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Stock Market Contagion and Spillover Effects of the Global Financial Crisis on Five ASEAN Countries

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Abstract: *The global financial crisis that occurred from 2007 through to 2009 caused a decline in economic performance in almost all countries. This study analysed the contagion and spillover effect from the developed stock market to the stock markets in five ASEAN countries using the DCC-GARCH model. The result showed that there was a significant increase of the DCC's coefficient on the crisis period confirming the contagion effect from the markets of the developed countries to those of five ASEAN stock markets, except Dow Jones Index to PSEI Philippines, and HSI to KLSE. Except for Malaysia, the spillover effect during the crisis period was greater than the pre-crisis period; on the other hand, the effect of volatility on the movement of stock returns in the five ASEAN countries was smaller in the crisis period.*

Keywords: Contagion, Spillover, Financial market, DCC, GARCH-VAR
JEL Classification: G1

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1. Introduction

The study of contagion is critical given the process of globalisation, integration, and interconnection between financial markets, causing crises to occur in one country to spread rapidly not only regionally, but on a global scale. Financial contagion can be a considerable risk for a country integrated into global financial markets. If a country is affected by a crisis, the rescue cost will be substantial. An understanding of contagion is also important for mapping the risks of which countries or variables can pose a greater crisis risk.

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The stock market is one of the most sensitive channels for transmitting shocks so that by having good information about transmission patterns, appropriate and anticipatory policies can be taken. This research is also beneficial for investors in diversifying, and developing the liquidity of the stock market to cope with the exposure of shock infiltration. The more integrated the financial markets are, the smaller the opportunity the investors have to diversify. Therefore, investors must design their investment strategies by considering the integration of different markets. By detecting the occurrence of contagion or spillover, this research is also important for policymakers to develop financial systems and make the system resistant to international shock propagation so that the central bank or government can determine the right policy in case the financial shock happens. Policymakers should consider the integration of financial markets as an important phenomenon because, in times of crisis, negative shocks will quickly spread from one market to another, thus affecting the entire financial market.

King & Wadhwani (1990), Masih & Masih (1997), Forbes & Rigobon (1999), Beirne et al. (2009), Lyocsa & Horvath (2018) and many more used the Granger's Causality Test, impulse response function (IRF), cointegration test and DCC-MGARCH to determine contagion. In most literature, determining the existence of contagion is to compare the correlation coefficients in the period before the crisis with the time of the crisis. If there is a significant increase in correlation, the occurrence of contagion can be concluded. This research uses the paired sample tests to test whether the correlation before the crisis is significantly different from after the crisis. It also analyses the trend of the DCC coefficient using the HP-trend. The argument for using the HP-trend is that the DCC coefficient can increase or decrease very quickly and sometimes experience the opposite pattern of relationship (positive and negative correlation) so that the HP-trend can capture the tendency of the DCC coefficient.

This research aims to detect the occurrence of contagion effect and spillover from four developed stock markets (USA, EU, Japan, China) to the five stock markets in ASEAN countries (Indonesia, Malaysia, Singapore, Thailand, Philippines). The novelty of this research is the comparative analysis of the spillover effect in the pre-crisis and post the crisis, and the paired sample test to determine whether or not the correlation increases in the crisis period compared to the normal period. This analysis is important to

ascertain whether there is a pattern of changes in financial market behaviour, which has an impact on volatility spillover. In this context, it was hypothesised that volatility spillover differs substantially before and after the crisis. It is expected that through the analysis, the hypothesis is proved. The analysis of pre and post-crisis are also important to determine (i) whether the market is more integrated in the period after the crisis, (ii) whether negative shock (crisis period) generates higher volatility than the standard period, (iii) whether volatility spillover pre and post-crisis has the same or different magnitude.

We use DCC-GARCH to analyse the presence of contagion, and the Forecast Error Variance Decomposition for spillover analysis. The use of DCC models have several advantages. (i) The model can capture the dynamic correlation between asset returns, (ii) it enables to provide dynamic and varied correlation coefficients over time, and conditional correlations between financial markets through the decomposition of covariance matrix into conditional standard deviations and correlations matrix, (iii) the multivariate volatility enables to examine conditional formation that varies according to time, in significant time series pairs, (iv) based on Kearny and Poti (2006), the two-stage approximation way will provide an estimation result that is consistent with the conditional covariance matrix, and (v) according to Chiang et al. (2007), DCC-GARCH is used not only to measure the financial market movements but also it is beneficial to quantify the level of movement among the market.

The spillover analysis in this study used the Forecast Error Variance Decomposition (FEVD) of the VAR model. Some studies on spillover also used this analysis (Diebold & Yilmaz 2007, 2012; Yilmaz, 2009; Urbina & Jilber, 2013). The FEVD shows the sum of information from each variable's contribution to other variables in autoregression. This can signify how many forecast error variances of each variable can be explained by exogenous disturbance to other variables.

The global financial crisis started in August 2007 with a subprime mortgage crisis in the United States which then spread to other countries. The crisis caused the global stock index to decline sharply and quickly in emerging markets and advanced financial markets. The US stock market declined by 33.57% during the July 2007 - May 2009 period, 39.24% in the European stock market, 46.58% and 41.4% for Hongkong Shanghai Index (HSI) and Jakarta Composite Index (JKSE) respectively. Losses in the stock market

were even greater in some financial markets such as the Japanese and Singapore stocks which fell sharply to 53.65% and 52.94% (www.finance.yahoo.com, data processed). The facts showed that the severity of the global financial crisis had impacts on the stock markets around the world. Almost all stock markets in the world experiencing movements in the same direction, which is sharply decreasing. The important question is whether increased relations between financial markets, especially since the stock market during the crisis period indicated contagion.

2. Literature Review

2.1 Contagion & Spillover Effect

Contagion can be defined as a significant increase in cross-market correlations following the occurrence of shocks in one country or group of countries. The cross-market linkages can be measured through the correlation of asset return (Forbes & Rigobon, 1999). The occurrence of higher transmission risk was in countries with similar macroeconomic characteristics, as well as financial relationships (e.g. via commercial banks or capital markets) with crisis-stricken countries. (Owen et al., 2000).

A contagion or contagious effect is a phenomenon when a financial crisis occurs in a country that triggers a crisis in another country and shows as a series of weakening economies. Contagion theory states that no country in a region can circumvent the effects of contagion. For example, the economic crisis or currency crisis. There is more than one definition that can explain the contagion effect. The World Bank has three definitions (Tracy Yang, 2002):

a. Contagion in a broad sense: Shocks transmitted across national borders, or the occurrence of interrelationships between countries. Contagion can occur in normal or crisis conditions. Contagions are not always associated with crisis conditions, although some studies tend to emphasise this condition.

b. Transmission of a shock passes across national borders, or generally a significant correlation between countries that occurs outside of some fundamental conduits.

c. A narrower definition associates the contagion with a phenomenon when the correlations between countries increase during the crisis period compared with the correlations in the normal economic period.

