1827.9	2477.9	2967.3
Q(20)	113.72**	128.32**	105.09**	247.82**	52.56**	30.09**	68.94**	39.8**	90.47**
Q^2(20)	1946.6**	1003.7**	1345.5**	1086.3**	1399**	1392.9**	4112.1**	1487.4**	713.54**
ARCH(2)	618.33**	112.002**	236.29**	90.61**	281.42**	96.99**	276.52**	131.71**	88.24**
Panel B:	**Pre-Crisis**								
	MA	**SI**	**TH**	**IN**	**HK**	**KO**	**TA**	**US**	**JA**
Mean	0.015	0.011	-0.011	0.0134	0.0372	-0.0041	-0.0014	0.0205	-0.0128
Max	4.2179	2.2975	3.7624	4.7200	2.4788	3.5555	5.5745	1.5927	4.5519
Min	-3.3422	-3.2672	-4.0366	-2.5962	-3.8013	-3.6395	-4.4682	-1.6186	-3.1354
Std.	0.5024	0.4363	0.7191	0.4309	0.5770	0.6088	0.9307	0.3176	0.5240
Skewness	-0.0275	-0.3958	-0.2466	1.4987	-0.5117	0.2552	-0.0757	-0.1648	0.2684
Kurtosis	10.4846	9.2884	8.2770	22.0893	8.0001	5.7885	6.4806	5.2404	10.4247
J-Bera	4565.9	3273.9	2289.3	30430.8	2123.6	654.9	989.18	417.9	4516.2
Q(20)	108.87**	108.81**	56.158**	286.61**	29.835	24.801	52.062**	31.285	76.228**
Q^2(20)	721.19**	458.57**	926.16**	77.82**	306.58**	510.47**	2795.7**	286.26**	455.79**
ARCH(2)	129.62**	85.83**	154.34**	34.06**	49.86**	54.37**	177.31**	19.88**	57.74**
Panel C:	**Post-Crisis**								
	MA	**SI**	**TH**	**IN**	**HK**	**KO**	**TA**	**US**	**JA**
Mean	0.0279	0.0109	0.0175	0.0256	0.0097	0.0129	-0.0012	-0.0004	0.0003
Max	5.8504	2.3990	4.4422	4.6502	2.3601	3.3428	3.7001	2.4204	2.5310
Min	-6.3422	-3.9499	-3.1901	-4.7484	-4.0326	-5.5610	-4.3152	-2.6080	-3.1805
Std	1.1405	0.5539	0.7062	0.6619	0.6339	0.9145	0.7605	0.5339	0.5889
Skewness	-0.1443	-0.3266	0.2446	0.0044	-0.2343	-0.3545	-0.0120	0.1119	-0.3041
Kurtosis	7.8838	6.9726	6.4067	8.1150	5.8706	5.5144	5.1597	4.7637	5.0468
J-Bera	1560.7	1056.9	772.4	1706.1	551.6	445.1	304.2	206.1	297.3
Q(20)	77.46**	25.084	46.446**	50.726**	18.040	25.705	33.928*	26.607	41.664**
Q^2(20)	323.4**	134.89**	144.18**	105.47**	148.92**	89.69**	261.22**	530.30**	157.94**
ARCH(2)	59.19**	14.38**	22.71**	29.82**	3.14*	12.73**	28.75**	39.48**	17.11**

Notes: J-Bera is the Jarque and Bera (1987) test for normality, ARCH(2) refers to Engle (1982) LM test for presence of ARCH at lag 2. Q-test is Box-Pierce test of serial correlation for linear and non-linear (squared) returns. *, ** Significance at 5% and 1% respectively.

Pre-Crisis:

$$\begin{aligned}\begin{bmatrix} h_{Ma,t} \\ h_{Ja,t} \end{bmatrix} &= \begin{bmatrix} 0.0926 & -0.1256 \\ (0.3091) & (0.0260) \\ & 0.0002 \\ & (0.000) \end{bmatrix} + \begin{bmatrix} 0.10170 & -0.2134 \\ (0.3774) & (0.0274) \\ -0.2743 & -0.2897 \\ (0.0304) & (0.0406) \end{bmatrix} \begin{bmatrix} \varepsilon^2_{MA,t-1} & \varepsilon_{MA,t-1}\varepsilon_{Ja,t-1} \\ \varepsilon_{Ja,t-1}\varepsilon_{MA,t-1} & \varepsilon^2_{Ja,t-1} \end{bmatrix} \\ &+ \begin{bmatrix} 0.9329 & 0.5077 \\ (0.0196) & (0.0181) \\ -0.4933 & 0.6186 \\ (0.0225) & (0.0275) \end{bmatrix} \begin{bmatrix} h_{Ma,t-1} \\ h_{Ja,t-1} \end{bmatrix}\end{aligned} \tag{8}$$

