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Abstract

We attempted to investigate the ***contagion effects of the US subprime crisis on ASEAN-5 stock markets [including Malaysia (conventional and Islamic), Thailand, Singapore, Indonesia, Philippines]*** *by applying MGARCH-DCC through the period of January 1, 2004 to July 5, 2012 on daily stock indices returns, and also Continuous Wavelet Transform coherence method through the period of January 1, 2006 to December 31, 2009[1] on daily stock indices returns. This is motivated by the fact that the 2007-2009 crises in the US mortgage market were transmitted to the rest of the world through cross-country banking linkages. This paper, to our best knowledge, is the first attempt to explore such issue for the ASEAN-5 markets (including Malaysia Islamic stock market) using the most recent econometric techniques. We found evidence that there were statistically* ***significant contagion effects*** *from the US sub-prime crisis to the ASEAN-5 countries and the contagion occurred probably around mid-2008. Our results tend to indicate* ***consistent co-movement*** *between most of the ASEAN-5 stock markets and the US stock market in the long run. We also uncovered evidence of a* ***wide variation in co-movement across different timescales*** *during the financial crisis. The* ***Malaysia conventional*** *stock market is found to be more contagious than its counterpart, the Malaysia Islamic stock market, and the latter is* ***negatively correlated w****ith the US stock market with a decreasing co-movement pattern even during the crisis period indicating policy implications for portfolio diversification.*

[1] The period of August 1, 2007 to August 31, 2009 was initially taken as "crisis period" to conduct wavelet coherence analysis, but the time length seemed too short and failed to address long term fundamental co-movement in the graphs. Therefore, the period extended to from January 1, 2006 to December 31, 2009, where the markets are correlated fundamentally and in consistency with theory.

1. Introduction

In 2008, the United States experienced a major financial crisis which led to the most serious recession since the Second World War. The collapse of Bear Stearns on March 16, 2008, and that of Lehman Brothers on September 15, 2008, has triggered turmoil not only in the US financial market, but also in the global financial market. The crisis transmitted to the emerging markets economies has once again raised the question of contagion effects. In a seminal paper, Allen and Gale (2000) explain "contagion" as a consequence of excess spillover effects. Contagion in their view is hence the phenomenon of extreme amplification of spillover effects. Therefore spillover effects are a necessary - but not a sufficient - condition for contagion. Contagion is also defined as an occurrence when volatility of assets prices spills over from the crisis country to other countries. Moreover, a significant increase in cross-market linkages after a shock to an individual country (or group of countries) can be observed. As the saying goes, "when US sneezes, the world catches a cold", knowing that during US subprime crisis the emerging Asia stock market index dropped by 17%, where the largest stock market declines (over the crisis period as a whole) have occurred in Singapo re (-27 percent), Thailand (-21 percent), and the Philippines (-21 percent) [2], in this paper we attempt to investigate the contagion effects of US subprime crisis on ASEAN-5 stock.

Theoretically, there are mixed views on whether the volatility transmitted during the crisis constitutes contagion. In the other words: transmission of a large shock during a crisis is the contagion effect or it is just a continuation of the same cross-market linkages (interdependence) that exists during more tranquil periods. Broadly, there are two groups of theories proposed by Forbes and Rigobon (?) discussing on how shocks are propagated internationally with the respect to contagion verses interdependence: crisis-contingent and non-crisis-contingent theories. Crisis-contingent theories are those that explain why transmission mechanisms change during a crisis and therefore why cross-market linkages increase after a shock. Whereas non-crisis-contingent theories explains how shocks could be propagated internationally do not generate contagion. These theories assume that transmission mechanisms after an initial shock are not significantly different than before the crisis. Instead, any large cross market correlations after a shock are a continuation of linkages

[2] Source: Anderson (2009), UBS

that existed before the crisis. These channels are often called "real linkages" since many (although not all) are based on economic fundamentals. Evidence of shift-contagion would support the group of crisis-contingent theories, while no evidence of contagion would support the group of non-crisis-contingent theories, thus the theories on the contagion effect are not conclusive.

Furthermore, in empirical studies the existence of contagion effect in relation to recent US subprime crisis remains a debatable issue. Some studies show a significant rise in the estimated time-varying correlation in the period of August 2007 to March 2009 during the global crisis, and conclude that there was a contagion effect (Yiu, Ho & Lu, 2010). Conversely, other researchers found that the US stock market is not generating contagious effects into the Asian stock markets (Morales & Andresso, 2009). Yet, the research done by Anis Omri & Sonia G. Z. (2011) concludes "some contagion, some interdependence". Therefore, the empirical evidences on the contagion effects remine unsolved.

There are extensive attempts in studying the contagion effects from the US sub-prime crisis to the Asia-Pacific stock markets. Among others, Loh (2013) found consistent co-movement between most of the Asia-Pacific stock markets and that of Europe and the US in the long run, and also uncovered evidence of a wide variation in co-movement across the time scale of the financial crises**.** Although Loh's paper gave us a good insight of volatility transmission issue from US sub-prime to Asia-Pacific stock markets, our work differs from it in the following ways. Firstly we focus on the contagion effects from the recent US subprime crisis to the ASEAN-5 stock markets since these markets have top-5 GDP ranking[3] and are considered as region with great potential; Secondly, the Islamic stock market is also included, where the contagion between Malaysia conventional stock market and Malaysia Islamic market are compared; Thirdly, not only we examined the time-variation and scale-variation in co-movements between these markets by applying Continuous Wavelet coherence method, but also we adopted very recent additional techniques known as MGARCH-DCC; The last but not the least, the combination of the techniques to analyse such issue and scope in depth, from our knowledge, could be the first attempt in the existing literature.

Therefore, to fill the gap, we will study this important yet unresolved issue: the contagion effects of the US sub-prime crisis on the ASEAN-5 stock markets [including Malaysia (conventional and Islamic), Thailand, Singapore, Indonesia, Philippines stock markets] by applying MGARCH-DCC from January 1, 2004 to July 5, 2012 on daily stock indices returns,

[3] International Monetary Fund 2011 estimates

and also, Continuous Wavelet Transform coherence method through period of January 1, 2006 to December 31, 2009[4] on daily stock indices returns. We propose the following research questions:

1. Is there empirical evidence of contagion effects of the US subprime crisis on the ASEAN-5 stock markets?
2. If so, what is the time length and the extent of increased correlation of the contagion effects? What is the time-variation and the timescale-variation in co-movements between US and ASEAN-5 stock markets and among the regional stock markets? What is the lead-lag relationship of each pair?
3. Is Malaysia conventional stock market more/less contagious and high/low correlated with the US stock market compared to its counterpart during the global financial crisis? What are the time-variation and timescale-variation differences in co-movements between US-Malaysia conventional stock market pair and US-Malaysia Islamic stock market pair? What is the lead-lag relationship of each pair?