Based on these definitions, four criteria can be used to detect the presence or absence of a contagion effect. First, based on asset price correlations; second, the conditional probability of a currency crisis; third, the transmission of volatility changes; and fourth, the movement of financial capital flows. Dornbusch, Park & Claessens (2000) defined contagion as a significant increase of links between some financial markets after the shock, which was transmitted to several countries or groups of countries. Rigobon (1999) defined a contagion through three distinctions as follows; (i) contagion can be interpreted as a crisis in a country, and then the crisis leads to speculative attacks on other countries, (ii) based on these facts, a country which is in a crisis will undergo an increase in its volatility return, so that contagion can be characterised as a volatility transmission between one country and another, and (iii) contagions can also be defined as the shock changes overspread among countries.

Some theoretical frameworks of contagion effect state that there are two perspectives of a contagion effect first referred to as "fundamental", and second as "pure contagion". The contagion that occurs in various countries after the shock is transmitted through commercial channels, followed by currency depreciation that will affect the fundamentals of other countries (Gerlach & Smets, 1995). Pure contagion encompasses the transmission mechanism of a shock, which is not associated with "fundamentals", but related to the presence of asymmetric information problems, associated with the market failure, and a spate of impacts among investors (King & Wadwhani, 1990).

A contagion refers to the spread of shock that occurs in financial markets from one country to another through exchange rate movements, equity prices, bond spreads, and capital flows. The cause of contagion can be conceptually distinguished into two categories (Dornbusch et al., 2000; Masson, 1998; Wolf, 1999; Forbes and Rigobon, 1999; Pritsker, 2000), namely (i) fundamentals-based contagion and (ii) investor behaviour.

Fundamentals-based contagion emphasises the spillovers resulting from the interdependence between markets so that the shocks

occurring locally or globally can be transmitted across countries or regions through (i) common shock, (ii) trade relations & exchange rate devaluation to enhance competitiveness, and (iii) financial relationship. Fundamental factors of contagion include macroeconomic shock impacting on an international and local scale. Although the investor's behaviour can affect the spread of crises through the channels unrelated to the changes of macroeconomic fundamentals, it is solely due to the conduct of investors or other financial agents. A contagion appears when the co-movement takes place, even when there is no international shock or no interdependence. For example, a disturbance in one country causes investors to withdraw their investment from several markets, regardless of the economic fundamentals between countries. These contagions are often referred to as "irrational phenomena", e.g., financial panic, herd behaviour, loss of confidence, and rising risk aversion.

Spillover effects are usually defined as conditions where fluctuations in asset prices in one country (or region) trigger changes in prices of the same asset or different assets in another country or region (Agenor & Da Silva, 2018). This fluctuation can reflect the desired overflow effect, for example relating to future asset prices, and less desirable ones, for example, the excessive transmission of volatility. This definition implies that the quantitative impact of spillover depends on several factors, namely: (a) the type of shock that causes asset price fluctuations in the country of origin, (b) spillover channels, both real and financial, through which financial shocks are transmitted internationally, (c) mitigation mechanisms applied in the source countries of shocks, (d)the nature of macroeconomic and macroprudential policy regimes in source and recipient countries, (e) scope of authority for policymakers in recipient countries to respond to shocks promptly.

Contagion and spillover measure the movement of the volatility of asset returns together or cross-country transmission of shocks. Nevertheless, there are differences in characteristics. Table 1 summarises the differences.

Table 1: The Differences Between Contagion & Spillover

	Definition	Implication
Contagion	▪ It is usually associated with excessive co-movements, which are generally referred to herding behaviour. In a narrower definition, contagion occurs when correlations between countries increase during the crisis period, compared to normal periods (Forbes and Rigobon, 2002). ▪ The occurrence of contagion has implications for the increasing closeness between financial markets after shocks in one or more countries.	▪ It is necessary to control general volatility during the financial crisis ▪ It occurs in a relatively short period. Two financial markets are said to be contagious if the correlation coefficients between them rise significantly from the normal period after the shock occurs ▪ To detect a contagion, focusing on stability of cross-market linkage rather than just using a plain correlation coefficient is needed.
Spillover	▪ Spillovers are always present in good and bad time (Rigobon, 2016) ▪ Focusing on variance decomposition in the stock return Vector Autoregression (VAR) model, the spillover index can be interpreted as an aggregate return spillover between various markets. (Cheung et al., 2008; Diebold and Yilmaz, 2009; 2012).	▪ It occurs in longer period of time ▪ A higher spillover coefficient implies that a greater proportion of volatility in one financial market can be caused by shocks that occur in other financial markets

2.2 Previous Literature

Some studies examined the contagion effect from developed countries to some developing countries or emerging markets, and measure the degree of spillover effect on the country. Boubaker et al. (2016) in his research on financial contagion between the US and ten countries covering the developed countries and the emerging markets, stated that there was evidence of contagion occurrence from the US equity markets to the developed and emerging stock markets, using Granger's Causality Test, impulse response function, and cointegration test. Besides this, Emche et al. (2016) investigated to test the hypothesis of contagion from the US stock market, in the

context of the subprime crisis, to ten developed and developing country stock markets using the DCC-MGARCH method. The findings provided two interesting contributions, namely the increase of dynamic correlation after the subprime crisis, and the test of pure contagion (Forbes & Rigobon 2002). The result showed that pure contagion had occurred.

Lyocsa & Horvath (2018) in their research about a contagion effect on the stock market with a sample of seven developed countries, namely US, Japan, Hong Kong, Germany, France, Canada and the UK, analysed whether there was a co-movement between the stock market in the US and some of these countries. The results showed that the movement of the stock index in the US caused stock movements in several countries, which was initially caused by unexpected volatility during the crisis period. The explanation was that when a market participant gets bad news, he will make adjustments to his portfolio investment, and this will cause a contagion. These findings were different from most contagion literature. In this study, the contagion did not only occur in the turmoil period (July 2007 - mid-May 2009), but also occurred before and after the crisis. The co-movement of the stock market cannot be described by movements in other market assets such as exchange rate movements, gold or oil prices. This confirms that fundamental factors do not drive the stock market co-movement.

