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REGIONAL AND INTERNATIONAL LINKAGES OF THE ASEAN-5 STOCK MARKETS: A MULTIVARIATE GARCH APPROACH

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ABSTRACT

This paper examines the linkages among the ASEAN-5 stock exchanges, and their relationship with the Hong Kong and U.S. markets by using the multivariate GARCH approach for the period before and after the global financial crisis. The mean and volatility spillover effects are analysed. The mean, past-volatility, and past-shock spillovers between the ASEAN stock markets occurred to a lesser extent in the post-crisis period. While these findings suggest weaker linkages, the reaction to bad market news has strengthened after the crisis. The U.S. market is the main source to the mean spillover effects. Although the past-volatility and past-shock spillovers effects from the Hong Kong market are larger, the ASEAN markets tend to react more strongly towards unfavourable U.S. market news.

Keywords: global crisis, linkages, multivariate GARCH, spillover effects, stock market

INTRODUCTION

Over time, different economies have become more integrated due to factors such as improvement in mobility and communication technology, the development of trade regionalism, liberalisation of cross-border transactions, free flow of capital, and reduction in the cost of trade (Ethier, 2001). At the same time, international stock markets have been perceived to become more integrated as well. A shock that occurs in one market will be transmitted very quickly into other markets given the efficiency of borderless information flow. Masson (1998) termed this as 'monsoonal effects'. The subject of stock market integration has been defined broadly from the asset pricing and the statistical viewpoint (Naranjo & Aris, 1997; Cheng, 2000). Theoretically, the definition based on the asset pricing is that the perfectly integrated markets obey the law of one price (Kleimeier & Herald, 2000). The rationale behind this definition is that similar securities with the same risk characteristics should have same valuations regardless of the locations in which they are traded. Perfect financial integration will occur when capital controls and other institutional barriers do not exist, and hence, there will be no arbitrage opportunity. The definition based on the statistical viewpoint is that stock markets are integrated when the prices of different markets share a common equilibrium path in the long run.

A considerable amount of empirical works have been conducted on the integration of stock markets in terms of linkages of stock markets in the first moment of the distribution of returns. Time-series econometric techniques such as VAR and cointegration were applied to examine the transmission of stock market movements. Among others, such works include Palac-McMiken (1997), Wong, Penm, Terrell and Lim (2004), Goh, Wong and Kok (2005), Hawati, Ruhani and Roselee (2007), Karim and Majid (2009), Kamaralzaman, Samad and Isa (2011), and Yeoh, Hooy and Arsad (2010). More recent works such as that of Lean and Smyth (2013) highlighted the need to use cointegration methods with structural breaks to take into account of the changes due to crises that affect stock market integration. There were also studies that advocated the application of other techniques such as the bounds test of cointegration in the mean process based on autoregressive distributed lag models (e.g. Bakri & Zulkefly, 2012).

The focus of this paper is on linkages of stock markets in the second moment. Stock market can fluctuate in a dramatic manner and the price movements can appear to be too volatile to be justified by fundamentals alone. In addition to fundamentals, market volatility is also driven by information in the market and market expectation. Such phenomenon remains the key to modern financial market research where the subject of stock market volatility has been under examination extensively (Shiller, 1981). The importance of volatility in finance is obvious – the equilibrium price from asset pricing models is vulnerable to changes in volatility, fund managers put great emphasis on the mean-variance hypothesis, and the valuation of derivatives depends on the volatility forecast. Portfolio managers, risk managers, arbitrageurs, and treasurers monitor volatility trends closely as variations in prices will have significant effects on investment and risk decisions.

The 1987 international crash of stock markets remains the catalyst to the proliferation of studies on volatility linkages across markets. The common results of Aderhold, Cumming and Harwood (1988), Bennett and Kelleher (1988), Dwyer and Hafer (1988), Goodhart (1988), and Neumark, Tinsley and Tosini (1988) indicated that the high co-movement of international stock markets during the Black Monday crash was transitory in nature. At the same time, many studies showed that the linkages between stock markets have increased significantly after the 1987 crash period. The findings increased the inclination to implement certain regulations and institutional rules in order to reduce the cross-market impacts of large stock prices movements. Volatility of spillovers were also studied by Susmel and Engle (1994), Koutmos and Booth (1995), Longin and Solnik (1995), and Kanas (1998). Common findings are that linkages between stock markets are inclined to increase in the period of high volatility, and higher degree of spillovers was observed during the post-crash period than the pre-crash period, suggesting that these stock markets were more interconnected after the crisis. The 1997 Asian financial crisis sparked similar interest on the linkages of the stock markets in Asia (see, for example, In, Kim, Yoon & Viney, 2001; Worthington & Higgs, 2004; Lee, 2009; Joshi, 2011). Again, the crisis has contributed to more evidence of higher volatility spillover. Another interest finding is that own-volatility spillover was higher than cross-market spillover for the emerging stock markets. The fact that the changes in volatility due to domestic innovations were relatively more significant is itself a revelation of market integration to a lesser extent, a feature of the Asian markets.

A key development in the literature on linkages in the second moment is the recent shift in the application of univariate approaches to multivariate GARCH modelling. Xu and Sun (2010), for example, employed the multivariate GARCH in the form of BEKK to investigate the dynamic linkages between China and the U.S. stock markets under two recent financial crises, namely, the Asian financial crisis and the 2007–2010 subprime global crisis. The dynamic conditional correlation multivariate GARCH model was applied by Teng, Yen, Chua and Lean (2013) to study if the stock markets of ASEAN-5 are integrated with China and India. Lean and Teng (2013) used the same method to estimate volatility spillover from advanced markets and emerging powers to the Malaysian stock exchange. Following this development, this paper examines the linkages of ASEAN stock markets with the application of multivariate GARCH for modelling the second moment of the distribution of returns while taking into account the effect of the global financial crisis. This research initiative has not been sufficiently explored in the literature.

The five founder countries of ASEAN are selected to study the linkages in terms of the stock return and volatility transmission among their stock markets, as well as with the developed stock markets. Price movements in the Hong Kong and U.S. stock markets are included to represent movements in the regional and world markets, respectively. Given the massive evidence of integration among the developed and developing stock markets, Kearney and Lucey (2004) pointed out that investors around the world need to keep an eye on risks associated with the increased welfares of portfolio diversification. This reinforces the intention to study the linkages among these liberalised stock markets.