$$\begin{aligned}\begin{bmatrix} h_{Ma,t} \\ h_{US,t} \end{bmatrix} &= \begin{bmatrix} 0.1112 & 0.00137 \\ (0.1247) & (0.0074) \\ & 0.0082 \\ & (2.1523) \end{bmatrix} + \begin{bmatrix} 0.3594 & 0.0241 \\ (0.0762) & (0.0091) \\ 0.0888 & 0.14401 \\ (0.0343) & (0.0144) \end{bmatrix} \begin{bmatrix} \varepsilon^2_{Ma,t-1} & \varepsilon_{MA,t-1}\varepsilon_{US,t-1} \\ \varepsilon_{Ja,t-1}\varepsilon_{MA,t-1} & \varepsilon^2_{US,t-1} \end{bmatrix} \\ &+ \begin{bmatrix} 0.9029 & -0.0108 \\ (0.0177) & (0.0041) \\ -0.0005 & 0.9899 \\ (0.0099) & (0.0029) \end{bmatrix} \begin{bmatrix} h_{Ma,t-1} \\ h_{US,t-1} \end{bmatrix}\end{aligned} \tag{9}$$

Post-Crisis:

$$\begin{aligned}\begin{bmatrix} h_{Ma,t} \\ h_{Ja,t} \end{bmatrix} &= \begin{bmatrix} 0.0212 & -0.1275 \\ (1.4214) & (0.0237) \\ & 0.0119 \\ & (13.2015) \end{bmatrix} + \begin{bmatrix} 0.2097 & 0.0053 \\ (0.1482) & (0.0107) \\ -0.3229 & -0.2572 \\ (0.0404) & (0.0277) \end{bmatrix} \begin{bmatrix} \varepsilon^2_{MA,t-1} & \varepsilon_{MA,t-1}\varepsilon_{Ja,t-1} \\ \varepsilon_{Ja,t-1}\varepsilon_{MA,t-1} & \varepsilon^2_{Ja,t-1} \end{bmatrix} \\ &+ \begin{bmatrix} 0.9672 & -0.0127 \\ (0.0226) & (0.0429) \\ -0.4933 & -0.9362 \\ (0.0225) & (0.0235) \end{bmatrix} \begin{bmatrix} h_{Ma,t-1} \\ h_{Ja,t-1} \end{bmatrix}\end{aligned} \tag{10}$$

$$\begin{aligned}\begin{bmatrix} h_{Ma,t} \\ h_{US,t} \end{bmatrix} &= \begin{bmatrix} 0.0886 & 0.0479 \\ (0.2159) & (0.0094) \\ & 0.0001 \\ & (27.141) \end{bmatrix} + \begin{bmatrix} 0.2029 & 0.0322 \\ (0.1102) & (0.0076) \\ 0.0289 & -0.2047 \\ (0.0380) & (0.0210) \end{bmatrix} \begin{bmatrix} \varepsilon^2_{Ma,t-1} & \varepsilon_{MA,t-1}\varepsilon_{US,t-1} \\ \varepsilon_{Ja,t-1}\varepsilon_{MA,t-1} & \varepsilon^2_{US,t-1} \end{bmatrix} \\ &+ \begin{bmatrix} 0.9752 & -0.0064 \\ (0.0057) & (0.0018) \\ -0.0087 & 0.9723 \\ (0.0095) & (0.0055) \end{bmatrix} \begin{bmatrix} h_{Ma,t-1} \\ h_{US,t-1} \end{bmatrix}\end{aligned} \tag{11}$$

- Overall US return spillover, in general, had a positive effect on returns in all non-US markets, as evidenced by positive and statistically significant coefficients in Table 2. This suggests that the US mean returns, on average, improved market sentiments in the Asia-Pacific leading to upward adjustments of earnings forecasts for the markets since the Asia-Pacific return increase when the US return increases. In the other hand, the Japanese mean return spillover effects are reported in Table 2. There is no immediately discernable pattern of response to overall mean spillover across the markets as shown by non-significant coefficients (except Taiwan for the post-crisis period). The results can be attributed to the time difference of opening and closing hours between the Asia-Pacific markets and the US markets.

- Turning to Singapore, the results are similar to the case of Malaysia, the Japanese and US volatility is transmitted through the product of innovations of the two markets and the US volatility only during the more recent period. While through the innovation during the pre-crisis period. In this sense, more intense volatility spillovers are expected during the post-1997 period and milder ones during the pre-1997 one, mainly due to the persistence of the US volatility.

- Indonesia, the volatility is transmitted through both the Japanese and US volatility for the first period. While through the US market volatility and the Japanese innovation for the second period.

- No volatility is transmitted to Thailand market from the US; however it is transmitted through the Japanese market volatility during the first sub-sample.

- Contrary, to the aforementioned countries, Korea and Taiwan stock markets paint a whole different picture. During the pre-crisis and post-crisis no cross-market dependencies are apparent (except for Korea shows that it is affected by the Japanese volatility for the second period), as indicated by the diagonality of the corresponding BEKK models.

- Hong Kong market is not affected by the Japanese and US market volatility during the pre-crises, while there is volatility transformation from the US to the Hong Kong market for the post-crises. This is surprising, one would expect the Hong Kong and US economies to be closely linked. This finding suggests that volatility in Hong Kong may be driven heavily by local shocks or other shocks unrelated to the US markets, such as political risk and shocks from china.