As a summary, the finding showed that there is statistically significant contagion effects from the US sub-prime crisis to ASEAN-5 countries and the contagion occurred probably around misd-2008. The unconditional volatility is the highest in Indonesia market returns (.0082549), and the lowest in Malaysia market returns (.0047155). In the cross return correlations, the results suggested that Singapore and Malaysia were highly positively correlated (.63433). In addition, Malaysia conventional stock market was found more contagious in respond to the US subprime crisis than Malaysian Islamic stock market during the global financial crisis period. Negative correlation was also found in co-movement between Malaysia Islamic stock market and US stock market (-.8446E-3). We provided evidence that there were time-variation and scale-variation in co-movements between these markets. The co-movement during a financial crisis was unstable over time and across scale. The results showed consistent co-movement between most of the ASEAN-5 stock markets and the US stock market in the long run. We also discovered evidence of a wide variation in co-movement across the time scale of the financial crisis. For most ASEAN-5 stock markets, the co-movement concentrated at the 1-32 day time scale prior to the US sub-prime crisis, while the co-movement extended to a 32-128 day time scales during the crisis. Mid-2008 was the

[4] The period of August 1, 2007 to August 31, 2009 was initially taken as "crisis period" to conduct wavelet coherence analysis, but the time length seemed too short and failed to address long term fundamental co-movement in the graphs. Therefore, the period extended to from January 1, 2006 to December 31, 2009, where the markets are correlated fundamentally and in consistency with theory.

period where we can observe the sudden increase in volatilities and correlation of all markets. On contrary, Malaysian Islamic stock market was negatively correlated with US stock market and showed a decrease in co-movement pattern during the crisis.

The paper is organized as follows: Section 2 briefly underpins theoretical framework; Section 3 reviews some existing literatures; Section 4 discusses the data and methodologies used; Section 5 discusses the research results and answers the research questions; and we move on to policy implications and research limitations in Section 6; Section 7 concludes the paper with the summary findings and implications.

2. Theoretical Framework

Crisis-contingent theories of how shocks are transmitted internationally can be divided into three mechanisms: multiple equilibria (Masson, 1998; Mullainathan, 1998), endogenous liquidity (Valdés, 1996; Calvo, 1999), and political economy (Drazen, 1998). This group of crisis-contingent theories suggests a number of very different channels through which shocks could be transmitted internationally: multiple equilibria based on investor psychology; endogenous-liquidity shocks causing a portfolio recomposition; and political economy affecting exchange rate regimes. Despite the different approaches and models used to develop these theories, they all share one critical implication: the transmission mechanism during (or directly after) the crisis is inherently different than that before the shock. The crisis causes a structural shift, so that shocks are propagated via a channel that does not exist in stable periods. Therefore, each of these theories could explain the existence of contagion defined as a significant increase in cross-market linkages after a shock.

On the other hand, non-crisis-contingent of explaining how shocks could be propagated internationally does not generate shift-contagion can be divided into four broad channels: trade[5], policy coordination, country re-evaluation[6], and random aggregate shocks. The first transmission mechanism could not only have a direct impact on a country's sales and output, but if the loss in competitiveness is severe enough, it could increase expectations of an exchange rate devaluation and/or lead to an attack on another country's currency. The second mechanism links economies because one country's response to an economic shock could

[5] Gerlach and Smets (1995) first developed this theory with respect to bilateral trade and Corsetti et al. (2000) used micro foundations to extend this to competition in third markets.

[6] This includes models of pure learning, such as Rigobon (1998), as well as models of herding and informational cascades, such as Chari and Kehoe (1999) and Calvo and Mendoza (1998).

force another country to follow similar policies. The third propagation mechanism, country re-evaluation or learning, argues that investors may apply the lessons learned after a shock in one country to other countries with similar macroeconomic structures and policies.

From the theoretical frameworks and controversies we may rise up a question: is the US subprime crisis on ASEAN-5 stock markets contagion effects or interdependency? It seems our research questions cannot be precisely addressed by the theoretical answers. Therefore, there is a need for an empirical answer to the issues that we proposed.

3. Literature Review

The similar issues have been examined in various research papers. Some studies found that Asian stock markets did not experience contagion effects during the global financial crisis. Forbes and Rigobon (2002) analyze the impact of the Asian crisis 1997, Mexican devaluation and 1987 U.S.market crash on the equity markets of emerging and developed countries, and concluded, with adjusted correlation tests, that most of the changes (16 out of 17 countries) seen as a high level of market co-movement were due to interdependence rather than the contagion effects.

However, the opposite findings are also presented in many papers.

Inchang, In, and Kim (2010) examine the contagion effects of the U.S. subprime crisis on international stock markets. The results suggest a significant rise of conditional correlation during the subprime period. The authors state this as an evidence of contagion and they suggest the contagion effects were stronger during the subprime crisis compared to Asian crisis. Kim, Kim & Lee (2012) examine spillover effects of the recent U.S. financial crisis on five emerging Asian countries (Indonesia, Korea, the Philippines, Thailand, and Taiwan), and they found some evidence of financial contagion around the collapse of Lehman Brothers in September 2008. Kim and Kim S. (2013) argue that Korea's recent financial distresses reflect contagion of the crisis, beyond normal interdependence between the Korean financial market and other regional financial markets. They found that the contagion occurs mainly during Leman's bankruptcy and the financial market instability in February 2009. Their estimation results suggest that exogenous shocks are transmitted to the domestic financial market and they are further facilitated by the structural weakness of domestic financial system. Loh (2013) finds consistent co-movement between most of the Asia-Pacific stock markets and that of Europe and the US in the long run, and also uncovered evidence of a

wide variation in co-movement across the time scale of the financial crises; the co-movement dynamics of the Asia-Pacific markets with that of Europe and the US are different during the two financial crises. The researcher further pointed out that the difference in the co-movement dynamics could be the result of the different natures of the financial crises or a change in regime. Chan & Mohd (2010) find that the market returns in the stock market in ASEAN-5 were highly dependent on their own past returns. Besides that, stock market in the United States was found to be more influential in terms of returns and volatility compared to the Japanese stock market. Intraregional linkages were also found among the stock price movements in the ASEAN-5. In addition, stock market in the Philippines and Thailand appeared to be more vulnerable to stock movements from other countries.

There are also related studies to the financial contagion in the context of Islamic stock markets. For instance, Mahmoud (2013) finds that the Islamic bank assets' diversification strategy across the regions reduces the likelihood of financial contagion among conventional banks. S. Kabir, O. Bacha & Masih (2013) find that both returns and volatility in Islamic equity markets are affected by the financial turmoil. Their findings also suggest that Islamic equity returns are relatively more sensitive to the regional rather than the global market conditions and also to the lower leverage ratio of firms as part of their stock screening methods. B. Saiti, G. Dewandaru & Mansur Masih (2013) argue that in all cases the changes in the wavelet correlation coefficients are insignificant for selective *Shari'ah*-compliant stock markets at all timescales during the US subprime crisis. They conclude this is due to overlapping of confidence intervals implying that there is no clear evidence of contagion at all timescales.

However, none of the above research examined the contagion effects of the US subprime crisis on ASEAN-5 stock markets (including Malaysian Islamic stock market) by using very recent financial econometric techniques MGARCH-DCC and Continuous Wavelet Transform coherence method. Hence, we conclude that our issues both theoretically and empirically are still inconclusive, and we humbly attempt to fill this gap in finance literature.