The liberalisation process of the financial markets in the recent years has attracted investors to expose themselves to the international stock markets which offer various sophisticated investment instruments. Liberalisation means the result of the loosening in home price and quantity restrictions, higher foreign involvement in local financial markets, higher capital movements among countries, and new innovative financial products and services. Asian countries such as Malaysia, Indonesia, Philippines, Thailand, Singapore, and Hong Kong have undergone stock market liberalisations at different period of time which can be summarised using three indicators, namely, the official liberalisation date, the first country fund, and the first ADR (American Depository Receipts) as in Table 1. The official liberalisation date can be defined as a date of regulatory change after which the foreign investors have the option to transact in local shares and local investors have the same privilege to invest in the liberalised foreign stock markets (Bekaert & Harvey, 2000). Closed-end mutual funds (investment entity that manages a portfolio which consists of foreign assets but issues fixed number of shares locally), were the first vehicle for foreign investment in developing financial markets. ADR is a right to foreign stocks that are traded in dollar currency on the U.S. stock exchange or over-the-counter (OTC). Since ADRs are normally treated as U.S. securities, they allow pension funds, mutual funds, and other U.S. institutions to hold securities with the flexibility of exchangeable or replaceable with foreign shares. From these indicators, the financial markets of Hong Kong and ASEAN-5 countries had liberalised since beginning of 1990s. It should be noted that liberalisation does not mean that foreign investments can freely flow given the various forms of direct and indirect barriers. Harrison (1994) elaborated that the barriers which existed at the end of 1989 for the institutional investors include limits on foreign ownership, withholding taxes on dividend and taxes on capital gains.

This study also examines if there are significant changes in the degree of linkages among the selected stock markets before and after the 2008 global financial crisis. The financial crisis 2007–2008 that saw the collapse of many prominent financial institutions was regarded as the worst financial crisis since the Great Depression in 1930. The financial leverage that was increased significantly by these institutions before the crisis led to high exposure to financial shocks. The institutions that have high ratios of debt relative to equity were unable to deleverage concurrently without significant decreases in the value of their assets. This situation had led to the distress of the whole economy where business and consumer confidence dropped significantly, and economic activities suffered a downturn, which in turn increased the unemployment rate. This crisis had resulted downturns in the stock markets around the world. Issues and problems related to bank solvency, shortage of credit availability and discredited investor confidence were among the factors that affected the global stock markets where share prices declined dramatically during 2008 and early 2009.

Table 1
Indicators of stock market liberalisation

Country	Official Liberalisation Date	First Country Fund	First ADR
Hong Kong	January 1973[a]	–	–
Malaysia	December 1988[b]	December 1987[b]	August 1992[b]
Indonesia	September 1989[b]	February 1989[b]	April 1991[c]
Thailand	September 1987[c]	July 1985[b]	January 1991[b]
Philippines	June 1991[c]	May 1986[b]	March 1991[b]
Singapore	June 1978[a]	–	–

[a] see Phylaktis and Ravazzolo (2002), [b] see Bekaert and Harvey (1998), and [c] see Bekaert and Harvey (2000).

METHODOLOGY AND DATA

The Sup Wald test proposed by Vogelsang (1997) was used to estimate the occurrence of the break points related to the crisis. The advantage of this test is that there is no need for prior logical setting about the structural break dates while it provides endogenous estimates. In addition, this test is applicable to data which have the characteristics of unit root, non-constant mean, and the presence of autocorrelation problems. The Sup Wald test involves the estimation of an autoregressive process around the *n*-th order deterministic trend with a break at T_b which can be stated as:

$$\ln p_{it} = \alpha + \sum_{j=0}^{n} \beta_j^{t^j} + \sum_{j=0}^{n} \gamma_j DT_{jt} + \sum_{j=1}^{m} \delta_j \ln p_{it-j} + \varepsilon_{it} \tag{1}$$

where p_{it} is the stock market index for country i at period t, $i = 1, 2, \ldots, 7$ (representing the stock market of U.S., Hong Kong, and the ASEAN-5 (Malaysia, Indonesia, Thailand, Philippines, Singapore), respectively), $t = 1, 2, \ldots, T$ with T being the number of observations for the period under consideration, while $DT_{jt} = (t - T_b)^j$ if $t > T_b$, and zero otherwise. Equation (1) was estimated sequentially for each possible break date. As the crisis is known to evolve around 2007–2008, the search for break points was performed within the three-year period up to the end of 2008 to identify the exact date of structural change due to the crisis. The three years thereafter were also searched for another date for the recovery from the crisis. Equation (1) was estimated in a consecutive manner for each possible break date with 5 percent trimming in the range of $0.05T < T_b < 0.95T$. The Wald statistic $W_T^n(T_b/T)$ is computed in order to test the null hypothesis of $\gamma_0 = \gamma_1 = \ldots = \gamma_n = 0$ in each stage. The supremum statistic is stated as follows:

$$\sup W_T^n = \sup_{T_b \in C} W_T^n (T_b / T) \tag{2}$$

where C is the set consisting of the possible break point dates. The Sup Wald statistic is for testing the null hypothesis of no break change against the alternative hypothesis that at least one of the polynomial trends has a structural break. The critical values for the stationary and unit root case are given in Vogelsang (1997). The critical values for 5% trimming used in this study were interpolated from the the critical values for 1% and 15% trimming. The test was performed on n = 0, 1 and 2 and as in the equations below:

$$\ln p_{it} = \alpha + \beta_0 + \gamma_0 DT_{0t} + \sum\nolimits_{j=1}^{m} \delta_j \ln p_{i,t-j} + \varepsilon_{it} \tag{3a}$$

$$\ln p_{it} = \alpha + \beta_0 + \beta_1 t + \gamma_0 DT_{0t} + \gamma_1 DT_{1t} + \sum\nolimits_{j=1}^{m} \delta_j \ln p_{i,t-j} + \varepsilon_{it} \tag{3b}$$

$$\ln p_{it} = \alpha + \beta_0 + \beta_1 t + \beta_2 t^2 + \gamma_0 DT_{0t} + \gamma_1 DT_{1t} + \gamma_2 DT_{2t} + \sum\nolimits_{j=1}^{m} \delta_j \ln p_{i,t-j} + \varepsilon_{it} \tag{3c}$$

The break dates identified were used to define the pre-, during, and post-global crisis period.