Beirne et al. (2009) researched spillover from a mature market to an emerging market. They analysed whether there was a change in the transmission mechanism during the turbulence period and examined its implications for the conditional correlation between the mature and emerging market return. The method used was trivariate GARCH-BEKK, with a sample of 41 emerging market countries, divided into the emerging market of Asia, Europe & South Africa, Latin America and the Middle East & North Africa. Most research samples showed an increase in the conditional correlation between the mature markets during the crisis period. When the volatility in the local market increases, the mature markets will experience greater volatility. However, in some emerging markets, spillovers from mature markets only appear during the turbulence period. From the policy perspective, the economies of these countries need to ensure that the right domestic policy structure is available so that when there is a distortion to the local stock market as the effect of spillover, it can be anticipated.

Chuinxiu & Masih (2014) conducted a contagion effect study from the US subprime crisis on the ASEAN-5 stock market, namely Malaysia (conventional and Islamic), Thailand, Singapore, Indonesia and Philippines, using MGARCH-DCC, with the analysis period from January 1, 2004, to July 5, 2012. The results of their research showed that there was a contagion effect of the subprime crisis on the equity market in the five ASEAN countries, in mid-2008. These findings indicated a consistent co-movement between the five ASEAN countries and the US stock market in the long run. Malaysia (conventional) stock market showed a negative correlation with the US stock market with a declining co-movement pattern even during the crisis period, showing the policy involvement through portfolio diversification.

King & Wadhwani (1990), in their research on changes in cross-market correlation between stock markets in the US, UK, and Japan, stated that stock market movements could be explained through the International Capital Asset Pricing Model (ICAPM), and the concept of rational expectation. The concept of rational expectation of the equilibrium price and the model of inter-market transmission is a rational attempt to use all imperfect information about events relevant to the value of the stock. Because of their accessibility to different sets of information, investors (including market makers) can infer the changes in stock prices from other financial markets. This is because the information gathered should affect all markets at the same time, but the importance can be different between countries. Therefore, not all information can be used as inference. The important information of the stock is valued in the price, at which the investors or traders are willing to buy. Hence, the individual market players in one market (e.g. London) can infer the disclosed price through the price changes in other financial markets, for example, in New York or Tokyo.

The changes in price that occurred in one market will be used as information by investors in other markets. In the rational expectations model, the equilibrium price with asymmetric information reveals all the information available to the agent, noting that the information structure is relatively simple. When this happens, the market information is efficient, and the stock price reflects the fundamentals. However, when the market information is more complex, the market price equilibrium will not fully reflect the fundamentals. Under this non-fully-revealing conditions (where the market price does not fully reflect the fundamentals), a change in

equilibrium price in one market depends on the price changes in other markets or countries through the structural contagion. The shocks or idiosyncratic changes in one market will be transmitted to other markets, and there will be increased volatility.
There is a difference between the Walrasian Efficient market, and non-fully revealed rational expectations model, and there are features of both models. The stock market does not fully operate 24 hours a day. In the non-fully revealing condition (not Walrasian Equilibrium conditions), there is a change or price spike in stock markets in different time zones when a market begins to open, reflecting the information carried over at the opening price. The relationship between stock markets varies over time, and increases will follow an increase in the correlations between stock markets in volatility.

3. Research Method

3.1 Data and Sample

This study used a stock index of four developed countries and five ASEAN countries during the entire crisis period. It covered the pre-crisis period (03/01/2005 – 07/26/2007), crisis period (07/27/2007 – 08/31/2009), and the aggregation of the entire period, with daily data series. There were several methods to determine the period of crisis and when to recover. Among them were the graphical modelling method (Rea at al., 2014), Markov regime-switching framework, BenSaïda et al. (2018), literature that places the bankruptcy of the Lehman Brothers as the beginning of the crisis period (Xua et al., 2018), and comparing stock return using the Hodrick-Prescott Filters (HP-Filters) (Cheung et al., 2008). In this research, the method from Cheung et al. (2008) was used where a period of crisis or financial markets turmoil are identified when the volatility of the conditional variance is greater than 50% compared to the trend, and the returns are smaller than the average long-term return (Cheung et al., 2008). This technique was used because it can determine at which period the return volatility was above the limit. The period when the return volatility is not in its normal conditions or above the limit indicates a crisis.
The Hodrick-Prescott Filter also called the Bandpass Filter, is usually used in applied econometrics to decipher economic data into trends and cycle components, especially for business cycle

measurements. HP-filters are often used to produce new time series which are potential values of a variable (e.g., Potential GDP), to measure output gaps that are useful for macroeconomic modelling and monetary research purposes. (Philips, Peter. 2015). The advantage of HP filtering for financial data is that newer observations are given a higher weight, which can be an effective way to capture structural breaks. The basic idea is that when the deviation between variables is measured large through the trend captured, it becomes a signal that the financial crisis will occur within the next periods. As a consequence, the policymakers will increase the resilience of the financial system from negative turmoil (Gerdrup et al., 2013).

The selection of the five ASEAN countries (Indonesia, Malaysia, Singapore, Thailand, Philippines) was based on the consideration that these countries were the five largest economies, having a relatively large trading volume with their global trading partners in ASEAN. In terms of trade, the five ASEAN countries also have significant trade openness with the global economy (calculated as a percentage of foreign trade to GDP), where the trade relation shows the great interconnection between the five ASEAN countries and the global economy. The sample research was as follows:

Table 2: The Data used in the analysis

Sample of Countries	Stock Index	Symbol	Sources
United States of America (USA)	Dow Jones Composite Average Price Index	^DJA	finance.yahoo.com
European Union	Euronext 100	^N100	finance.yahoo.com
	FTSE 100 Price Index	^FTSE	finance.yahoo.com
Japan	NIKKEI 225 Stock Average Price Index	^N225	finance.yahoo.com
China	Hang Seng Price Index	^HSI	finance.yahoo.com
Indonesia	Jakarta Composite Index	^JKSE	finance.yahoo.com
Malaysia	FTSE Bursa Malaysia KLCI	^KLSE	finance.yahoo.com
Singapore	Straits Times Index	^STI	finance.yahoo.com
Thailand	Stock Exchange of Thailand SET Index	^SET	finance.yahoo.com
Philippines	Philippine Stock Stock Exchange Composite Index	PSEI.PS	finance.yahoo.com

3.2 Estimation Method

3.2.1 Estimation of Volatility Using GARCH

Stock price volatility is obtained using the ARCH/ GARCH (Autoregressive Conditional Heteroscedasticity / General Autoregressive Conditional Heteroscedasticity). Volatile data implies that variance error is not constant, resulting in heteroscedasticity. An efficient estimate can be obtained when the error in heteroscedasticity is treated properly.