4. Data and Methodologies

4.1 Data

The daily stock indices returns are used for the period of January 1, 2004 to July 5, 2012 including the US Dow Jones Industrial Average, DJGI (Dow Jones Global Indices) Malaysia,

DJGI Indonesia, DJGI Thailand, DJGI Singapore, DJGI Philippines and DJ Malaysia Islamic, where the data were retrieved from DataStream and Bloomberg. Data from January 2004 till December 2009 are used for MGARCH-DCC models estimation. Furthermore, to conduct Wavelet coherence analysis, data from January 1 2006 till December 31, 2009 are used.

For each compounded daily return series of each index, it is generated as follows:

$$r_t = 100\ x\ ln\left(\frac{p_t}{p_{t-1}}\right)$$

Where r_t is the return for period t; p_t and p_{t-1} are closing price index on days t and t-1 and ln is the natural logarithm.

The notations are as follows. DOWJ is for Dow Jones Industrials Average; DJMY is for DJGI Malaysia; IDX is for DJGI Indonesia, THD is for DJGI Thailand; SIG is for DJGI Singapore; PHIP is for DJGI Philippines; and DJIMY is for DJGI Malaysia Islamic.

4.2 Methodologies

MGARCH (Multivariate Generalized Autoregressive Conditional Heteroskedasticity)

In this paper, we use MGARCH (Multivariate Generalized Autoregressive Conditional Heteroskedasticity) framework with DCC (Dynamic Conditional Correlation) specification by Engle (2002) for the estimation, which allows for heteroskedasticity of the data and a time-varying correlation in the conditional variance. The main merit of DCC in relation to other time varying estimation methods (such as MGARCH CCC, rolling regressions and Kalman filters and their variants such as Flexible Least Squares) is that it accounts for changes in both the mean and variance of the time series (unlike the above methods which account for only the time-varying changes in the mean). In other words, DCC allows for changes in both for the first moment (mean) and second moment (variance). Furthermore, MGARCH-DCC modelling allows us to pinpoint changes (both *when* they occur and *how*) in the interdependence between time series variables.

The DCC model is a two-step algorithm to estimate the parameters which makes it relatively simple to use in practice. In the first stage, the conditional variance is estimated by means of univariate GARCH model, respectively, for each asset. In the second step, the parameters for the conditional correlation, given the parameters of the first stage, are estimated. Finally, the DCC model includes conditions that make the covariance matrix positive definite at all points in time and the covariance between assets volatility a stationary process.

To estimate H_t, we follow two- steps estimation for MGARCH-DCC:

(i) Univariate volatility parameters are estimated by using GARCH models for each of the variables. So if there are two variables, then two GARCH equations are estimated. Just as an example:

$$h_t = c_0 + a_1\varepsilon_{t-1}^2 + b_1 h_{t-1} + b_2 h_{t-2} + m_1\varepsilon_{t-1}^2 I_{\varepsilon>0}$$

(GJR, 1993 Asymmetric GARCH equation).

Where *I* is an indicator function in which it equals 1 when the standardized residuals of the series (ε_t) are positive and equals 0 otherwise. A negative value of 'm' implies that periods with negative residuals would be immediately followed by periods of higher variance compared to the periods of positive residuals. The equation for GARCH is estimated in step 1 (for each variable) to estimate the residual (ε_t).

(ii) The standardized residuals (ε_t) from the first step are used as inputs for estimating a time-varying correlation matrix (by estimating DCC equation parameters).

$$H_t = D_t R_t D_t$$

Here:

H_t : Conditional covariance matrix

D_t : Diagonal matrix of conditional time varying standardized residuals (ε_t) that are obtained from the univariate GARCH models (on-diagonal elements or variance or volatility component)

R_t : Time varying correlation matrix (off-diagonal elements)

The likelihood of the DCC estimator is written as:

$$L = -0.5 \sum_{t=1}^{T} (k \log(2\pi) + 2\log(|D_t|) + \log(|R_t| + \varepsilon_t' R_t^{-1} \varepsilon_t)$$

(a) In the first step, only the volatility component (D_t) is maximized; i.e. the log likelihood is reduced to the sum of the log likelihood of univariate GARCH equations.

(b) In the second step, correlation component (R_t) is maximized (conditional on the estimated D_t) with elements ε_t from step 1. This step gives the DCC parameters, α and β,

$$R_t = (1 - \alpha - \beta)\,\overline{R} + \alpha\varepsilon_{t-1}\varepsilon_{t-1}' + \beta R_{t-1} \qquad \text{(DCC equation)}$$

If $\alpha = \beta = 0$[7], then R_t is simply $\overline{R}$ and CCC model is sufficient. The models have GARCH-type dynamics for both the conditional correlations and the conditional variances. The time-varying conditional variances can be interpreted as a measure of uncertainty and thus give us insight into what causes movement in the variance.

The two-step estimation of the likelihood function is consistent, albeit inefficient (Engle and Sheppard, 2001). The DCC allows asymmetries, meaning the weights are different for positive and negative changes to a series. The asymmetries are in the variances (not in the correlations) (Cappiello, Engle and Shephard, 2003).

The estimation of two models responds to the research questions we want to address. Model 1 intends to address research questions 1-2, consisting of US, Malaysia (conventional), Indonesia, Thailand, Singapore and Philippines stock market indices. Model 2 intends to address research question 3, consisting of US, Malaysia (Islamic), Indonesia, Thailand, Singapore and Philippines .stock market indices

Although MGARCH-DCC accounts for changes in both the mean and variance of the time series, its problem is that it cannot tell the dynamics of market co-movement at different time scales and the lead-lag relationship. Hence, apart from MGARCH- DCC technique, we also applied Continuous Wavelet coherence to extend our understanding towards the issue. The advantage of wavelet coherence is the analysis allows a better understanding of the time-variation and timescale-variation in co-movements between stock markets.

Continuous Wavelet Transform Coherence

Compared to Fourier analysis, which is as one of the origins of wavelets analysis that the fundamental idea is that any deterministic function of frequency can be approximated by an infinite sum of trigonometric functions called the Fourier representation, Wavelet analysis has three distinctive advantages over Fourier analysis. Firstly, wavelet analysis has the ability to decompose the data into several time scales instead of the frequency domain. This advantage allows us to examine the behaviour of a signal over various time scales. This is very critical because different market participants have different investment horizon. Investment horizon (time scale) is an important aspect that affects trading behaviour (Müller et al., 1997; Lynch & Zumbach, 2003). Noted that many heterogeneous investors make decisions over different time scales and perform each movement on different time scales,

[7] β close to 1 indicates a strong degree of persistence in the series for correlations (R_t), while ($\alpha + \beta$) close to 1 indicates high persistence in the conditional variance.

market co-movement varies across different time scales according to the investment horizons of different investors. Secondly, the wavelet transform enables windows to vary. In order to isolate signal discontinuities, one would like to have some very short basic functions. At the same time, in order to obtain detailed frequency analysis, one would like to have some very long basis functions. Fortunately, wavelet transforms allow us to do both. Lastly**,** the ability to handle non-stationary data, and unlike others it is free of restrictive assumptions. In fact in the real world, 99% of financial data are non-stationary.