The multivariate GARCH model was used to explore empirically the linkages of the seven selected stock markets. Let the return of the stock market be defined as $r_{it} = \ln p_{it} - \ln p_{it-1}$. The multivariate GARCH model will be used to examine the combined mechanisms which are related to the market returns. The model for the mean of the process was estimated by:

$$r_t = \mu + \Gamma r_{t-1} + \varepsilon_t \tag{4}$$

where $r_t = (r_{1t}, r_{2t}, ..., r_{7t})'$ is a 7 × 1 vector of returns at time t, r represents a 7 × 7 matrix which contains the parameters attached to the lagged returns, and $\varepsilon_t \left| I_{t-1} \sim N(0, H_t)\right.$. The diagonal elements, say γ_{ii} , in matrix, r, represent the own-market mean spillovers while the off-diagonal elements, γ_{ij}, represent the cross-market mean spillovers. The term $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, ..., \varepsilon_{7t})'$ is a 7 × 1 vector of random errors, representing the shock of each stock market. The information set, I_{t-1} represents the information available to all the markets at time t – 1 and α is the 7 × 1 vector of constants. The conditional variance-covariance matrix H_t that consists of both diagonal (variance) and non-diagonal elements (covariance) can be stated as follows:

$$H_t = \begin{pmatrix} h_{11t} & h_{12t} & h_{13t} & h_{14t} & h_{15t} & h_{16t} & h_{17t} \\ h_{21t} & h_{22t} & h_{23t} & h_{24t} & h_{25t} & h_{26t} & h_{27t} \\ h_{31t} & h_{32t} & h_{33t} & h_{34t} & h_{35t} & h_{36t} & h_{37t} \\ h_{41t} & h_{42t} & h_{43t} & h_{44t} & h_{45t} & h_{46t} & h_{47t} \\ h_{51t} & h_{52t} & h_{53t} & h_{54t} & h_{55t} & h_{56t} & h_{57t} \\ h_{61t} & h_{62t} & h_{63t} & h_{64t} & h_{65t} & h_{66t} & h_{67t} \\ h_{71t} & h_{72t} & h_{73t} & h_{74t} & h_{75t} & h_{76t} & h_{77t} \end{pmatrix} \tag{5}$$

where h_{iit} represents the conditional variance of stock market i, and h_{ijt} represents the conditional covariance between stock markets i and j, $i \neq j$, at time t.

Engle and Kroner (1995) suggested the BEKK model as follows:

$$H_t = C'C + A'H_{t-1}A + B'\varepsilon_{t-1}\varepsilon'_{t-1}B \tag{6}$$

An advantage of this model is that it ensures H_t is positive definite due to the quadratic form of the terms in the right-hand-side of Equation (6). There is an extension to the BEKK model proposed by Kroner and Ng (1998) which allows the asymmetric element to be taken into account. In other words, this extension provides the measurement about the asymmetric responses due to the different sign of the innovation. The general view is that the volatility of a stock market is relatively higher due to the response towards the negative shocks compared to the positive counterparts. The extension to the BEKK model is expressed as:

$$H_t = C'C + A'H_{t-1}A + B'\varepsilon_{t-1}\varepsilon'_{t-1}B + D'E_{t-1}E'_{t-1}D \tag{7}$$

where $E_t = \varepsilon_t$ if $\varepsilon_t < 0$ and zero if $\varepsilon_t < 0$. Therefore, the fourth term of the right-hand-side of Equation (7) captures the measurement of the asymmetric responses towards positive and negative shocks. A, B and D are parameter matrices of 7×7 and C represents the 7×7 matrix of constants. The model may be untenable due to the large number of parameters that need to be estimated. When restrictions are imposed on the A, B and D matrices, a diagonal version of the BEKK model is obtained, which contains lesser parameters. The diagonal version of the BEKK model can be formulated from the full BEKK parameterization if and only if each of the matrices mentioned in Equation (7) are diagonal. The formulation will be as follows:

$$h_{iit} = c_{ii} + a_{ii}^2 h_{iit-1} + b_{ii}^2 \varepsilon_{it-1}^2 + d_{ii}^2 E_{it-1}^2 \tag{8}$$

$$h_{ijt} = c_{ij} + a_{ii} a_{jj} h_{ijt-1} + b_{ii} b_{jj} \varepsilon_{it-1} \varepsilon_{jt-1} + d_{ii} d_{jj} E_{it-1} E_{jt-1} \tag{9}$$

where c_{ii} and c_{ij} are constants, a_{ii} is the diagonal element of A, b_{ii} is the diagonal element of B, and d_{ii} is the diagonal element of D. The term a_{ii}^2 is the coefficient of lagged own-volatility of market i, b_{ii}^2 is the coefficient of lagged own-volatility shocks of market i, and d_{ii}^2 is the coefficient of lagged own-negative volatility shocks.

These specifications imply that the volatility spillovers within one series depend on the past volatility spillovers (the effects arising from past volatility), past shocks (the effects arising from past squared innovations), and past negative shocks. The co-volatility spillovers are due to the past co-volatility, cross-products of past disturbances, and cross-products of past negative shocks between two markets (i and j). The effects are given by the cross-products of diagonal elements of A ($a_{ii}a_{jj}$), B ($b_{ii}b_{jj}$), and D ($d_{ii}d_{jj}$), respectively. Let these effects be denoted by $\alpha_{ij} = a_{ii}a_{jj}$, $\beta_{ij} = b_{ii}b_{jj}$ and $\delta_{ij} = d_{ii}d_{jj}$. The parameters of these models are estimated by using the maximum log-likelihood method. The mechanism of this estimation is to maximise the log-likehood function specified as:

$$\ell(\theta) = -\frac{7T}{2}\ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T}(\ln|H_t| + \varepsilon_t' H_t^{-1} \varepsilon_t) \tag{10}$$

where θ denotes the vector of all the unknown parameters to be estimated.