The ease in identifying the homoskedastic assumptions on OLS methods became the basis in modelling the residual variance of the ARCH method. It is easily used when there is a standard OLS model as the following:

$$Y_t = \alpha + \beta X_t + u_t \quad (1)$$

Based on the OLS assumption, u_t is normally distributed with zero average and constant variance value (homoscedastic). In order to form the ARCH model, Engle (1982) set the correlation of value of the variance in a period with its past value. Modelling heteroscedasticity allows changes in variance between time. Thus, significant volatility in the past can be captured into the model. The ARCH specification (1) will then form as follows:

$$\sigma_t^2 = \sigma^2 + \gamma_1 u_{t-1}^2 \quad (2)$$

In equation (2), the variance is not constant. The variance in at-period consists of two components. The first component is a constant variance. The second component is the relationship of current variance to the magnitude of volatility in the previous period. Considerable volatility in the previous period (either positive or negative) will result in significant variances at the moment. In the development, a longer lag may be used to describe the earlier effect of variances volatility using the current variance.

It is often found in many cases that one volatility in the past will influence the value of the current variance. This causes too many parameters in the conditional variance to be estimated. Estimating parameters with high precision and within large quantities will be challenging. Therefore, Bollerslev (1986) introduced the GARCH method (Generalised Autoregressive Conditional Heteroscedasticity) by modelling the residual variance which is

constructed by three components: constant variance (σ^2), the volatility of the variance in the previous period u_{t-q}^2 (the tribe ARCH), and the variance in the previous period σ_{t-p}^2, (GARCH tribe). The GARCH model (p, q) will be formed as follows:

$$\sigma_t^2 = \sigma^2 + \gamma_1 u_{t-1}^2 + \gamma_2 u_{t-2}^2 + ... + \gamma_q u_{t-q}^2 + \Phi_1 \sigma_{t-1}^2 + ... + \Phi_p \sigma_{t-p}^2 \quad (3)$$

3.2.2 Contagion Effect Testing with Dynamic Conditional Correlation (DCC-GARCH)

The DCC-GARCH introduced by Engle and Sheppard (2001) aims to capture the dynamic correlation between asset returns. Moreover, referring to the definition of contagion proposed by Dornbusch, Park & Cleassens (2000), Forbes & Rigobon (2001), World Bank, Forbes & Rigobon (2002), Bekeart, Harvey & Ng (2005), and Calvo & Reinhart (1996), it is stated that the contagion occurs when there is an increase in the cross-market linkage, increase in correlation or increase in co-movement asset return. Related to DCC estimation, the contagion measurement is performed by comparing the DCC coefficient before the crisis with the DCC coefficient at the time of crisis. If there is a significant increase in the DCC coefficient during the crisis period, it can be concluded that contagion has occurred.
DCC-GARCH, including the classes of conditional variance and covariance, have several advantages of flexibility. First, it allows us to provide dynamic and varied correlation coefficients over time, and conditional correlations between financial markets through the decomposition of the covariance matrix into conditional standard deviations and correlations matrix. The conditional heteroscedasticity of financial data supports this decomposition. Second, the multivariate volatility allows us to examine conditional formation that varies within time, in significant time series pairs. Third, based on Kearny and Poti (2006), the two-stage approximation way will provide an estimation result that is consistent with the conditional covariance matrix. Fourth, according to Chiang et al. (2007), DCC-GARCH is beneficial not only to measure the financial market movements but also to quantify the level of co-movement in the market.

Based on Engle (2002), the DCC is a model for the volatilities and correlation that could be estimated in two steps. First, estimate univariate volatility models for all assets. Second, construct standardised residual (returns divided by conditional standard deviations) and after that estimate correlations between standardised residuals. Suppose, the returns a_t, from n assets with expected value 0 and covariance matrix H_t, then the Dynamic Conditional Correlation (DCC-GARCH) model is defined as:

$$r_t = u_t + a_t$$
$$a_t = H_t^{1/2} z_t$$
$$H_t = D_t R_t D_t$$

Notation:

r_t: n x 1 vector of return of n assets at time t.

a_t: n x 1 vector of mean-corrected return of n assets at time t, i.e. $E[a_t] = 0$.
$Cov[a_t] = H_t$.

u_t: nx 1 vector of the expected value of the conditional r_t.

H_t: n x n matrix of conditional variances of a_t at time t.

$H_t^{1/2}$: Any n x n matrix at time *t* such that H_t is the conditional variance matrix of a_t. $H_t^{1/2}$ may be obtained by Cholesky factorisation of H_t.

D_t: n x n diagonal matrix of confitional standard deviation of a_t at time *t.*

R_t: n x n conditional correlation matrix of a_t at time *t.* R is time varying correlation matrix

$$\varepsilon_t \equiv D_t^{-1} r_t, \quad E_{t-1}(\varepsilon_t \varepsilon_t^{'}) = R$$

z_t: n x 1 vector of iid errors such that $E[z_t] = 0$, and $E\left[z_t z_t^T \right] = I$.

The element in the diagonal matrix D_t are standard deviations from univariate GARCH models.

$$D_t = \begin{bmatrix} \sqrt{h_{1t}} & 0 & \text{K} & 0 \\ 0 & \sqrt{h_{2t}} & \text{O} & \text{M} \\ \text{M} & \text{O} & \text{O} & 0 \\ 0 & \text{K} & 0 & \sqrt{h_{nt}} \end{bmatrix}$$

Where

$$h_{it} = \alpha_{i0} + \sum_{q=1}^{Qi} \alpha_{iq} a_{i,t-q}^2 + \sum_{p=1}^{Pi} \beta_{ip} h_{i,t-p}$$

R_t is the conditional correlation matrix of the standardised disturbances

Since R_t is correlation matrix it is symmetric.

$$R_t = \begin{bmatrix} 1 & \rho_{12,t} & \rho_{13,t} & \text{K} & \rho_{1n,t} \\ \rho_{12,t} & 1 & \rho_{23,t} & & \rho_{2n,t} \\ \rho_{13,t} & \rho_{23,t} & 1 & \text{O} & \text{M} \\ \text{M} & \text{M} & \text{O} & \text{O} & \rho_{n-1,n,t} \\ \rho_{1n,t} & \rho_{2n,t} & \text{K} & \rho_{n-1,n,t} & 1 \end{bmatrix}$$