Basically, there are three types of wavelets that exist and are adopted in economics and finance: discrete wavelet transform (DWT), maximal overlap discrete wavelet transform (MODWT), and continuous wavelet transform (CWT). This paper uses CWT to examine co-movement between stock market returns since it possesses the ability to construct a time-frequency representation of a signal that offers very good time and frequency localization.

The CWT Wx(u, s) is obtained by projecting a specific wavelet ψ (.) onto the examined time series X(T) $\epsilon 1^2$(R). CWT is defined as:

$$W_x(u,s) = \int_{-\infty}^{\infty} x(t)\frac{1}{\sqrt{s}}\psi\left(\frac{t-u}{s}\right)dt$$

A wavelet has two control parameters, u and s. The 'u' is the location parameter that determines the exact position of the wavelet and the 's' is the scale parameter that defines how the wavelet is stretched or dilated.

An important aspect of the wavelet transform is the ability to decompose and guarantee perfectly the reconstruction of the function x(t) ϵ L^2(R):

$$x(t) = \frac{1}{C_\psi}\int_0^{\infty}\left[\int_{-\infty}^{\infty} W_x(u,s)\psi_{u,s}(t)du\right]\frac{ds}{s^2} \quad s>0$$

The energy of the x(t) is preserved by the wavelet transform, such that:

$$\|x\|^2 = \frac{1}{C_\psi}\int_0^{\infty}\left[\int_{-\infty}^{\infty}\left|W_x(u,s)\right|^2 du\right]\frac{ds}{s^2}$$

To analyse co-movement between stock returns, we need to deploy wavelet coherence which is a bivariate framework. Wavelet coherence will show the regions in which the two time series in time-scale space co-move but may not have high power. Wavelet coherence can be

viewed as the local correlate ion, both in time and frequency, between two time series. This concept is particularly useful in analysing the correlation between financial data during different regimes without having to sub-divide the data into different sample periods. Standard time series econometric methods analyse the time and frequency components separately but wavelet coherence allows three-dimensional analysis of time series data. We can simultaneously consider the time and frequency components, and the strength of the co-movement. Following Torrence and Webster (1999), we define wavelet coherence as follows:

's' is a smoothing operator; without smoothing, coherency is identically 1 at all scales and times. Smoothing is achieved by convolution in time and scale. (See Grinsted et al. (2004) for details on smoothing). Wxy(u, s) is the cross wavelet power, and it uncovers the region in time-scale space in which the time series show high common power. Cross-wavelet power can be viewed as the local covariance between two time series at each scale. Torrence and Compo (1998) defined cross wavelet power of two time series x(t) and y(t) as:

$$W_{x,y}(u,s) = W_x(u,s)W_y^*(u,s)$$

where Wx(u, s) and Wy(u, s) are continuous wavelet transforms of x(t) and y(t), respectively. The symbol * denotes a complex conjugate.

The wavelet coherence phase differences show the lead-lag relationships between the two time series. Following Torrence and Webster (1999), the wavelet coherence phase is defined as follows:

$$\phi_{xy}(u,s) = \tan^{-1}\left(\frac{I\{S(s^{-1}W_{xy}(u,s))\}}{R\{S(s^{-1}W_{xy}(u,s))\}}\right)$$

where I and R are the imaginary and real parts, respectively, of the smooth power spectrum.

The phase is represented by an arrow in the wavelet coherence plots. A zero phase difference means that the two time series move together on a particular scale. Arrows point to the right (left) when the time series are in phase (anti-phase). When the two series are in phase, indicating that they move in the same direction, anti-phase means that they move in the opposite direction. Arrows pointing up mean that the first time series leads the second one by 90°, while arrows pointing down indicate that the second time series leads the first one by 90°.

5. Discussion of Results

Table 1 reports the estimated unconditional volatilities and unconditional correlation cross correlations between stock indices returns. The off diagonal elements represent unconditional correlation (Red colour and bolded are highest correlation coefficients) and diagonal elements represent unconditional volatilities of the stock indices returns (blue colour, bolded, and ranked). We can see that unconditional volatility is the highest for Indonesia market returns (.0082549) and lowest for Malaysia (.0047155), which implies that overall, Malaysia stock market returns are almost two times more stable than Indonesia market returns. Investors should be aware of this before investing in these stock markets. Regarding the cross return correlation, we observe that return from Singapore and Malaysia are highly positively correlated (.63433), which shows the possible direction of movement and the degree of association (+63%) between the return of Singapore and Malaysia stocks returns. It is also a concern for the investors because any movement in the return of either of the two could cause another to change in the same direction with a great magnitude.

Table 1: Estimated Unconditional Volatility Matrix for 6 Markets (Model 1)

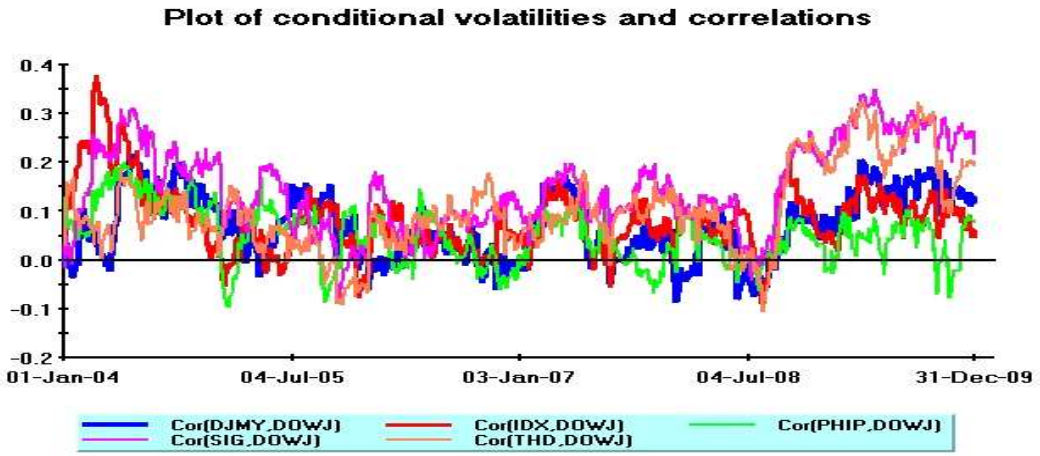
	DOWJ	DJMY	IDX	PHIP	SIG	THD
DOWJ	**.0055426 (5)**	.10168	.079124	**.040784 (3)**	25319	.20552
DJMY	.10168	**.0047155** (6)	.46811	.47887	**.63433 (1)**	.41393
IDX	.079124	.46811	**.0082549** (1)	.41798	**.55972 (2)**	.42149
PHIP	.040784	.47887	.41798	**.0067560(3)**	.47604	.35122
SIG	.25319	.63433	.55972	.47604	**.0060592(4)**	.55319
THD	.20552	.41393	.42149	.35122	.55319	**.0073383(2)**