The data used in this study are the daily closing prices of the stock markets of Malaysia, Indonesia, Thailand, the Philippines, Singapore, U.S., and Hong Kong. The stock indices selected are Kuala Lumpur Composite Index (now known as the FTSE Bursa Malaysia KLCI), Jakarta Composite Index (JCI), Stock Exchange of Thailand Index (SET), the Philippines Composite Index (PCOMP), Straits Times Index (STI), the S&P 500 Index (SPX), and Hang Seng Index (HSI). The S&P 500 Index represents the market indicator of the global financial centre, while the Hang Seng Index represents the regional financial centre in South-East Asia. These daily data span from 2 January 2002 to 30 December 2011.[1] The raw data were obtained from the Bloomberg. The data were synchronised by omitting all the observations if a series has a missing value on a particular non-trading day, and also for time zone differences. There are a total of 2,046 observations for each of the indices.

RESULTS

The results of the Vogelsang test are reported in Table 2. For the crisis period, significant break points were found between August 2007 and September 2008 for the Singapore, Indonesia, Thailand, Hong Kong, and the U.S. stock markets. For the recovery period, significant break dates were detected for Malaysia, Singapore, Indonesia, Hong Kong, and the U.S. stock markets between March and May 2009. The results are consistent with the prior views that the crisis started from the mid-2007 to 2008 and the stock markets have mostly recovered since March 2009.

The results provide some indication of the period when the crisis started and when it ended. The earliest significant crisis break point from Table 2 is 16 August 2007. This implies that the previous day, 15 August 2007, is the end of the pre-crisis period for at least one of the markets. The latest significant crisis break date is represented by 29 September 2008. By this date, the crisis had affected all the selected markets. For the recovery period, the earliest significant break point corresponded with 2 March 2009 and this suggests 27 February 2009 marks the end of the crisis for at least one of the markets. The significant break date indicating the last market recovery is 7 May 2009 and hence, the beginning of the post-crisis period for all the markets. The preceding discussion suggests that all the seven markets went through the three sub-periods defined as follows:

1. Pre-crisis period – 2 January 2002 to 15 August 2007
2. Crisis period – 29 September 2008 to 27 February 2009
3. Post-crisis period – 7 May 2009 to 29 December 2011

Table 2
Sup Wald statistics of break dates

Country	*n* = 0		*n* = 1		*n* = 2	
	$\sup W_T^n$	T_b	$\sup W_T^n$	T_b	$\sup W_T^n$	T_b
Crisis Break Points						
Malaysia	13.8023	14 Jan 2008	17.2322	14 Jan 2008	18.7356	23 Feb 2007
Singapore	18.2841**	02 Sep 2008	23.3061*	24 Sep 2008	32.7346**	29 Sep 2008
Indonesia	11.7788	02 Sep 2008	24.0361*	29 Sep 2008	33.1317**	29 Sep 2008
Thailand	18.9489**	12 Sep 2008	34.0536***	26 Sep 2008	37.3255**	26 Sep 2008

(*continued on next page*)

Table 2: (*continued*)

Country	n = 0		n = 1		n = 2	
	$\sup W_T^n$	T_b	$\sup W_T^n$	T_b	$\sup W_T^n$	T_b
Philippines	11.7965	09 Sep 2008	16.4945	08 Oct 2007	22.2635	29 Sep 2008
Hong Kong	11.1744	01 Aug 2008	22.6562*	16 Aug 2007	24.2694	26 Sep 2008
U.S.	26.6354***	26 Sep 2008	41.3842***	26 Sep 2008	65.4660***	26 Sep 2008
Recovery Break Points						
Malaysia	21.1439**	17 Mar 2009	23.5388*	17 Mar 2009	-	-
Singapore	29.2691***	12 Mar 2009	30.1283**	12 Mar 2009	38.6539***	07 May 2009
Indonesia	16.3427*	02 Mar 2009	22.706*	07 May 2009	25.0561	19 Oct 2009
Thailand	10.3908	12 Mar 2009	16.3709	10 Jun 2009	18.001	14 Jan 2010
Philippines	14.1252	19 Mar 2009	19.9719	19 Mar 2009	20.3504	16 Mar 2009
Hong Kong	18.8383**	10 Mar 2009	20.4314	10 Mar 2009	28.0462	25 May 2010
U.S.	26.3973***	06 Mar 2009	33.0141***	06 Mar 2009	29.9466*	05 Mar 2009

Note: ***, **, * denote significance at the 1%, 5% and 10% levels, respectively. The 10% critical values are 8.60, 12.83, and 15.36, 5% critical values are 10.23, 14.72, and 17.21, and 1% critical values are 14, 19.10, and 21.07 for n = 0, 1 and 2, respectively, for an I(0) process. The 10% critical values are 16.02, 22.49, and 28.07, 5% critical values are 18.09, 25.21, and 31.33, and 1% critical values are 22.59, 30.41, and 38.40 for n = 0, 1 and 2, respectively, for an I(1) process. In the case of Malaysia, the test statistic for n = 2 could not be computed due to perfect collinearity problem.

Table 3 shows the mean daily returns of these markets. Those of the pre-crisis period for Malaysia, Singapore, Indonesia, Thailand, Philippines, and Hong Kong are significantly positive while the mean for U.S. is not significantly different from zero. The stock market returns in the Asian countries were performing fairly well before the crisis. The mean returns for Singapore and U.S. stock markets are negative for the crisis period while the mean returns for the rest of the other stock markets are not statistically different from zero. The post-crisis mean returns for these seven markets are positive, showing sign of recovery from the crisis.

Table 3
Average daily returns (%)

Period	Malaysia	Singapore	Indonesia	Thailand	Philippines	Hong Kong	U.S.
Pre-crisis	0.0524**	0.0583**	0.1440***	0.0804**	0.0851**	0.0547**	0.0171
	(0.7931)	(1.1313)	(1.4683)	(1.4307)	(1.3947)	(1.1163)	(1.1013)
Crisis	–0.1660	–0.5042*	–0.4414	–0.4399	–0.3992	–0.4600	–0.6108*
	(1.5686)	(3.2993)	(3.6293)	(3.1445)	(3.1350)	(4.0011)	(3.6509)
Post-crisis	0.0715**	0.0378	0.1390**	0.1244**	0.1267**	0.0164	0.0588
	(0.7214)	(1.1502)	(1.5122)	(1.4683)	(1.2679)	(1.5524)	(1.3782)

Note: ***, **, * denote significance at the 1%, 5% and 10% levels, respectively (1-tailed test). Figures in parentheses are standard deviations.