The elements of $H_t = D_t R_t D_t$ is:

$$[H_t]_{ij} = \sqrt{h_{it} h_{jt} \rho_{ij}}$$

Conditional correlation can be defined as:

$$\rho_{x,y,t} \equiv \frac{E_{t-1}(x_t y_t)}{\sqrt{E_{t-1}(x_t^2)E_{t-1}(y_t^2)}}$$ and letting

$$y_t \equiv \sqrt{h_{y,t}\varepsilon_{y,t}},\ x \equiv \sqrt{h_{x,j}\varepsilon_{x,t}}$$

$$\rho_{x,y,t} \equiv \frac{E_{t-1}(\varepsilon_{x,t}\varepsilon_{y,t})}{\sqrt{E_{t-1}(\varepsilon_{x,t}^2)E_{t-1}(E_{y,t}^2)}} = E_{t-1}(\varepsilon_{x,t}\varepsilon_{y,t})$$

3.2.3 Estimation of Spillover Using Forecast Error Variance Decomposition (FEVD)

It is critical to explain the spillover from the developed stock market to the stock markets of five ASEAN countries. This is because the five ASEAN countries are included in the emerging market countries that are vulnerable to the global financial turmoil. To estimate the spillover, the empirical approach proposed by Diebold and Yilmaz (2009, 2012) is used which is based on Variance Decomposition Analysis (VDA) in the VAR model, over the pre-crisis and crisis period.
The ordering variable used is:

$$d(dja) \rightarrow d(eu) \rightarrow d(ftse) \rightarrow d(nikkei) \rightarrow d(hsi) \rightarrow d(sti) \rightarrow d(klse) \rightarrow d(set) \rightarrow d(psei) \rightarrow d(jkse)$$

The *"d*" indicates that the data used are different at first, since it is not stationary in the level of data. The maximum lag selection is based on Lag Order Selection Criteria, i.e., FPE (Final Prediction Error), AIC (Akaike information criterion), SC (Schwarz information criterion) and HQ (Hannan-Quinn information criterion), and the optimum lag is determined by Inverse Root of AR Characteristic Polynomial.

4. Findings

4.1 Statistic Descriptive and Stock Return Volatility

Table 3 shows the mean in the pre-crisis period. It can be seen that the Nikkei Stock Index and Hongkong Shanghai Index showed the highest returns from developed countries, while the Jakarta Composite Index from the ASEAN region earned the highest return.

However, the JKSE return also showed the highest deviation standard, indicating a relative fluctuation pattern return over time. In the crisis period, the developed stock markets showed a negative return except for the Hongkong Shanghai Index. On the other hand, in ASEAN countries, JKSE and KLSE still generated positive returns. Kurtosis is defined as data distribution discrepancy. The more pointed the value of kurtosis, the more homogeneous the data. It implies that when the value of kurtosis becomes smaller, the data tends to be more heterogeneous. In the post-crisis period, all the values of kurtosis in developed countries increased. This means that after the crisis period, the volatility of returns has become more homogeneous, as was the case in Thailand and the Philippines. Furthermore, JKSE, KLSE, and STI experienced an actual decline showed in a more heterogeneous distribution of return volatility. In the period before the crisis, the skewness values were all negative, which meant that the distribution of data was leaning to the left and the value of mean was smaller than the values of median and mode respectively. After the crisis, the skewness values were positive, which meant that the distribution of data leaned to the right. It means that the value of the mean was greater than the values of median and mode except for the Nikkei, JKSE, and PSEI.

Table 3: Statistic Descriptive of Stock Return

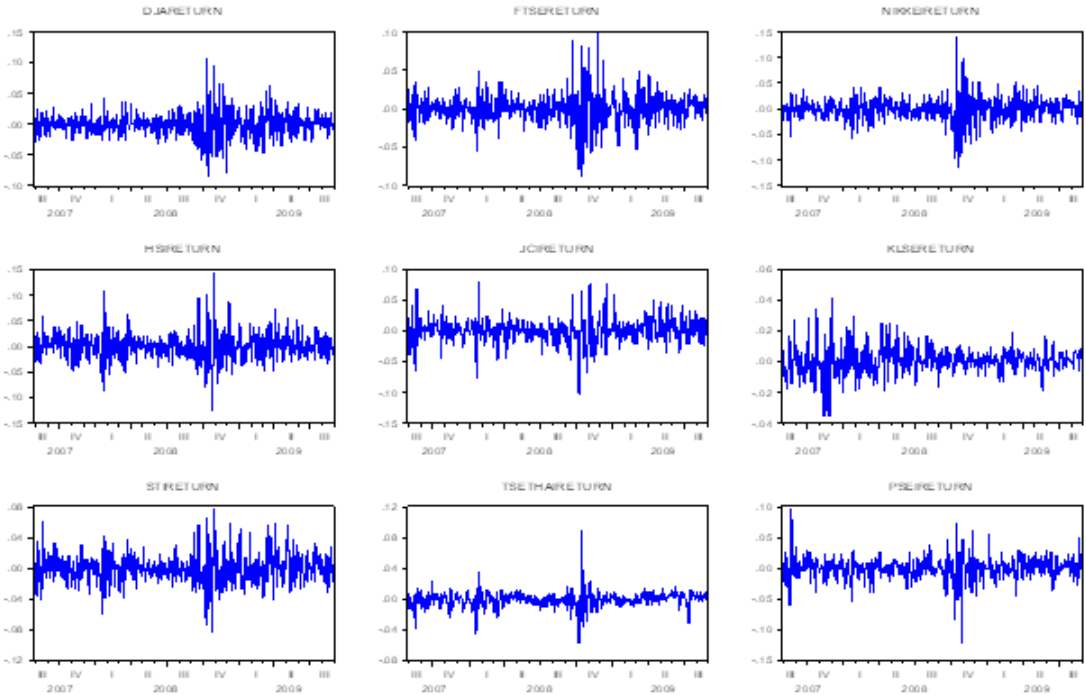
Pre-Crisis Period										
	DJA	EU	FTSE	NIKKEI	HSI	JKSE	KLSE	STI	TSET	PSEI
Mean	0.00046	0.00065	0.00039	0.00071	0.00082	0.00133	0.00052	0.00091	0.00033	0.00098
Std. Dev.	0.00740	0.00781	0.00711	0.01034	0.00872	0.01183	0.00965	0.00855	0.00923	0.01223
Skewness	-0.2779	-0.4940	-0.4752	-0.2563	-0.4096	-0.6702	-2.0331	-0.6335	-1.873	-0.47265
Kurtosis	4.093	4.767	5.070	4.293	4.561	7.086	20.329	5.345	15.627	7.03106
Jarque-Bera	39.40	107.25	135.86	50.64	81.36	483.91	8290.74	185.93	4539.56	448.570
Observations	628	628	628	628	628	628	628	628	628	628
Crisis Period										
	DJA	EU	FTSE	NIKKEI	HSI	JKSE	KLSE	STI	TSET	PSEI
Mean	-0.00039	-0.00067	-0.00025	-0.00069	0.00006	0.00020	0.00037	-0.00036	-0.00101	-0.00027
Std. Dev.	0.01996	0.01962	0.01948	0.02306	0.02699	0.02080	0.00895	0.01976	0.01048	0.01841
Skewness	0.17499	0.22775	0.17479	-0.054	0.391	-0.298	0.112	0.122	0.044	-0.45526
Kurtosis	6.599	7.107	7.278	8.521	6.804	6.803	5.716	4.864	17.028	9.11190
Jarque-Bera	298.00	389.24	420.04	695.030	343.79	337.73	169.36	80.62	4485.60	870.28
Observations	547	547	547	547	547	547	547	547	547	547