5.1 Discussions of Estimated Conditional Correlation between US and ASEAN-5 and among regional markets

In this section we try to answer research question No. 1 and research question No. 2 . From Figure 1, we can see that the correlation between US and ASEAN-5 stock markets, with time-varying consideration, in general experienced ups and downs with an upward-slop moving pattern throughout the study period. It is easy to observe that during the crisis period, the correlations for all pairs increased sharply since the mid-2008, except the correlation between the US and Philippines stock market where there are no substantial changes for the

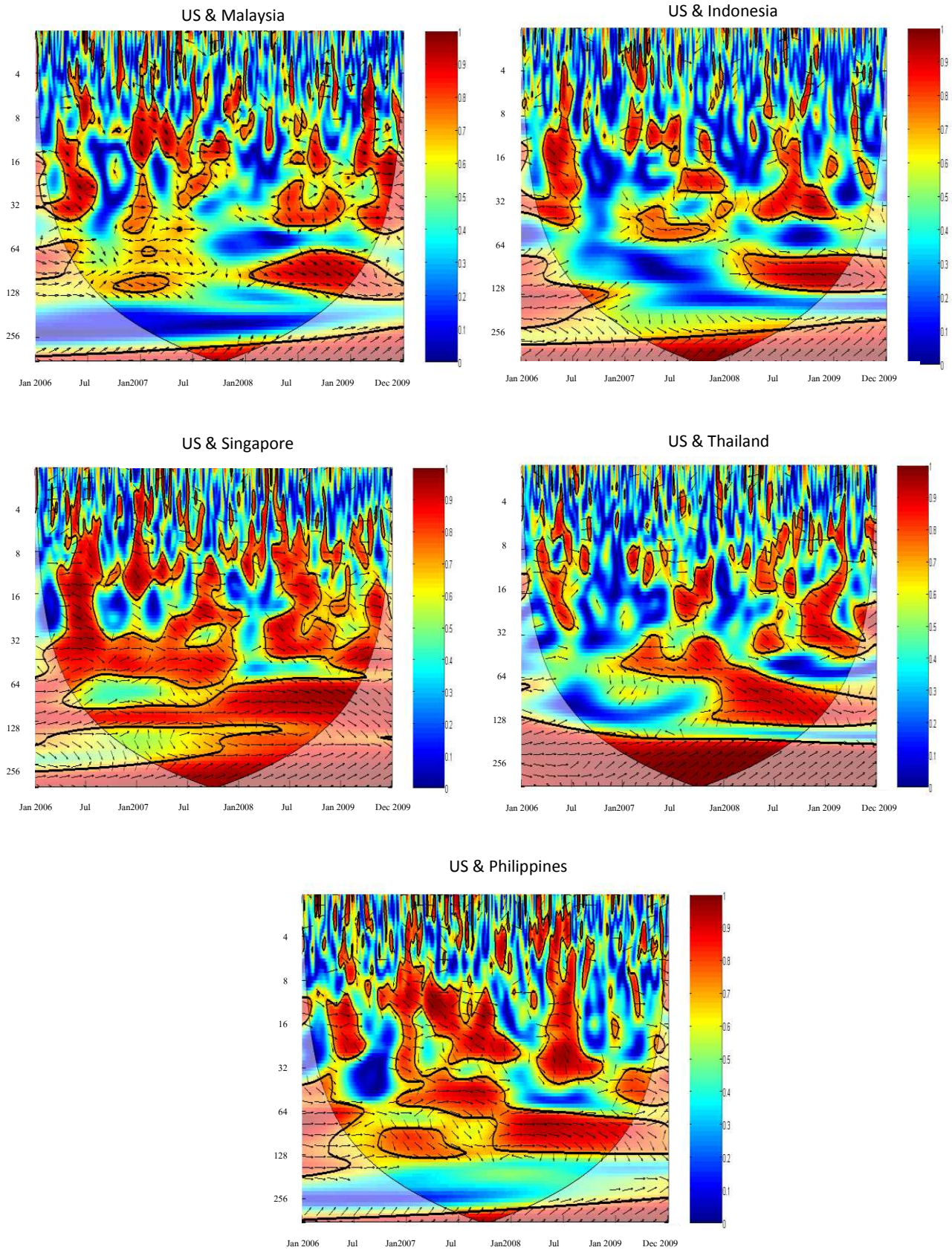
pattern of correlation. The coherence analysis in Figure 2 tends to confirm the pattern movements seen from Figure 1 whereby the ups from Figure 1 show as a higher correlation (more red color at different time scales) in Figure 2, and the downs show as lower/non correlation (more blue color at different time scales).

Figure 1: Conditional correlation of variables: Model 1, corr (DOWJ,X)



Overall, the co-movements between these pair markets are instable and the patterns of relationship are not consistent and a wide variation in co-movements across different timescales during the financial crisis is found. The uniqueness of correlation between US and Malaysia (conventional) is that the co-movement occurs more to 4-32 day time scale and inconsistent though. Very limited co-movement for 32-256 day and more time scale is found, and the co-movement increased since January 2008 for all scales. The results indicate similar changes for the pattern of correlation between the US and Indonesia pair (except it showed a much low co-movement with US market since January 2009). US and Singapore pair has the highest correlation coefficient (0.25). The co-movement of this pair is more concentrated at longer time scale (above 30 days) throughout the study period with the exception that the co-movement at 16 to 64-day time scale was relatively weak, and this pattern lasted around 3 months. There is very low co-movement between US and Thailand from July 2006 till January 2007, and increase about May 2008. Philippines has the lowest correlation coefficient (0.04) with US market compared with the other four pairs. However, there is no dramatic change during crisis period. The correlation is more concentrated at 4-128 day time scale but not for the even longer time scales. Overall, the co-movement of each pair is not stable and the pattern of relationship is not consistent. Moreover, Figure 2 suggests that US dominated positive leading position towards Malaysia (conventional), Indonesia, Singapore,

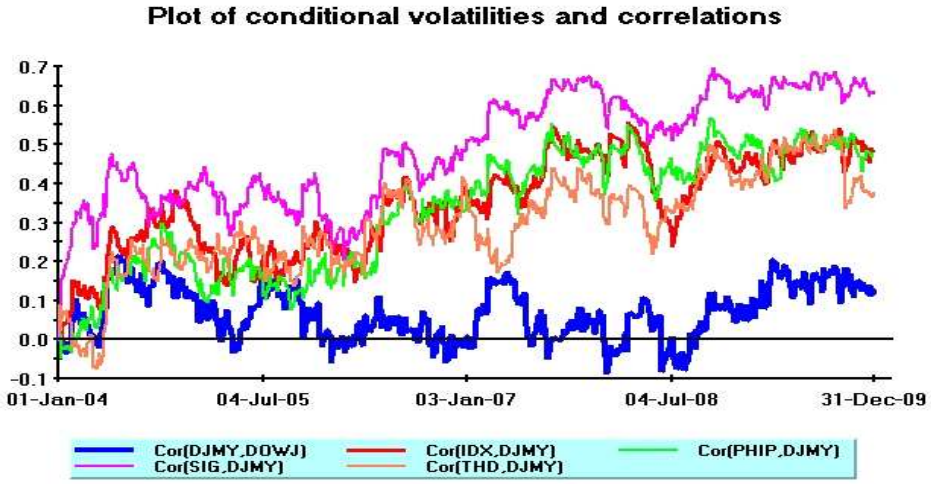
Figure 2: Co-movement between US, Malaysia, Indonesia, Singapore, Thailand and Philippines



Thailand, and Philippines' stock markets and it implies that the ASEAN-5 stock markets were largely and more influenced by the movements of US stock market's past during global financial crisis, which intuitively makes sense as well for US is a developed and matured market.