The results for the test of equality of mean returns shown in Table 4 indicate differences for all three periods in all the markets based on the F-test. However, the Kruskal-Wallis test indicates that the mean returns for Philippines and Hong Kong are not significantly different for the three periods. The pre- and post-crisis mean returns are significantly greater than the mean returns in the crisis period. These seven markets performed relatively worse in the crisis period. The means for the pre- and post-crisis periods are not significantly different. This suggests that the market had recovered to the pre-crisis level after the crisis.

Table 4
Equality test for mean returns

Country	Malaysia	Singapore	Indonesia	Thailand	Philippines	Hong Kong	U.S.
Equality test of mean returns for all three periods							
Kruskal-Wallis test statistic	4.975*	6.932**	5.904*	4.794*	3.209	3.224	7.114**
F test statistic	2.999**	7.028***	4.942***	4.727***	4.540**	4.465**	8.307***
Cross-period differences in means (%)							
Pre-crisis & crisis	0.218*	0.563***	0.585***	0.520**	0.484**	0.515***	0.628***
Post-crisis & crisis	0.238**	0.542***	0.580***	0.564***	0.526***	0.476**	0.669***
Pre- & post-crisis	–0.019	0.020	0.005	–0.044	–0.042	0.038	–0.042

Note: The Bonferroni comparison tests were performed to assess the cross-period differences of the mean returns. ***, **, * denote significance at the 1%, 5% and 10% levels, respectively.

Pairwise comparisons were made between the pre- and post-crisis correlations. The results in Table 5 show clear change of the co-movement relationships among all the stock markets in ASEAN, as well as their relationship with the Hong Kong and U.S. markets. The correlations before the crisis are lower than the post-crisis correlations, and the degree of the correlations among all the stock markets has strengthened substantially after the crisis. The post-crisis period also saw stronger relationship between the ASEAN and the Hong Kong markets, but less so with the U.S. market.

The results for the ADF unit root test are reported in Table 6. All the indices are integrated of order one except the U.S. where it is integrated of order zero in the pre-crisis period. The test provides evidence that all the stock market indices are stationary at level during the crisis period, suggesting that the innovations to these stock markets are relatively short-lived during the crisis period. The stock indices in the post-crisis period are all I(1).

Table 5
Test of equality of pre- and post-crisis correlations of stock market returns

Country	Malaysia	Singapore	Indonesia	Thailand	Philippines	Hong Kong
Malaysia						
Singapore	–3.8128***					
Indonesia	–6.4141***	–8.0856***				
Thailand	–4.5769***	–4.6213***	–4.8766***			
Philippines	–5.3375***	–3.0201***	–3.9378***	–3.3319***		
Hong Kong	–5.3211***	–5.4671***	–6.2019***	–4.9290***	–3.6268***	
U.S.	–3.8494***	–2.0275	–2.9936***	–2.3779**	–1.7147	–1.2235

Note: The table reports the z-statistics of the test. Bonferroni adjustments were made for test of significance. ***, **, * denote significance at the 1%, 5% and 10% levels, respectively.

We proceed to study the linkages of the stock markets using the stationary return series. For easy reference, Malaysia, Singapore, Indonesia, Thailand, Philippines, Hong Kong, and the U.S. are referred to as market 1, 2, 3, 4, 5, 6, and 7, respectively in the labelling of the coefficients.

Table 6
Augmented Dickey-Fuller test for unit root

Country	Pre-crisis period		Crisis period		Post-crisis period	
	Level	First difference	Level	First difference	Level	First difference
Malaysia	–1.7959 [1]	–29.2802 [0]***	–3.2959 [0]*	–7.7388 [0]***	–2.0902 [1]	–20.1632 [0]***
Singapore	–2.3056 [0]	–34.0719 [0]***	–3.9778 [0]**	–7.2906 [2]***	–1.9295 [0]	–21.9093 [0]***
Indonesia	–2.2087 [1]	–30.7543 [0]***	–4.0042 [1]**	–6.5896 [0]***	–2.6752 [0]	–18.0502 [1]***
Thailand	–1.8375 [0]	–34.4743 [0]***	–4.3549 [1]***	–6.9384 [0]***	–2.2529 [0]	–21.9353 [0]***
Philippines	–2.2604 [0]	–31.8312 [0]***	–3.9735 [0]**	–7.8951 [0]***	–2.8705 [1]	–20.7619 [0]***
Hong Kong	–2.8752 [0]	–33.3985 [0]***	–3.5216 [0]**	–8.8459 [0]***	–2.2169 [0]	–22.2967 [0]***
U.S.	–3.4889 [0]**	–35.8923 [0]***	–4.7034 [0]***	–10.1709 [0]***	–2.6890 [0]	–23.7217 [0]***

Notes: ***, **, * represent significance at the 1%, 5% and 10% levels, respectively. Figures in [ ] indicates the number of lags chosen using the SIC criterion. The test regression contains a constant and a time trend.