- No evidence of volatility feed back from the Asia-Pacific markets to the US market, except for Singapore and Indonesia, for the pre-crisis and only Singapore for the post-crisis.

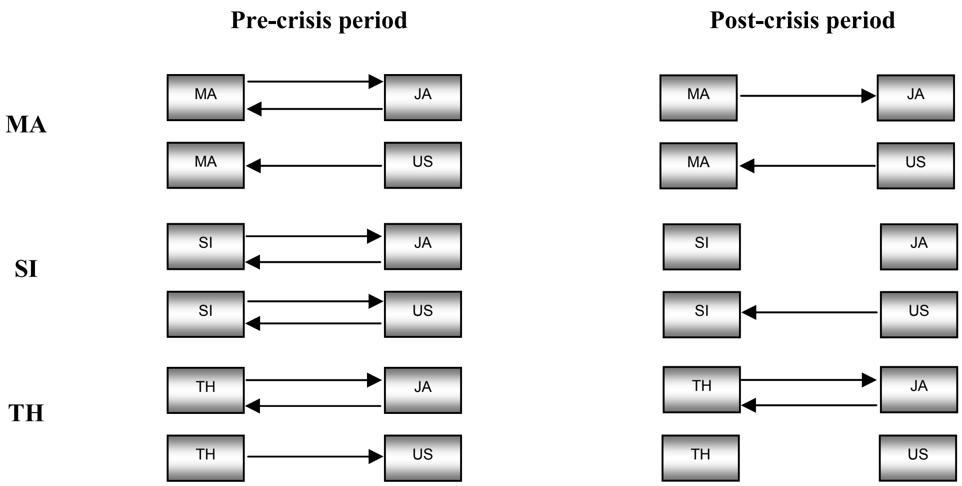
- In general, our results corroborate and extend the results of Ng (2000), Kim (2003) and Miyakoshi (2003). Ng (2000), suggest a greater influence from the US, whereas Miyakoshi (2003) study suggests a greater influence from the Japan on the Asia-Pacific markets. However, all these studies were performed with one whole sample without taking any consideration for the crisis.

Table 2: Time-varying spillover effects

	Pre-Crisis				**Post-Crisis**			
	Mean Spillover from Japan	**Mean Spillover from USA**	**Volatility Spillover from Japan**	**Volatility Spillover from USA**	**Mean Spillover from Japan**	**Mean Spillover from USA**	**Volatility Spillover from Japan**	**Volatility Spillover from USA**
MA	-0.00907 (0.02380) [0.7032]	0.31675 (0.02869) [0.0001]	0.50770 (0.01814) [0.0001]	-0.0108 (0.00410) [0.0082]	0.04571 (0.04304) [0.2885]	0.43857 (0.04415) [0.0001]	-0.01273 (0.04289) [0.7667]	-0.0064 (0.00182) [0.0004]
SI	0.00183 (0.02141) [0.9319]	0.43435 (0.02909) [0.0001]	0.92278 (0.03281) [0.0001]	-0.25189 (0.10479) [0.0163]	-0.02258 (0.02608) [0.3868]	0.33938 (0.02595) [0.0001]	-0.01073 (0.01407) [0.4458]	0.77583 (0.02461) [0.0001]
TH	0.04309 (0.02525) [0.0880]	0.29105 (0.04296) [0.0001]	0.02324 (0.0069) [0.0008]	0.00462 (0.00304) [0.1282]	0.02114 (0.02904) [0.4667]	0.21080 (0.02967) [0.0001]	0.17704 (0.07539) [0.0190]	0.02461 (0.05657) [0.6636]
IN	-0.00951 (0.01712) [0.5786]	0.13070 (0.02571) [0.0001]	0.20819 (0.06464) [0.0013]	-0.23065 (0.03158) [0.0001]	-0.03100 (0.02583) [0.2303]	0.19971 (0.02783) [0.0001]	-0.03611 (0.01372) [0.0086]	0.12433 (0.05597) [0.0265]
HK	-0.02845 (0.02226) [0.2014]	0.52361 (0.03395) [0.0001]	-0.01325 (0.00633) [0.0365]	0.00663 (0.03124) [0.8318]	0.01062 (0.02930) [0.7171]	0.52672 (0.02847) [0.0001]	0.01659 (0.00836) [0.0475]	0.55144 (0.01562) [0.0001]
KO	0.05277 (0.02600) [0.0425]	0.12265 (0.03996) [0.0022]	-0.03928 (0.05851) [0.5020]	-0.0078 (0.00495) [0.1135]	0.02822 (0.04228) [0.5046]	0.56852 (0.04001) [0.0001]	-0.01061 (0.00370) [0.0042]	0.11048 (0.06809) [0.1049]
TA	0.05311 (0.03419) [0.1205]	0.16464 (0.05143) [0.0014]	0.03800 (0.03118) [0.2231]	0.05033 (0.02801) [0.0726]	0.12110 (0.03079) [0.0001]	0.34553 (0.03310) [0.0001]	0.09654 (0.07851) [0.2190]	0.12021 (0.06882) [0.0809]

Note: Standard errors are given in parentheses; p-values are given in brackets.