Like the ups and downs with an upward-slop co-movement pattern in Figure 1, in Figure 3 we can all see similar correlation between Malaysia and other ASEAN-5 stock markets throughout the study period. Also starting from mid-2008, the correlations for all pairs increased sharply. The coherence analysis in Figure 4 tend to confirm the pattern movements seen from Figure 3 whereby the ups from Figure 3 show as a higher correlation (more red color at different time scales) in Figure 4, and the downs show as lower/non correlation (more blue color at different time scales).

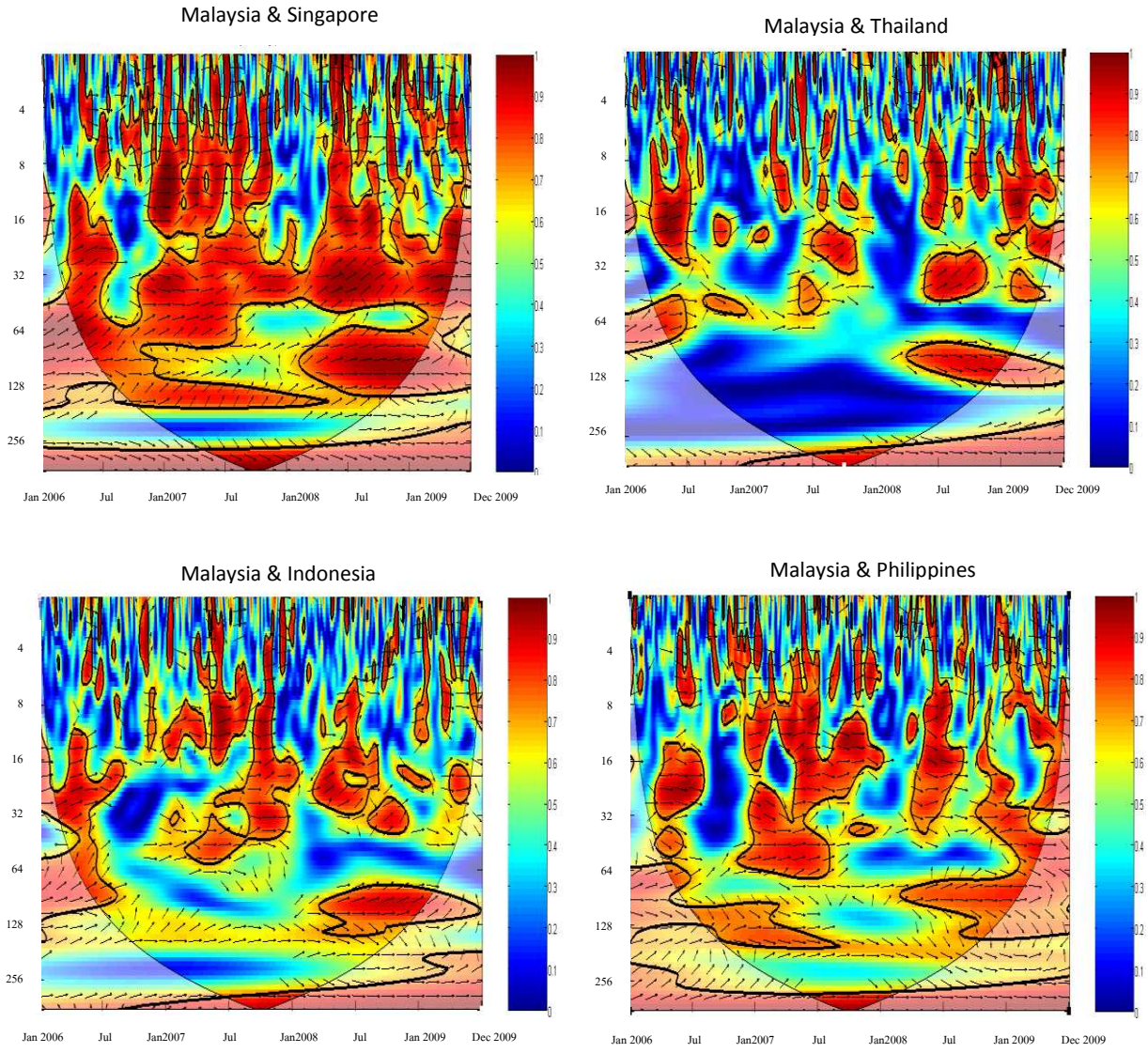
Figure 3: Conditional correlation of variables (Model 1)



Malaysia (conventional) and Singapore has the highest correlation (0.63) among all pairs throughout the whole period as shown in Figure 3 except from December 2007 till May 2008 whereby a weak correlation was found. This is also captured and confirmed by the result in Figure 4. Besides, Figure 4 also suggested us that this low co-movement occurred at 4-32 day and 64-128 day time scale. The co-movement between Singapore and Malaysia pair has increased after earlier 2008, but the dependency is weak. Malaysia (conventional) and Thailand has the second highest correlation (0.56) after Malaysia (conventional) and Singapore pair, and the co-movement increased since April 2008. Figure 4 seems to suggest that most of the time Thailand market led Malaysia market. The co-movement between Malaysia (conventional) and Indonesia is more concentrated around end of 2006 till end of 2007 at 4-64 day time scale with inconsistent pattern and unstable. There was an increase in co-movement from April 2008 and these two markets co-moved more at longer time scale of

64-128 day and less at 8-64 day time scale. Malaysia (conventional) and Philippines co-moved similarly with Malaysia (conventional) and Indonesia.

Figure 4: Co-movement between Malaysia, Indonesia, Singapore, Thailand and Philippines



World Bank states that contagion occurs when cross-country correlations increase during "crisis times" relative to correlations during "tranquil times." Furthermore, noted by Kim & Kim S. (2013), the important judgments about the contagion effect depend heavily on the time length and the extent of increased correlations. Our findings above suggest that the sharp increases in the correlation of each pair (except US-Philippines) would be a strong indication of the contagion effect causing from the US subprime crisis. The tests based on the correlation coefficients estimated from the DCC-GARCH and the continuous wavelet coherence methods lend support to our argument. The contagion occurs around mid-2008 in ASEAN-5 economies. The estimation results suggest that exogenous shocks are transmitted

to the ASEAN-5 stock markets and they are further facilitated by the high level of interdependency with US stock market.