Sources: www.finance.yahoo.com (data processed)

Figure 1 confirms the plot of the stock return volatility was based on the time series and clearly showed the excess volatility, especially in the period of crisis. Increased volatility in almost all markets in the same period (global financial crisis) can be an indication of co-movements. It also shows that most stock markets

in the period of the crisis had high sensitivity, and there was a tendency to move together.

Figure 1: Stock Return Volatility

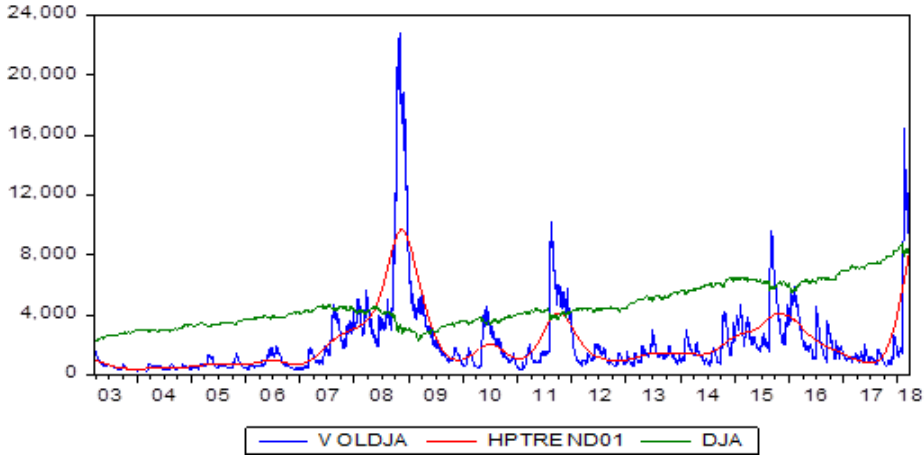


Sources: www.finance.yahoo.com (data processed)

4.2 Determination of Crisis Period

The periods of stability and crisis are determined by the conditional variance return of DJA, which was estimated using the GARCH model, then the results were compared with the HP-filtered trend series. A period is identified as the beginning of market turmoil is when the volatility of the conditional variance is greater than 50% compared to the trend, and the returns are smaller than the average long-term return. Based on the estimation, the result showed that the crisis period began at the end of July 2007 and ended at the end of 2009, as shown in the figure below.

Figure 2: The Determination of the Crisis Period



Sources: www.finance.yahoo.com (data processed)

4.3 Contagion Testing using DCC-GARCH and Mapping the Relationship

Testing for contagion from four developed stock markets to five stock markets in ASEAN countries was done by using DCC based on the correlation method. To conclude whether or not the existence of contagion was detected, a paired sample t-test of two stock returns was applied. The significance of the t-test indicated that the mean of DCC coefficients at the pre-crisis period is different from the period of crisis and, hence, it can be concluded that there is an occurrence of contagion. Table 4 shows the DCC coefficients in the pre-crisis and crisis periods. It confirmed that the effect of contagion almost occurred on the overall relation of the developed countries' stock market to those of the five ASEAN countries, except from the US stock market to the Philippines stock market (DJA vs PSEI), and from Hong Kong to the Kuala Lumpur stock market (HSI vs KLSE). Both stock markets showed the intensity of weakening relationships in the crisis period.

Table 4: The Coefficient of DCC

	Coeff. of DCC		Paired sample test		The occurrence of contagion
	Before the crisis	Crisis period	t-stat	Sign.	
DJA vs JKSE	0.02218368	0.140415	-42.014	0,000	V
DJA vs KLSE	-0.0118772	0.023955	-15.926	0,000	V
DJA vs STI	0.09495787	0.232161	-36.955	0,000	V
DJA vs SET	0.0103523	0.054616	-21.106	0,000	V
DJAa vs PSEI	0.0653041	0.016668	-11.076	0,000	0
FTSE vs JKSE	0.23610291	0.340148	-18.9744	0,000	V
FTSE vs KLSE	-0.0599732	0.010036	-26.3138	0,000	V
FTSE vs STI	0.33346897	0.480694	-22.0567	0,000	V
FTSE vs SET	0.17263451	0.270633	-22.2855	0,000	V
FTSE vs PSEI	0.08344162	0.194989	-35.6278	0,000	V
Nikkei vs JKSE	0.37969391	0.464214	-8.84369	0,000	V
Nikkei vs KLSE	-0.0088726	0.044779	-28.5818	0,000	V
Nikkei vs STI	0.5351173	0.597137	-6.73222	0,000	V
Nikkei vs TSE	0.59553677	0.745271	-10.7855	0,000	V
Nikkei vs PSEI	0.281978	0.468636	-28.6278	0,000	V
HSI vs JKSE	0.09838055	0.577284	-63.9532	0,000	V
HSI vs KLSE	0.01426894	-0.05642	27.04263	0,000	0
HSI vs STI	0.56836523	0.776716	-17.4371	0,000	V
HSI vs TSE	0.25863892	0.49469	-32.7661	0,000	V
HSI vs PSEI	0.27611635	0.436307	-19.5106	0,000	V

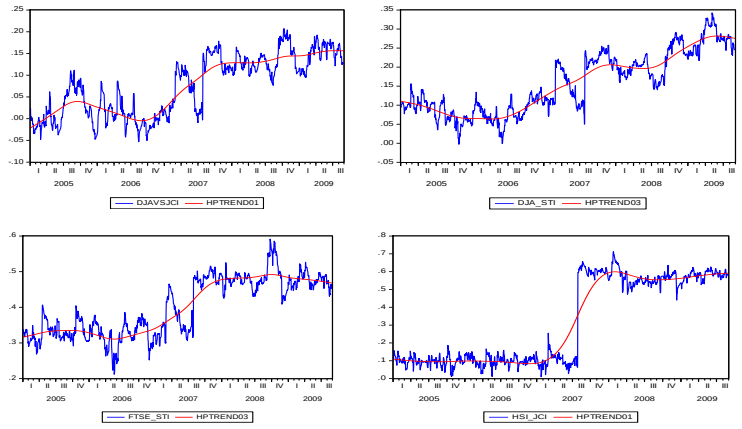
Sources: www.finance.yahoo.com (data processed)
Note: V, indicates the occurrence of contagion, and 0, indicate contagion does not occur