Table 7
Parameter estimates for the diagonal BEKK model for the pre-crisis period

$$r_t = \alpha + \Gamma r_{t-1} + \varepsilon_t$$

$$H_t = C'C + A'H_{t-1}A + B'\varepsilon_{t-1}\varepsilon'_{t-1}B + D'E_{t-1}E'_{t-1}D$$

Country	Malaysia ($i = 1$)	Singapore ($i = 2$)	Indonesia ($i = 3$)	Thailand ($i = 4$)	Philippines ($i = 5$)	Hong Kong ($i = 6$)	U.S. ($i = 7$)
μ	0.0005**	0.0006*	0.0013***	0.0007	0.0004	0.0007**	0.0001
	(0.0002)	(0.0003)	(0.0004)	(0.0005)	(0.0004)	(0.0003)	(0.0003)
γ_{i1}	0.1314***	0.1006**	0.0713	0.1671**	0.1239**	0.0559	0.0307
	(0.0325)	(0.0460)	(0.0645)	(0.0672)	(0.0595)	(0.0486)	(0.0431)
γ_{i2}	–0.0072	–0.0642	–0.1336***	–0.1007*	–0.0352	–0.0177	–0.0711**
	(0.0272)	(0.0403)	(0.0490)	(0.0554)	(0.0543)	(0.0396)	(0.0321)
γ_{i3}	0.0121	-0.0209	0.1305***	0.0376	0.0333	–0.0183	–0.0240
	(0.0175)	(0.0248)	(0.0386)	(0.0395)	(0.0365)	(0.0263)	(0.0216)
γ_{i4}	0.0096	0.0139	0.0250	0.0607	0.0906**	0.0053	0.0092
	(0.0159)	(0.0303)	(0.0349)	(0.0401)	(0.0384)	(0.0260)	(0.0216)
γ_{i5}	–0.0310*	–0.0023	0.0285	0.0348	0.0332	0.0019	0.0161
	(0.0166)	(0.0217)	(0.0309)	(0.0387)	(0.0345)	(0.0243)	(0.0207)
γ_{i6}	0.0052	–0.0670	0.0378	–0.0514	–0.0009	–0.0486	0.0229
	(0.0284)	(0.0416)	(0.0516)	(0.0529)	(0.0546)	(0.0414)	(0.0372)
γ_{i7}	0.1775***	0.2934***	0.2914***	0.2657***	0.3286***	0.3459***	–0.0910***
	(0.0223)	(0.0266)	(0.0377)	(0.0419)	(0.0358)	(0.0270)	(0.0346)
α_{i1}	0.9592***						
	(0.0078)						
α_{i2}	0.9695***	0.9799***					
	(0.0046)	(0.0040)					
α_{i3}	0.8329***	0.8418***	0.7232***				
	(0.0209)	(0.0210)	(0.0359)				
α_{i4}	0.8718***	0.8812***	0.7570***	0.7924***			
	(0.0257)	(0.0259)	(0.0295)	(0.0464)			
α_{i5}	0.7777***	0.7861***	0.6753***	0.7069***	0.6306***		
	(0.0652)	(0.0656)	(0.0597)	(0.0624)	(0.1055)		
α_{i6}	0.9676***	0.9779***	0.8402***	0.8795***	0.7845***	0.9761***	
	(0.0049)	(0.0041)	(0.0211)	(0.0259)	(0.0655)	(0.0059)	
α_{i7}	0.9472***	0.9574***	0.8225***	0.8609***	0.7680***	0.9555***	0.9354***
	(0.0072)	(0.0062)	(0.0206)	(0.0258)	(0.0644)	(0.0066)	(0.0117)
β_{i1}	0.0266***						
	(0.0059)						
β_{i2}	0.0176***	0.0116***					
	(0.0028)	(0.0024)					
β_{i3}	0.0501***	0.0331***	0.0942***				
	(0.0083)	(0.0047)	(0.0205)				
β_{i4}	0.0354***	0.0234***	0.0666***	0.0471***			
	(0.0065)	(0.0046)	(0.0121)	(0.0146)			

(*continued on next page*)

Table 7: (*continued*)

Country	Malaysia (i = 1)	Singapore (i = 2)	Indonesia (i = 3)	Thailand (i = 4)	Philippines (i = 5)	Hong Kong (i = 6)	U.S. (i = 7)
β_{i5}	0.0327***	0.0216***	0.0614***	0.0434***	0.0401**		
	(0.0072)	(0.0051)	(0.0138)	(0.0119)	(0.0167)		
β_{i6}	0.0172***	0.0114***	0.0323***	0.0228***	0.0211***	0.0111***	
	(0.0030)	(0.0022)	(0.0054)	(0.0049)	(0.0053)	(0.0029)	
β_{i7}	0.0083	0.0055	0.0157	0.0111	0.0102	0.0054	0.0026
	(0.0052)	(0.0035)	(0.0097)	(0.0073)	(0.0068)	(0.0035)	(0.0033)
δ_{i1}	0.0039						
	(0.0037)						
δ_{i2}	–0.0029**	0.0022					
	(0.0014)	(0.0019)					
δ_{i3}	0.0105*	–0.0078**	0.0284				
	(0.0063)	(0.0033)	(0.0181)				
δ_{i4}	–0.0104**	0.0077*	–0.0281***	0.0277*			
	(0.0047)	(0.0046)	(0.0108)	(0.0152)			
δ_{i5}	–0.0098*	0.0073	–0.0265**	0.0261**	0.0246		
	(0.0052)	(0.0046)	(0.0112)	(0.0132)	(0.0179)		
δ_{i6}	–0.0027*	0.0020	–0.0074**	0.0073	0.0069	0.0019	
	(0.0016)	(0.0017)	(0.0036)	(0.0049)	(0.0048)	(0.0020)	
δ_{i7}	–0.0189**	0.0141**	–0.0513***	0.0506***	0.0477***	0.0133*	0.0925***
	(0.0092)	(0.0065)	(0.0166)	(0.0149)	(0.0183)	(0.0073)	(0.0177)

Notes: ***, **, * represent significance at 1%, 5% and 10% levels, respectively. Figures in parentheses are standard errors. The estimates for the constants of the variance equation are not reported. The coefficients are as follows: $\alpha_{ij} = a_{ii}a_{jj}$, $\beta_{ij} = b_{ii}b_{jj}$ and $\delta_{ij} = d_{ii}d_{jj}$.

Table 7 shows the estimated results of the BEKK model for the pre-crisis period. Only a few stock markets have significant own-return linkages which include Malaysia, Indonesia and the U.S. The cross-mean spillovers that are significant among the ASEAN markets include Malaysia-Singapore, Malaysia-Thailand, Malaysia-Philippines, Singapore-Indonesia, Singapore-Thailand and Thailand-Philippines. It is seen that the return spillovers from Singapore market to the other ASEAN markets have a negative impact during the pre-crisis period. The U.S. stock market played a dominant role, which is evident from the significant positive return spillovers to all the other stock markets. The low coefficient for the Malaysia case indicates that its stock market is relatively exogenous to global influence compared to the others. The Hong Kong market does not seem to have any significant influence in the mean spillover to the ASEAN markets.