5.3 Is Malaysia conventional stock market more contagious than its Islamic counterpart during the global financial crisis? A comparison

This section is trying to answer research question No. 3. Similar with Table 1, in Table 2 the off diagonal elements represent unconditional correlation (Red colour and bolded is the lowest correlation coefficients) and diagonal elements represent unconditional volatilities of the stock indices returns (blue colour, bolded, and ranked). Our findings suggest that the unconditional volatility for Malaysia Islamic stock market (0048239) is slightly more volatile than Malaysia conventional stock market (.0047155), but the difference is very minor. Whereas the unconditional correlation with US market for Malaysia conventional stock market (.10168) is much stronger than its counterpart (-.8446E-3), and even Malaysia Islamic stock market negatively co-moved with US stock market during the crisis period.

Table 2: Estimated Unconditional Volatility Matrix for 6 Markets (Model 2)

	DOWJ	DJIMY	IDX	PHIP	SIG	THD
DOWJ	**.0055426** (5)	**-.8446E-3**	.079124	.040784	.25319	.20552
DJIMY	-.8446E-3	**.0048239**(6)	.023579	.015397	.039742	.043805
IDX	.079124	.023579	**.0082549**(1)	.41798	.55972	.42149
PHIP	.040784	.015397	.41798	**.0067560**(3)	.47604	.35122
SIG	.25319	.039742	.55972	.47604	**.0060592**(4)	.55319
THD	.20552	.043805	.42149	.35122	.55319	**.0073383**(2)

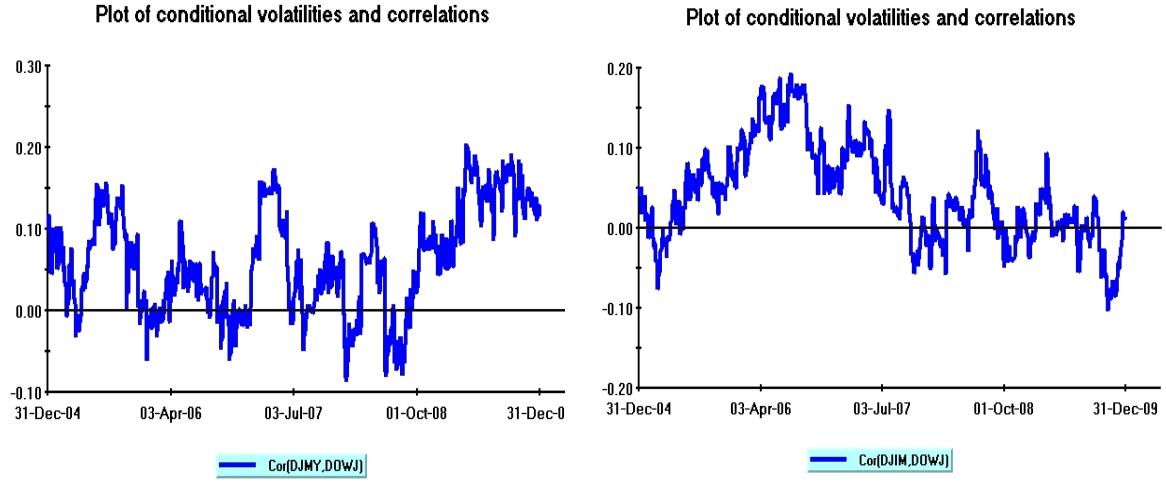
In order to stay focused, we plot Figure 5 to have simpler and clearer views on the responses of the correlations of these two pairs alone to the shocks over time, and Figure 6 presents the Continuous Wavelet Transform coherence analysis for the correlation between US and Malaysia Islamic stock market (Please refer to Appendix 2 Figure7 for Model 2 conditional correlation of other variables).

From Figure 5, we can see that the correlation for these two pairs both experienced ups and downs but with different patterns. As we have analyzed in the previous section of US and Malaysia conventional stock market pair, an upward-slop co-moving trend indicates the

correlation between this pair is getting stronger and stronger. In addition, it is also observed that around mid-2008, a sharp increase in co-movement between this pair, even it reached the most peak during study period. The result clearly implies a strong contagion of the crisis from the US subprime. On contrary, the correlation between US and Malaysia Islamic stock market pair displays a downward-slop co-moving trend for the same period. This trend actually began around August 2006 since the market experienced the strongest correlation with US market. This negative correlation coefficient (-.8446E-3) might imply that the shock from US brought negative impact to Malaysia Islamic stock market. In other words, to certain extent, the Islamic stock market performed even better and could have benefited from the crisis. Therefore, we could draw a conclusion that Malaysia conventional stock market is more contagious than its counterpart during the US subprime crisis.

The results in Figure 6 confirm the findings from the Figure 5 and it depicts the co-movements of these two pairs with the time-variation and timescale-variation elements, which enable us to have deeper understanding of the issue. It is observed that the Malaysia conventional stock market and US stock market co-moved relatively stronger at 4-32 day time scales till early 2008, and since then with the increase of co-movement between this pair, they are co-moved at 64-128 day a longer time scale as well. It suggests that the global financial crisis does have a fundamental impact to Malaysia conventional stock market's stability.

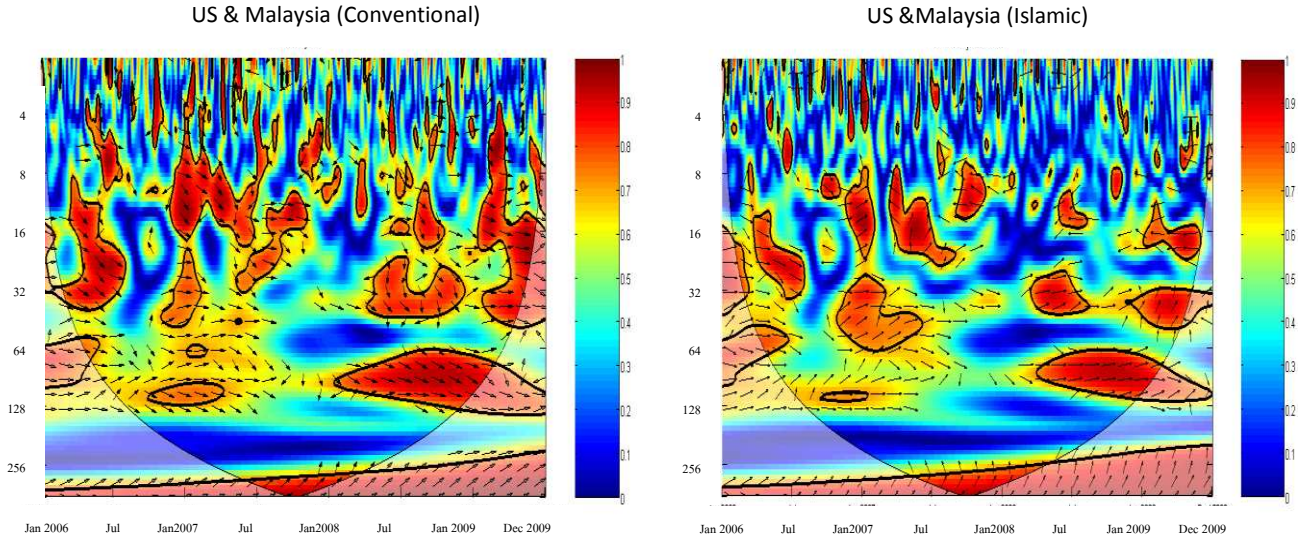
Figure 5: Conditional correlation US, Malaysia (conventional) and Malaysia (Islamic)



Given this co-movement pattern, it shows unstable over time and inconsistent over time scales. Compared with the US and Malaysia conventional pair, the co-movement between Malaysia Islamic stock market and US stock market is much weaker. This is also consistent with our finding in earlier where the correlation coefficient between Malaysia conventional

stock market and US market is 0.10168, whereas the correlation coefficient between Malaysia Islamic stock market and US market is -0.8446E-3. A negative correlation coefficient of this pair probably is evidenced by a decrease co-movement between this pair at 4-32 day time scales. Furthermore, this pair is co-moved at 64-128 day time scales after mid-2008 but the dependency is weak.