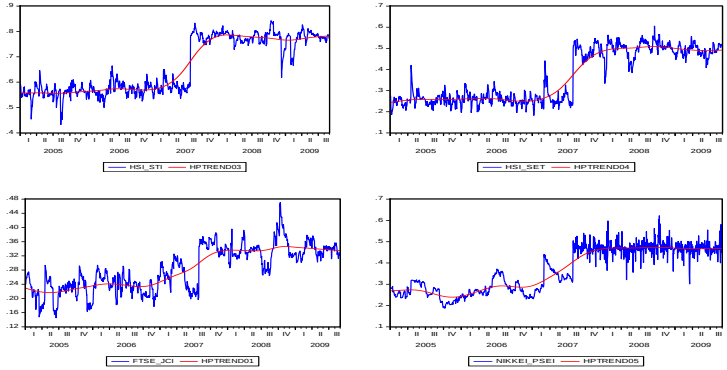
Figure 3 maps the relationship between two stock markets, i.e. the ones of developed countries and those of the five ASEAN countries. Several ASEAN countries experienced an increase in the intensity of relationships after the period of crisis, and others declined. The depiction of relationships was obtained by plotting a DCC coefficient of the two stock markets. After that, the HP-trend was used to show the direction and intensity of the relationship. The

following figure shows the relationship of the stock market experiencing an increase in the intensity after the crisis.

Figure 3 shows that the US stock market had an increased relationship with the Jakarta and Singapore stock markets (DJA_JKSE and DJA_STI), while Hongkong Shanghai stock markets increased its relationship with Jakarta, Singapore and Thailand stock markets (HSI_JKSE, HSI_STI, HSI_SET). On the other hand, the European stock market, which is proxied by FTSE, increased the intensity of its relationship with the Singapore, Indonesian and Philippine markets. These findings have implications that in addition to global markets (USA and EU), regional stock markets (Hongkong Shanghai) also have a significant influence on the movement of domestic stocks, and the intensity is greater than global stocks. Therefore, regional stock movement is also important to be observed and used as reference information for investors or the government and central banks.

Figure 3: The relationship of Two Stock Markets that Experienced Increased Intensity

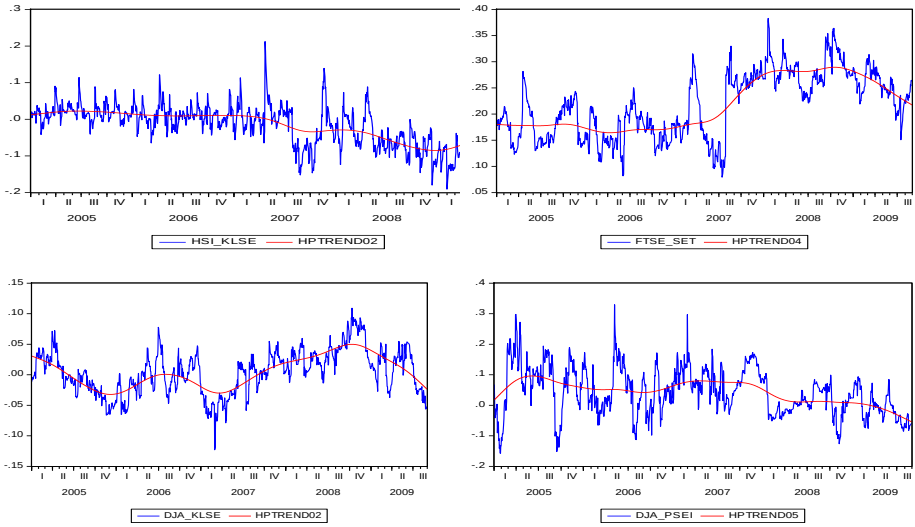




Sourceswww.finance.yahoo.com(data processed)

In addition to the increasing stock market relationships, Figure 4 displayed the stock market that experienced a decline in a relationship after the crisis period.

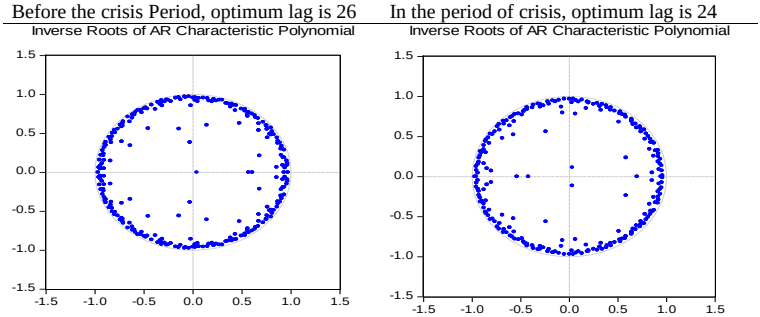
Figure 4: The relationship of Two Stock Markets that Experienced Decreased Intensity



4.4 Spillover Analysis from VAR Model

The spillover analysis was performed by estimating the variance decomposition served in the VAR model, based on the lag length criteria and the polynomial inverse root.

Figure 4: Optimum Lag Determination



Sources: www.finance.yahoo.com (data processed)

Table 5 shows the spillover effect from the developed country stock market to those of the five ASEAN countries in the normal period (before the crisis) and crisis period. In all periods, the developed stock market still had a dominant influence on the movement of the five stock indexes of ASEAN countries. Moreover, in European financial markets, based on the sample analysis, the influence of the EU stock index has a more significant spillover effect compared to FTSE London.

In the Indonesian stock market, the influence of the American stock market was even greater in the normal period. While in the period of crisis, the influence of the US remained the largest, reaching up to t+6, and the period t+9 the influence of HSI is larger than DJA. This result was in line with the DCC coefficient between JKSE and HSI, were in the crisis period, there was a drastic increase in the coefficient. From a geography standpoint, HSI has a strong influence on JKSE because Hong Kong is the largest regional exchange and financial centre, influencing the investment and financial flows of the two countries. Besides this, from the aspect of the trade, Hongkong happens to be the market gateway from Indonesia to China. This means that the stock movements in Indonesia are indirectly influenced by the stock market and economic activity in Hong Kong.