The behaviors of the conditional variances of the series are starkly different in periods of examination. More importantly, our estimates of the eigen-values of the BEKK models suggest that volatility has become more persistent in the recent years, indicating that the duration of volatility spillovers is likely to increase. Earlier findings by Billio and Pelizzon (2003) and other studies have pointed to increased persistence in the equity returns volatility.



4. Concluding remarks

This paper investigates the dynamic interaction and changing nature of the return and volatility spillovers from Japan and the US to the Asia-Pacific markets. Price and volatility spillovers are examined in the context of a multivariate Generalized Autoregressive Conditional Heteroskedastic (GARCH), by adopting a bivariate BEKK representation and splitting our sample into sub-periods. Unlike previous related studies, this paper fully takes into account the crisis period. The major empirical findings are fourfold. First, only the influence of the US market is important on the Asia-Pacific markets mean returns; there is no influence from Japan market for both periods on the Asia-Pacific markets (except for Taiwan for the post-crisis period). Secondly, significant volatility spillovers from the Japanese and US markets to Asia-Pacific markets. However, Asia-Pacific markets volatility is influenced more by the Japanese market than by the US market for the pre-crisis period. Thirdly, there exists an adverse influence of volatility from the Asia-Pacific markets to the Japanese market. Finally, Asia-Pacific markets are more sensitive to volatility originating in other markets, especially when there is adverse volatility. A pre-and-post crisis analysis reveals that the Asia-Pacific markets have become more sensitive to innovations originating from Japan. In contrast to Ng (2000) and Miyakoshi (2003) studies which represents the primary previous research in this field, the results of this study suggest a greater influence from the Japan on Asian volatility than from the US for the pre-crisis period and find a new adverse influence from Asia-Pacific to Japan.

The differences between our results and the previous studies stem from a strong economic relationship between Japan and Asia-Pacific countries through the large amount of portfolio investment during the later half of 1990s. The previous studies did not take into account the crisis period. Thus, our paper purely examines the volatility spillover effects of the Japanese and US market within two sub-periods. Our finding suggests that for international investors to get profits from the returns of Asia-Pacific securities, it is necessary to pay attention to the US market directly. However, Asia-Pacific volatility is influenced more by Japanese market volatility. The stabilization of Asia-Pacific governments for their own markets is needed for Japanese market. Implementing global hedging strategies and asset allocation decisions on Asia-Pacific markets requires the information concerning the Japanese volatility behaviour.

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Appendix

Table 2 : Correlation matrix for all sample

	MA	SI	TH	IN	HK	KO	TA	US	JA
MA	1.0000	0.4545	0.3291	0.2470	0.3670	0.1838	0.1541	0.0209	0.2281
SI		1.0000	0.4189	0.3559	0.6016	0.3039	0.2331	0.1398	0.3712
TH			1.0000	0.2727	0.3436	0.2511	0.1752	0.0646	0.2179
IN				1.0000	0.2941	0.1656	0.1182	0.0075	0.1671
HK					1.0000	0.2829	0.2110	0.1158	0.3541
KO						1.0000	0.1963	0.0907	0.2526
TA							1.0000	0.0513	0.2147
US								1.0000	0.1123
JA									1.0000

Notes: Correlation is significant at the 0.01 level.

Table 3: Unrestricted estimated GARCH(1,1)-BEKK models
Spillover from US
Sub-sample Pre-Crisis (01JAN1990-30JUN1997)