Significant own- and cross-volatility shock spillovers are evident for all the stock markets. Volatility persistence is found to be high, with coefficients ranging from 0.63 to 0.98 that are significant at the 1 percent level. In terms of cross-volatility spillovers, Hong Kong stock market has a more significant role than the U.S. stock market in influencing the ASEAN markets. In this case, the Hong Kong stock market has reasonable influence as the regional financial center. The cross-volatility shock spillovers are also prevalent but across the ASEAN and Hong Kong stock markets only. It appears that the effects of past innovations from the Hong Kong stock market are relatively lower than the effects of past innovations from the other ASEAN stock markets. On the other hand, the past shocks from the U.S. market did not have a significant impact. There is clear evidence of own- and cross-market asymmetric responses. Good news seemed to have a higher impact on market volatility in general before the crisis. Nonetheless, the volatility of all the ASEAN markets are generally higher in response to the negative shocks from the U.S. market than the positive shocks.

Table 8 reports the results for the post-crisis period. The linkages in returns of the ASEAN market found before the crisis have become mostly insignificant after the crisis. However, the U.S. market continued to influence the mean returns of the ASEAN market. The mean spillover effect from the Hong Kong market remains insignificant. Linkages in the mean appeared to have weakened considerably after the crisis.

Table 8
Parameter estimates for the diagonal BEKK model for the post-crisis period
$r_t = \alpha + \Gamma r_{t-1} + \varepsilon_t$
$H_t = C'C + A'H_{t-1}A + B'\varepsilon_{t-1}\varepsilon'_{t-1}B + D'E_{t-1}E'_{t-1}D$

Country	Malaysia (1)	Singapore (2)	Indonesia (3)	Thailand (4)	Philippines (5)	Hong Kong (6)	U.S. (7)
α	0.0007**	0.0002	0.0009	0.0008	0.0007	–0.0001	0.0005
	(0.0003)	(0.0005)	(0.0006)	(0.0006)	(0.0005)	(0.0006)	(0.0006)
γ_{i1}	–0.0485	–0.0819	–0.1781	0.0213	–0.0573	–0.0776	0.0786
	(0.0681)	(0.0892)	(0.1149)	(0.1151)	(0.0981)	(0.1158)	(0.1159)
γ_{i2}	–0.0171	–0.0973	–0.0715	–0.1412	0.0370	0.0230	–0.0389
	(0.0428)	(0.0689)	(0.0899)	(0.0934)	(0.0752)	(0.0771)	(0.0970)
γ_{i3}	0.0299	–0.0119	0.0835	–0.0132	0.1198**	–0.0358	–0.0273
	(0.0279)	(0.0419)	(0.0670)	(0.0557)	(0.0485)	(0.0560)	(0.0639)
γ_{i4}	–0.0033	–0.0321	–0.0752	–0.0105	0.0358	–0.0465	–0.0577
	(0.0270)	(0.0431)	(0.0512)	(0.0536)	(0.0504)	(0.0482)	(0.0509)
γ_{i5}	0.0169	0.0028	–0.0137	0.0184	–0.0688	–0.0409	–0.0296
	(0.0267)	(0.0439)	(0.0509)	(0.0554)	(0.0510)	(0.0597)	(0.0522)
γ_{i6}	0.0380	0.0787	0.0593	0.1279*	0.0633	–0.0101	0.1418**
	(0.0336)	(0.0529)	(0.0674)	(0.0655)	(0.0655)	(0.0620)	(0.0619)
γ_{i7}	0.2064***	0.3917***	0.4132***	0.3098***	0.3215***	0.5713***	–0.0905*
	(0.0224)	(0.0359)	(0.0383)	(0.0517)	(0.0392)	(0.0469)	(0.0548)
α_{i1}	0.6384***						
	(0.0634)						
α_{i2}	0.7313***	0.8378***					
	(0.0409)	(0.0428)					
α_{i3}	0.6121***	0.7012***	0.5869***				
	(0.0478)	(0.0446)	(0.0649)				
α_{i4}	0.7341***	0.8409***	0.7039***	0.8442***			
	(0.0396)	(0.0260)	(0.0408)	(0.0241)			
α_{i5}	0.6313***	0.7232***	0.6053***	0.7259***	0.6243***		
	(0.0784)	(0.0763)	(0.0720)	(0.0752)	(0.1269)		
α_{i6}	0.7647***	0.8761***	0.7333***	0.8794***	0.7563***	0.9162***	
	(0.0421)	(0.0265)	(0.0427)	(0.0199)	(0.0782)	(0.0285)	

(*continued on next page*)

Table 8: (*continued*)

Country	Malaysia (1)	Singapore (2)	Indonesia (3)	Thailand (4)	Philippines (5)	Hong Kong (6)	U.S. (7)
α_{i7}	0.7565***	0.8667***	0.7254***	0.8699***	0.7482***	0.9063***	0.8966***
	(0.0395)	(0.0246)	(0.0421)	(0.0160)	(0.0767)	(0.0178)	(0.0216)
β_{i1}	0.1184***						
	(0.0422)						
β_{i2}	0.0135	0.0015					
	(0.0134)	(0.0029)					
β_{i3}	–0.0104	–0.0012	0.0009				
	(0.0189)	(0.0021)	(0.0034)				
β_{i4}	0.0371**	0.0042	–0.0032	0.0116			
	(0.0176)	(0.0048)	(0.0057)	(0.0092)			
β_{i5}	0.0369	0.0042	–0.0032	0.0116	0.0115		
	(0.0249)	(0.0049)	(0.0061)	(0.0089)	(0.0139)		
β_{i6}	0.0535***	0.0061	–0.0047	0.0168**	0.0167	0.0242**	
	(0.0165)	(0.0064)	(0.0086)	(0.0083)	(0.0112)	(0.0102)	
β_{i7}	–0.0317*	–0.0036	0.0028	–0.0099	–0.0099	–0.0144*	0.0085
	(0.0187)	(0.0034)	(0.0060)	(0.0063)	(0.0079)	(0.0085)	(0.0103)
δ_{i1}	0.0681*						
	(0.0354)						
δ_{i2}	0.0527***	0.0407**					
	(0.0186)	(0.0175)					
δ_{i3}	0.1314***	0.1016***	0.2535***				
	(0.0384)	(0.0256)	(0.0548)				
δ_{i4}	0.0845***	0.0654***	0.1631***	0.1049***			
	(0.0250)	(0.0163)	(0.0281)	(0.0232)			
δ_{i5}	0.0982***	0.0759***	0.1894***	0.1219***	0.1415**		
	(0.0355)	(0.0224)	(0.0494)	(0.0312)	(0.0595)		
δ_{i6}	0.0302**	0.0233**	0.0582***	0.0375***	0.0435**	0.0134	
	(0.0152)	(0.0112)	(0.0220)	(0.0143)	(0.0180)	(0.0092)	
δ_{i7}	0.0920***	0.0712***	0.1775***	0.1142***	0.1326***	0.0408***	0.1243***
	(0.0258)	(0.0188)	(0.0283)	(0.0176)	(0.0313)	(0.0152)	(0.0289)