On the stock market of Singapore, the influence of the American stock market was still very strong. This is particularly the case in the period after the crisis, not to mention the strong influence of the stock markets of Europe, China, and Japan. The stock market of Singapore was predominantly influenced by the American stock market, followed by China (Hongkong), Europe, and Japan, with the intensity of spillover increasing during the crisis period. The STI's index has the smallest spillover effect comparing to other ASEAN countries, affected by its movement. In contrast to other stock indices, KLSE received the smallest effect of global stock movements either in the period of pre-crisis or in the crisis. This meant that the movement is dominantly affected by itself. It also showed that the stock market in Malaysia was relatively independent against global shocks. For the stock market of Thailand, in the period before the crisis, it experienced more spillover effect from Japan (Nikkei225), while after the crisis, it was is strongly influenced by the stock market of America (DJA). The Philippine stock index is strongly affected by the US stock index both in the period before and after the crisis.

Table 5: The Comparison of Spillover in the Pre-crisis and Crisis Period

Variance Decomposition of D(JKSE):

Period	D(DJA)		D(EU)		D(FTSE)		D(NIKKKEI)		D(HSI)		D(JKSE)	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b
1	0.014	6.007	5.385	7.434	0.133	0.820	4.456	4.879	10.193	13.783	73.299	58.8
3	13.846	12.363	4.775	7.815	0.430	1.245	5.547	4.873	8.833	12.178	59.801	52.0
6	13.017	11.899	6.401	7.367	0.781	1.726	6.065	4.727	9.791	12.535	55.797	49.0
9	12.257	11.492	6.577	9.383	0.851	2.207	5.664	4.670	10.922	11.928	52.192	46.6
12	13.704	11.856	6.273	9.951	1.962	3.101	5.479	4.787	10.271	12.232	47.681	43.0
15	13.385	11.514	7.264	9.663	2.011	4.191	5.594	5.151	10.301	12.976	46.237	40.9

Variance Decomposition of D(STI):

Period	D(DJA)		D(EU)		D(FTSE)		D(NIK)		D(HSI)		D(STI)	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b
1	2.185	12.886	11.341	18.256	0.313	0.006	12.858	9.838	13.000	24.070	60.304	34.9
3	18.481	24.800	9.760	15.853	0.491	0.143	11.870	10.065	11.548	19.741	46.316	27.2
6	17.627	24.025	10.086	15.168	0.475	1.274	11.440	9.873	11.805	19.292	43.864	26.8
9	16.880	22.899	9.866	16.080	0.650	1.308	11.071	9.393	11.775	18.244	41.622	25.9
12	17.410	21.539	9.788	16.312	1.175	1.681	10.845	9.427	11.859	18.379	39.844	24.0
15	16.514	21.069	10.270	15.624	1.249	2.708	11.012	9.688	11.790	17.684	38.165	23.2

Variance Decomposition of D(KLSE):

Period	D(DJA)		D(EU)		D(FTSE)		D(NIK)		D(HSI)		D(KLSE)	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b
1	0.210	0.120	0.115	0.401	0.037	0.857	0.471	0.848	0.273	0.019	96.936	97.6
3	0.377	0.277	1.399	0.739	0.192	1.668	0.580	2.615	0.442	0.130	93.092	88.3
6	0.643	0.659	2.470	0.769	0.651	4.393	0.981	4.075	0.584	1.306	88.409	81.3
9	0.870	2.406	2.893	1.334	1.208	4.735	1.370	4.178	0.681	3.675	82.560	73.9
12	1.324	2.945	2.968	2.738	1.621	5.060	1.684	4.032	2.399	3.473	78.192	69.1
15	1.499	3.538	3.301	2.687	2.224	5.459	1.704	4.268	2.534	3.889	74.858	66.8

Variance Decomposition of D(SET):

Period	D(DJA)		D(EU)		D(FTSE)		D(NIKKKEI)		D(HSI)		D(SET)	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b
1	0.001	0.781	2.756	11.110	0.046	0.357	40.035	36.230	0.059	0.839	57.065	50.1
3	3.480	25.274	3.877	10.173	0.374	0.346	38.980	23.000	0.497	1.208	51.454	35.5
6	3.677	23.934	4.155	11.485	1.098	1.110	38.314	21.584	0.690	1.172	48.999	33.7
9	3.691	22.567	4.354	12.057	1.429	2.311	35.670	20.232	2.481	3.280	47.152	30.2
12	3.954	22.745	4.424	12.338	1.542	2.315	34.575	19.691	2.879	3.900	45.958	29.0
15	4.065	22.168	5.026	12.259	2.000	2.541	34.020	18.726	3.176	5.166	44.788	28.6

Variance Decomposition of D(PSEI):

Period	D(DJA)		D(EU)		D(FTSE)		D(NIK)		D(HSI)		D(PSEI)	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
1	0.975	0.792	0.044	2.375	0.286	0.486	1.710	1.732	3.154	3.962	86.485	88.0
3	13.171	28.552	4.208	5.056	0.543	0.369	1.575	1.775	2.725	2.778	70.390	53.6
6	12.491	26.895	5.178	5.885	1.689	1.209	2.445	2.037	2.733	2.843	64.008	51.0
9	12.229	26.048	5.677	7.229	1.833	1.523	2.536	2.920	3.299	4.126	60.944	47.2
12	11.783	25.695	5.272	7.200	2.532	1.838	3.077	3.167	3.941	4.895	57.747	44.9
15	11.522	25.549	5.116	8.380	2.854	2.422	3.207	3.030	4.385	5.580	56.482	42.0

Sources: www.finance.yahoo.com (data processed), Note: (a)= pre-crisis, (b) crisis period

5. Conclusion

Based on the standard deviation, it before the crisis period, Nikkei and Hangseng index yielded the highest return among other developed countries, while in the crisis period, the stock of developed countries produced a negative return, except the Hongkong Shanghai Index. In the ASEAN countries, JKSE gave the highest return, but with the most volatility.

The analysis of contagion with DCC and Paired Sample Test indicated that there was a significant increase coefficient before the

crisis and during the crisis period. This confirmed the contagion effect from the developed country stock return to those of the five ASEAN countries, except the Dow Jones Index to PSEI Philippines, and from HSI to KLSE. The correlation of stock return experienced a sharp increase in the crisis period. This occurred between the Hongkong Shanghai Index with JKSE, STI, and SET, then Dow Jones Index with JKSE & STI, FTSE with JCI, and the last between Nikkei & PSEI.

The spillover effect from the developed market during the crisis period was greater in the five ASEAN countries except for Malaysia, and the effect of volatility on the movement of stock returns in five Asian countries was smaller in the crisis period. This condition confirmed that the coordination between stock markets is greater, meaning that what happens in the global stock market served as the reference to the movement of domestic stocks. Besides that, the spillover from DJA to the five ASEAN countries remained the biggest among the developed countries in the period of crisis.

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