	C_{11}	C_{12} C_{22}	$\square_{11}$ $\square_{\square 1}$	$\square_{1\square}$ $\square_{\square\square}$	$\square_{11}$ $\square_{\square 1}$	$\square_{1\square}$ $\square_{\square\square}$	Eigen-values	AICC	SBC
MA	0.111155 (0.124672) [0.3727]	0.00137 (0.00744) [0.8543]	0.35944 (0.07617) [0.0001]	0.02406 (0.00909) [0.0082]	0.90290 (0.01774) [0.0001]	-0.0108 (0.00410) [0.0082]	0.9976 0.9477 0.9477 0.9435	-3.70461	-3.686
		0.00818 (2.15228) [0.9970]	0.08882 (0.03426) [0.0096]	0.14401 (0.01440) [0.0001]	-0.00051 (0.00988) [0.9583]	0.98997 (0.00291) [0.0001]		**Log-like** -1993.237	
SI	0.0009042 (0.000) [0.0001]	-0.23412 (0.000) [0.0001]	0.46280 (0.08376) [0.0001]	0.05022 (0.03330) [0.1317]	0.55693 (0.17475) [0.0015]	-0.25189 (0.10479) [0.0163]	0.6861 0.3849 0.2842 0.3529	-4.48141	-4.475
		0.13277 (0.000) [0.0001]	0.41897 (0.04168) [0.0001]	0.15390 (0.03739) [0.0001]	-0.88048 (0.0995i) [0.0001]	-0.32556 (0.03986) [0.0001]		**Log-like** -2177.5236	
TH	0.12416 (0.14562) [0.3940]	-0.000742 (0.01060) [0.9442]	0.37191 (0.06275) [0.0001]	-0.0040 (0.00739) [0.5855]	0.90478 (0.01407) [0.0001]	0.00462 (0.00304) [0.1282]	0.9943 0.9681 0.9423 0.9277	-2.11377	-2.108
		0.02218 (0.23604) [0.9251]	0.28419 (0.05388) [0.0001]	0.12406 (0.01735) [0.0001]	-0.03755 (0.01812) [0.0384]	0.98900 (0.00286) [0.0001]		**Log-like** -1313.2756	
IN	0.0000712 (0.000) [0.0001]	-0.03809 (0.66019) [0.9540]	0.71141 (0.04880) [0.0001]	0.03583 (0.02435) [0.1415]	0.47940 (0.09181) [0.0001]	-0.23065 (0.03158) [0.0001]	0.7082 0.2128 0.2474 0.2474	-3.97127	-3.965
		0.28118 (0.31987) [0.3795]	0.34732 (0.03562) [0.0001]	-0.11528 (0.03110) [0.0002]	0.72706 (0.03911) [0.0001]	0.29110 (0.05176) [0.0001]		**Log-like** -2228.3047	
HK	0.19362 (0.13222) [0.1432]	-0.01986 (0.00688) [0.0039]	0.40628 (0.09262) [0.0001]	0.01390 (0.00788) [0.0777]	0.83521 (0.04396) [0.0001]	0.00663 (0.03124) [0.8318]	0.9956 0.8613 0.7546 0.7617	-3.15945	-3.153
		0.000151 (0.000) [0.0001]	0.27597 (0.05832) [0.0001]	0.15755 (0.01697) [0.0001]	-0.23936 (0.10304) [0.0203]	-0.98590 (0.00508) [0.0001]		**Log-like** -1626.6995	
KO	0.16225 (0.11412) [0.1553]	-0.00255 (0.00783) [0.7444]	0.33675 (0.07126) [0.0001]	0.01332 (0.01035) [0.1981]	0.90150 (0.01663) [0.0001]	-0.0078 (0.00495) [0.1135]	0.9955 0.9401 0.9356 0.9356	-3.11051	-3.104
		0.00952 (1.76651) [0.9957]	0.02808 (0.05332) [0.5985]	0.14267 (0.01498) [0.0001]	0.01829 (0.01652) [0.2684]	0.98973 (0.00294) [0.0001]		**Log-like** -1492.4473	
TA	0.09362 (0.14898) [0.5298]	0.02300 (0.03203) [0.4728]	0.25085 (0.07476) [0.0008]	-0.01093 (0.00515) [0.0341]	0.95295 (0.01146) [0.0001]	0.05033 (0.02801) [0.0726]	0.9917 0.9861 0.9811 0.9817	-2.95609	-2.950
		0.00774 (10.96672) [0.9994]	0.07791 (0.04857) [0.1088]	-0.1312 (0.01548) [0.0001]	0.31739 (0.18527) [0.0868]	-0.9791 (0.00978) [0.0001]		**Log-like** -922.10369	
JA	0.10670 (0.11076) [0.3355]	0.00929 (0.00903) [0.3041]	0.40370 (0.06170) [0.0001]	0.01047 (0.01127) [0.3531]	0.88877 (0.01595) [0.0001]	-0.00532 (0.00540) [0.3244]	0.9956 0.9484 0.9435 0.9358	-4.07645	-4.070
		0.02104 (0.25503) [0.9343]	0.13005 (0.03704) [0.0005]	0.14927 (0.01682) [0.0001]	-0.01604 (0.01291) [0.2142]	0.98674 (0.00341) [0.0001]		**Log-like** -1965.858	

Notes: Standard errors are given in parentheses; p-values are given in brackets. Log-like is the log-likelihood function, AICC and SBC are the corrected Akaike Information criterion, Schwarz Bayesian Criterion respectively.

Table 4: Unrestricted estimated GARCH(1,1)-BEKK models
Spillover from US
Sub-sample Post-Crisis (01JAN1999-30DEC2004)