Notes: ***, **, * represent significance at 1%, 5% and 10% levels, respectively.

The past-volatility spillover remains highly significant among the ASEAN markets and between them and the Hong Kong and U.S. stock markets. However, volatility persistence has reduced after the crisis. Just as before the crisis, the impact from past volatility of the Hong Kong and U.S. markets is higher than the inter-ASEAN market impact. Also, the Hong Kong stock market continues to have higher past-volatility spillover effects than the U.S. stock market in influencing the ASEAN markets. The impact from past shocks in volatility almost disappears in the post-crisis period. Despite the smaller post-crisis impact, cross-shock volatility spillovers are more prevalent from the Hong Kong, but not the U.S. market. In contrast to spillovers from past volatility and shocks, the asymmetric spillover effects become stronger after the crisis. The magnitude of response is not only stronger, but also positive, suggesting that post-crisis bad news have a higher tendency to increase market volatility. The results are very different from the pre-crisis period where good news could also increase market volatility. This could be due the residual effects generated by the global crisis which have led the sentiments in the marketplaces to be more responsive towards negative news. The ASEAN markets are also more sensitive towards bad news from the U.S. market than those from the Hong Kong market.

Figures in parentheses are standard errors. The estimates for the constants of the variance equation are not reported. The coefficients are as follows: $\alpha_{ij} = a_{ii}a_{jj}$, $\beta_{ij} = b_{ii}b_{jj}$ and $\delta_{ij} = d_{ii}d_{jj}$.

CONCLUSION

This study examines the linkages in the form of stock returns and volatility spillovers between the stock exchanges in the ASEAN-5 countries with the Hong Kong and U.S. stock markets using the multivariate BEKK GARCH model, focusing on the period before and after the global financial crisis. The use of this multivariate model overcomes the weak assumption of market independence of the univariate GARCH model. While the model takes into account inter-market dependence, volatility spillover can be examined from three sources, namely, past volatility, past shocks, and past shocks due to bad market news.

In contrast to the pre-crisis period, the return spillovers among the ASEAN stock markets are almost non-existent during the post-crisis period. However, the positive return spillovers from the U.S. market to all of the ASEAN markets still exist. The same impact is not seen to originate from the Hong Kong market. Persistence of the past-volatility spillover, although reduced, continues to be present after the crisis. Interestingly, the past-volatility spillover effects from the U.S. and Hong Kong markets are larger than those from the ASEAN markets. The fluctuations of the ASEAN markets, hence, are not necessarily better explained by the domestic conditions as suggested by Masih and Masih (1999), but the regional and global market influence is increasingly growing in importance. For the post-crisis period, the past-shock spillovers are lesser in impact. The inter-ASEAN market influence is largely reduced. The Hong Kong market is an important source of this spillover, but not the U.S. market. Asymmetric responses to shocks are evident in both the pre- and post-crisis periods. However, the related spillover effects are much stronger after the crisis. This is particularly true for the shocks due to bad news from the U.S. market that lead to increased volatility in the ASEAN markets, and its impact is larger than the source from the Hong Kong market.

The weaker post-crisis return and volatility linkages support the study of Goh et al. (2005) that found that the long-run relationships that existed between the ASEAN markets had disappeared after the crisis. On the other hand, the results pose considerable challenges to many other studies that suggest stronger linkages between stock markets after the crisis. First, the impact from mean spillover has weakened after the crisis. Second, the persistence in the spillover from past volatility has also reduced. Third, the spillover effects from past shocks in the volatility have receded to a very low level. The linkages after the crisis, however, hinged strongly on the effects from bad market news.

Given the rising potential and its developed financial system (see, for example, Sheera and Bishnoi, 2013), more funds are focusing on the ASEAN region. The weaker post-crisis linkages of the ASEAN stock markets through mean and volatility spillovers suggest a higher degree of individual-market exogeneity that enhances portfolio diversification opportunities. These opportunities, however, have weaker prevalence during bad market conditions when the volatility spillover effects are high. Otherwise, the weaker mean and volatility spillovers among these markets during the post-crisis period indicate that there is a cool-off period after the recovery of the stock markets. This could be due to the cautiousness of investors after experiencing the financial turmoil that also causes them to be more sensitive to unfavourable market news. Whether these effects are transitory in nature requires further investigation. Investors who are able to predict the trough of the stock markets towards the end of the crisis period and the suitable time to get back into the stock markets could reap potential rewards once the market starts to rebound. This study could also be extended by adopting the asymmetric multivariate GARCH model that allows for asymmetric linkages of stock markets. The relaxation of the symmetry assumption facilitates a more effective estimation of cross-volatility shocks that occur in the markets.

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NOTES

1. The period of study was selected to avoid other events in order to focus on the comparison before and after the 2007–2008 world financial crisis.

It excluded the early 2000s economic slowdown that affected some developed nations, particularly the European Union. The latest data available at the time of research were used. With hindsight, the period of study ended before the worsening of Eurozone debt crisis into the year 2012.

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