	C_{11}	C_{12} C_{22}	α_{11} α_{21}	α_{12} α_{22}	β_{11} β_{21}	β_{12} β_{22}	**Eigen-values**	**AICC**	**SBC**
MA	0.08858	0.04793	0.20295	0.03224	0.97520	-0.0064			
	(0.2159)	(0.00935)	(0.11018)	(0.00765)	(0.00565)	(0.00182)	0.9933	-3.52052	-3.4999
	[0.6818]	[0.0001]	[0.0657]	[0.0001]	[0.0001]	[0.0004]	0.9906		
		0.00005	0.02887	-0.20471	-0.00871	0.97234	0.9057		
		(27.14160)	(0.03803)	(0.02104)	(0.00948)	(0.00551)	0.9033	**Log-like**	
		[1.0000]	[0.4479]	[0.0001]	[0.3586]	[0.0001]		419.2326	
SI	0.08775	0.02784	0.13167	-0.20625	0.68858	0.77583			
	0.19183	(0.06191)	(0.20052)	(0.02321)	(0.03525)	(0.02461)	0.9877	-4.89774	-4.8772
	0.6474	[0.6529]	[0.5115]	[0.0001]	[0.0001]	[0.0001]	0.9834		
		0.00023	0.17344	0.27593	-0.79260	0.43037	0.8389		
		(0.000)	(0.03225)	(0.02265)	(0.02483)	(0.02324)	0.8389	**Log-like**	
		[0.0001]	[0.0001]	[0.0001]	[0.0001]	[0.0001]		-670.7524	
TH	0.14514	0.02822	0.28875	0.01569	0.93560	0.02461			
	(0.22252)	(0.01605)	(0.09999)	(0.02808)	(0.01833)	(0.05657)	0.9973	-4.02377	-4.0032
	[0.5143]	[0.0789]	[0.0039]	[0.5763]	[0.0001]	[0.6636]	0.9549		
		0.000059	-0.07626	0.17691	-0.11119	-0.98396	0.8656		
		(60.96031)	(0.02951)	(0.02340)	(0.09777)	(0.00527)	0.8674	**Log-like**	
		[1.0000]	[0.0098]	[0.0001]	[0.2556]	[0.0001]		-184.4281	
IN	0.39411	0.03871	0.48248	0.08403	0.61138	0.12433			
	(0.09021)	(0.02000)	(0.07881)	(0.02007)	(0.11247)	(0.05597)	0.9936	-4.03096	-4.0104
	[0.0001]	[0.0531]	[0.0001]	[0.0001]	[0.0001]	[0.0265]	0.6137		
		0.000001	-0.11205	0.17552	0.14447	-0.96939	0.5165		
		(0.000)	(0.04499)	(0.01781)	(0.08365)	(0.01130)	0.5296	**Log-like**	
		[0.0001]	[0.0129]	[0.0001]	[0.0844]	[0.0001]		-312.7517	
HK	0.05877	-0.01814	0.16604	-0.08282	0.83544	0.55144			
	(0.49931)	(0.04728)	(0.14463)	(0.02536)	(0.02152)	(0.01562)	0.9939	-4.59019	-4.5696
	[0.9063]	[0.7013]	[0.2511]	[0.0011]	[0.0001]	[0.0001]	0.9938		
		0.000079	0.11753	0.19164	-0.67961	0.69122	0.9235		
		(26.65380)	(0.03868)	(0.02152)	(0.01994)	(0.01761)	0.9235	**Log-like**	
		[1.0000]	[0.0024]	[0.0001]	[0.0001]	[0.0001]		-466.3833	
KO	0.05734	-0.03068	0.15639	0.03544	0.98898	0.11048			
	(0.38413)	(0.000)	(0.22530)	(0.01668)	(0.01150)	(0.06809)	0.9952	-3.65797	-3.6374
	[0.8813]	[0.0001]	[0.4877]	[0.0338]	[0.0001]	[0.1049]	0.9947		
		0.01643	-0.02975	-0.21968	-0.06101	-0.97682	0.9926		
		(0.000)	(0.04513)	(0.02411)	(0.19257)	(0.01076)	0.9931	**Log-like**	
		[0.0001]	[0.5099]	[0.0001]	[0.7514]	[0.0001]		148.62487	
TA	0.10529	-0.02498	0.26181	0.01198	0.95683	0.12021			
	(0.19650)	(0.01858)	(0.10474)	(0.02130)	(0.01381)	(0.06882)	0.9962	-4.1835	-4.1629
	[0.5922]	[0.1790]	[0.0125]	[0.5740]	[0.0001]	[0.0809]	0.9807		
		0.00709	0.00524	-0.19319	-0.03111	-0.98105	0.9856		
		(7.87798)	(0.05638)	(0.02323)	(0.13938)	(0.00840)	0.9860	**Log-like**	
		[0.9993]	[0.9260]	[0.0001]	[0.8234]	[0.0001]		-103.6070	
JA	0.09537	-0.05114	0.000004	-0.19287	0.95599	0.38609			
	(0.27943)	(0.03618)	(0.000)	(0.02156)	(0.01755)	(0.01400)	0.9760	-3.95238	-3.9318
	[0.7329]	[0.1578]	[0.0001]	[0.0001]	[0.0001]	[0.0001]	0.8950		
		0.000183	-0.15800	0.19562	-0.38055	0.81439	0.9305		
		(19.64300)	(0.07488)	(0.06242)	(0.02264)	(0.02015)	0.9305	**Log-like**	
		[1.0000]	[0.0350]	[0.0018]	[0.0001]	[0.0001]		-533.8621	

Notes: Standard errors are given in parentheses; p-values are given in brackets. Log-like is the log-likelihood function, AICC and SBC are the corrected Akaike Information criterion, Schwarz Bayesian Criterion respectively.

Table 5: Unrestricted Estimated GARCH(1,1)-BEKK Models
Spillover from Japan
Sub-sample Pre-Crisis (01JAN1990-30JUN1997)

	C_{11}	C_{12} C_{22}	α_{11} α_{21}	α_{12} α_{22}	β_{11} β_{21}	β_{12} β_{22}	Eigen-values	AICC	SBC
MA	0.09259 (0.30905) [0.7645]	-0.12563 (0.02602) [0.0001]	0.10170 (0.37744) [0.7876]	-0.21342 (0.02740) [0.0001]	0.93298 (0.01960) [0.0001]	0.50770 (0.01814) [0.0001]	0.9356 0.7396 0.8286 0.8286	-4.00936	- 3.9922
		0.00015 (0.000) [0.0001]	-0.27427 (0.03044) [0.0001]	-0.28967 (0.04058) [0.0001]	-0.49333 (0.02254) [0.0001]	0.61861 (0.02754) [0.0001]		**Log-like** - 1132.5791	
SI	0.12298 (0.20345) [0.5456]	-0.12731 (0.03166) [0.0001]	0.28034 (0.08707) [0.0013]	-0.05313 (0.03550) [0.1347]	0.70742 (0.03633) [0.0001]	0.92278 (0.03281) [0.0001]	0.903 0.8672 0.6298 0.6298	-3.85797	- 3.8408
		0.00024 (11.13462) [1.0000]	0.23570 (0.02411) [0.0001]	0.36498 (0.03097) [0.0001]	-0.61239 (0.03076) [0.0001]	0.26464 (0.02904) [0.0001]		**Log-like** - 1468.3289	
TH	0.12581 (0.12962) [0.3319]	0.00710 (0.01519) [0.6403]	0.35444 (0.06190) [0.0001]	-0.02474 (0.01422) [0.0821]	0.91982 (0.01136) [0.0001]	0.02324 (0.0069) [0.0008]	0.9769 0.9737 0.9657 0.9657	-2.02248	- 2.0053
		0.08173 (0.10817) [0.4500]	0.10222 (0.02694) [0.0002]	0.31685 (0.01999) [0.0001]	-0.05355 (0.01169) [0.0001]	0.93235 (0.00761) [0.0001]		**Log-like** -561.0561	
IN	0.18661 (0.06449) [0.0038]	0.11902 (0.02147) [0.0001]	0.54129 (0.06156) [0.0001]	0.09862 (0.03002) [0.0010]	0.67833 (0.04394) [0.0001]	0.20819 (0.06464) [0.0013]	0.9684 0.7577 0.8219 0.8283	-4.03179	- 4.0146
		0.02528 (2.97869) [0.9932]	-0.15301 (0.01839) [0.0001]	-0.37606 (0.02235) [0.0001]	0.14546 (0.04230) 0.0006	-0.89868 0.01481 0.0001		**Log-like** - 1562.3007	
HK	0.10887 (0.11298) [0.3353]	0.06980 (0.01281) [0.0001]	0.25320 (0.09462) [0.0075]	0.01175 (0.01578) [0.4563]	0.94982 (0.00994) [0.0001]	-0.01325 (0.00633) [0.0365]	0.9831 0.9663 0.9576 0.9485	-3.03818	- 3.0210
		0.07655 (0.13949) [0.5832]	0.08359 (0.02087) [0.0001]	0.38502 (0.02283) [0.0001]	-0.03631 (0.00907) [0.0001]	0.90712 (0.01081) [0.0001]		**Log-like** -936.3601	
KO	0.20253 (0.16608) 0.2228	-0.10295 (0.01377) [0.0001]	0.33087 (0.09866) [0.0008]	-0.04713 (0.02022) [0.0199]	0.86214 (0.03546) [0.0001]	-0.03928 (0.05851) [0.5020]	0.9638 0.8670 0.6632 0.6667	-3.44251	- 3.4254
		0.000389 (0.000) [0.0001]	0.04935 (0.05507) [0.3703]	0.37574 (0.02473) [0.0001]	-0.27230 (0.09258) [0.0033]	-0.90371 (0.01713) [0.0001]		**Log-like** -700.0515	
TA	0.05833 (0.21182) [0.7831]	-0.10355 (0.01055) [0.0001]	0.20172 (0.07774) [0.0095]	-0.01780 (0.01479) [0.2292]	0.97942 (0.00446) [0.0001]	0.03800 (0.03118) [0.2231]	0.9923 0.9581 0.9578 0.9602	-3.14303	- 3.1259
		0.000215 (16.57564) [1.0000]	-0.10874 (0.03237) [0.0008]	-0.36803 (0.02484) [0.0001]	-0.20823 (0.09468) [0.0280]	-0.91069 (0.01177) [0.0001]		**Log-like** -138.5914	

Notes: Standard errors are given in parentheses; p-values are given in brackets. Log-like is the log-likelihood function, AICC and SBC are the corrected Akaike Information criterion, Schwarz Bayesian Criterion respectively.

Table 6: Unrestricted Estimated GARCH(1,1)-BEKK Models
Spillover from Japan
Sub-sample Post-Crisis (01JAN1999-30DEC2004)

	C_{11}	C_{12} C_{22}	α_{11} α_{21}	α_{12} α_{22}	β_{11} β_{21}	β_{12} β_{22}	Eigen-values	AICC	SBC
MA	0.02124 (1.42138) [0.9881]	-0.12758 (0.02372) [0.0001]	0.20974 (0.14821) [0.1572]	0.00532 (0.01068) [0.6188]	0.96719 (0.02255) [0.0001]	-0.01273 (0.04289) [0.7667]	0.9899 0.9525 0.9687 0.9705	-2.5532	-2.5326
		0.01193 (13.20149) [0.9993]	-0.32294 (0.04035) [0.0001]	-0.25722 (0.02768) [0.0001]	-0.86335 (0.12272) [0.0001]	-0.93619 (0.02347) [0.0001]		**Log-like** 627.5354	
SI	0.05591 (0.29894) [0.8517]	0.05740 (0.04845) [0.2363]	0.26108 (0.10467) [0.0127]	0.02691 (0.03237) [0.4060]	0.95513 (0.01089) [0.0001]	-0.01073 (0.01407) [0.4458]	0.9826 0.9239 0.8243 0.8183	-4.26208	-4.2415
		0.14200 (0.17331) [0.4127]	-0.22302 (0.02684) [0.0001]	-0.28596 (0.03297) [0.0001]	0.00515 (0.01657) [0.7563]	0.92862 (0.01784) [0.0001]		**Log-like** -520.4297	
TH	0.06574 (0.32925) [0.8418]	0.12627 (0.01722) [0.0001]	0.17666 (0.20730) [0.3942]	0.04796 (0.02120) [0.0238]	1.01339 (0.01026) [0.0001]	0.17704 (0.07539) [0.0190]	0.9931 0.9580 0.9660 0.9666	-3.4452	-3.4246
		0.00011 (0.000) [0.0001]	-0.13940 (0.02436) [0.0001]	-0.30374 (0.02655) [0.0001]	-0.33304 (0.10846) [0.0022]	-0.96506 (0.01302) [0.0001]		**Log-like** -15.31021	
IN	0.22758 (0.16044) [0.1563]	0.03632 (0.02710) [0.1804]	0.37399 (0.11053) [0.0007]	0.04267 (0.02200) [0.0527]	0.85675 (0.04440) [0.0001]	-0.03611 (0.01372) [0.0086]	0.9694 0.9171 0.9156 0.8909	-3.2472	-3.2266
		0.08907 (0.23009) [0.6987]	0.02606 (0.04308) [0.5453]	0.26376 (0.02560) [0.0001]	0.01174 (0.02554) [0.6459]	0.95606 (0.01043) [0.0001]		**Log-like** -132.3166	
HK	0.04584 (0.32979) [0.8895]	0.13382 (0.02080) [0.0001]	0.10222 (0.26506) [0.6998]	-0.07809 (0.03232) [0.0158]	0.99699 (0.00369) [0.0001]	0.01659 (0.00836) [0.0475]	0.9976 0.9588 0.9496 0.9496	-4.0136	-3.9930
		0.00011 (0.000) [0.0001]	0.11882 (0.02755) [0.0001]	0.33347 (0.03106) [0.0001]	-0.03861 (0.00927) [0.0001]	0.91761 (0.01542) [0.0001]		**Log-like** -335.1063	
KO	0.08879 (0.21016) [0.6727]	0.12290 (0.01796) [0.0001]	0.16597 (0.13167) [0.2077]	0.06268 (0.01850) [0.0007]	0.98426 (0.00385) [0.0001]	-0.01061 (0.00370) [0.0042]	0.9975 0.9432 0.9060 0.8954	-3.32704	-3.3065
		0.00001 (61.4169) [1.0000]	-0.25947 (0.03275) [0.0001]	-0.30662 (0.03038) [0.0001]	-0.01749 (0.01055) [0.0974]	0.94508 (0.01175) [0.0001]		**Log-like** 259.2548	
TA	0.12324 (0.15302) [0.4207]	0.14857 (0.02286) [0.0001]	0.24309 (0.12088) [0.0445]	-0.03623 (0.02388) [0.1295]	0.98951 (0.01857) [0.0001]	0.09654 (0.07851) [0.2190]	0.9892 0.9369 0.8248 0.8256	-3.42482	-3.4042
		0.000086 (54.1161) [1.0000]	-0.00436 (0.02973) [0.8835]	0.28099 (0.03120) [0.0001]	-0.54835 (0.11747) [0.0001]	-0.95674 (0.02468) [0.0001]		**Log-like** 63.75072	

Notes: Standard errors are given in parentheses; p-values are given in brackets. Log-like is the log-likelihood function, AICC and SBC are the corrected Akaike Information criterion, Schwarz Bayesian Criterion respectively.