Figure 6: Co-movement between US, Malaysia, Malaysia Islamic



Interestingly, although these two stock markets are correlated with US stock market in opposite directions, we found there is some similarity in their co-movement patterns at a macro-view. However these two markets still differ from the timescales and the degree of dependency with the US stock market. From Figure 6, we could observe that both pairs co-moved with US market from January 2007 till January 2008 at below-64-day time scale, and thereafter these pairs experience about half year a very low co-movement with US market. And then the co-movement for both pairs changed in different direction since mid-2008. We understood this similarity could be due to both Malaysia conventional stock market and Malaysia Islamic stock market are influenced by similar economic expectations, technological innovations, financial regulations or trading conditions.

From the above results, we can conclude that the US subprime crisis in 2007-2008 did have impact on the volatility of ASEAN-5 stock markets (including Malaysia Islamic stock market with negative impact though) and their correlations with US market. With the assistance of Continuous Wavelet coherence analysis, we further discovered that the co-movement between ASEAN-5 markets and US stock market concentrate at longer time scales. This observation is similar and consistent with findings by Graham et al. (2012) and Loh (2013).

Graham et al. (2012) studied the integration of 22 emerging stock markets with the US market. There was an increase in co-movement at shorter time scale during financial crises. Loh (2013) found that the results showed consistent co-movement between most of the Asia-Pacific stock markets and that of Europe and the US in the long run. Additionally, the evidence of a wide variation was also uncovered in co-movement across the time scale of the financial crises. These observations show that the dependency between ASEAN-5 markets and the US is a long-run dependency but includes short-term fluctuations during a financial crisis.

6. Policy implications and limitations of the paper

Due to the strong connectivity[8] and inter-linkage among these markets, to understand the distinct impact of the shocks from the advanced economy to these economies, and to understand how volatilities and correlations between asset returns change over time including their directions (positive or negative) and size (stronger or weaker) is of crucial importance and immensely valuable to not only investors but also policy makers. This is because in academic and practice, it has profound implications, inter alia for diversifying their portfolios for hedging against unforeseen risks, dynamic option pricing, corporate capital budgeting and international policy coordination. Therefore, in this section we try to elaborate on the implications of our discussions for the investors and the practitioners as well as policy makers.

As for investors, although the long-run diversification benefits tend to diminish in this more and more integrated world, we still try to propose some possible decision-making guides with the hope that the investors could seize potential opportunity for portfolio diversifications.

In the portfolio construction, investors may invest in the markets that least or less co-moved with US stock market, for example Malaysia stocks and Philippines stocks. However, it is not suggested to invest in Malaysia and Singapore at the same time because of very high correlation between these two markets. Even the correlation between these two markets is the strongest, ranging from 0.3 to 0.7, which implies that the correlation is even stronger after the global financial crisis. Besides that, the Malaysian Islamic stock market is found to be less contagious and negatively correlated with the US stock market, so investors may consider having Malaysian Islamic stocks in their portfolios. Furthermore, co-movement between two stock markets at different time scales is a great concern for investors. Our findings suggest

[8] ASEAN region is influenced by similar economic expectations, technological innovations, financial regulations or trading conditions

that the co-movement between the ASEAN-5 and the US shows primary concentration at a longer timescale over time with short timescale fluctuations during a financial crisis. For most ASEAN-5 stock markets, the co-movement concentrated at the 1-32 day time scale prior to the US sub-prime crisis, while the co-movement extended to a 32-128 day time scales during the crisis, where around mid-2008 is the time point we can observe the sudden increase in volatilities and correlation of all markets. Additionally, we also found the existence of strong co-movement between most of these markets and US market at a longer time scale. Our results imply that for an international investor who wants to hold a risky asset in ASEAN-5, he would not be able to achieve reap simultaneously the benefits of portfolio diversification and time diversification. We also found that all cross-border markets investigated have one similarity in their conditional correlation: a raise-up pattern since around mid-2008. This could indicate that mid-2008 is the point where the crisis strikes across ASEAN-5 markets with slight variation among countries. This could be the hint that starts from this point of time the investors should prolong their investment horizon. These findings may have important implications for the international investors as well.

For policy makers, enacting appropriate policies are very critical to move the economy out of troubled waters toward safer harbours. More importantly risks from contagion in international financial markets still remain, especially for developing countries. Therefore, with respect to the results we obtained earlier, we identified the following policies.

A. Strengthening the individual country policies

The most important means of reducing contagion and minimizing the effects of future financial crises is to strengthen individual country policies. As to what we have found, the Indonesia stock market is the most volatile (.0082549), whereas the Malaysia stock market is the least volatile (.0047155), we argue that it could reflect that Malaysia has a stronger financial system and Indonesia has a weaker financial system. For countries that have a weaker financial system, it can strengthen its financial system by conducting review of the quality of financial systems, including “stress tests” to evaluate the ability of the financial system to withstand shocks originating in other countries. Moreover, strengthening the corporate sector and the ability of banks to collect on defaulted loans are also very effective. Besides, many countries have also taken important steps to improve their bankruptcy systems and corporate governance. This includes providing better information on corporate accounts, which in turn helps banks and investors make more informed decisions. This is also a desirable practice for countries like Indonesia to strengthen the weaker financial system.

B. Better fiscal management and better debt management

Better fiscal management, and especially better debt management, has also received substantial attention since the 1990's and can reduce the risk of contagion. Malaysia recorded large fiscal deficits in 2009 at 7.0% of GDP in ASEAN-5 region (Appendix 3 Figure 8). In Malaysia, public spending increased with the implementation of an additional fiscal stimulus package, while revenue collection was adversely affected by the decline in global oil prices – resulting in a decline in petroleum royalties and petroleum income tax account. Thailand and the Philippines recorded substantial fiscal deficits in 2009 at 4.1% of GDP and 3.9% of GDP, respectively, attributed to both increasing public expenditure and declining public revenues. In Philippines, the government collected lower revenue owing to economic weakness and a range of tax cuts implemented at the start of 2009[9]. These poor fiscal managements, especially in Malaysia, indicate that its risk of contagion is more than the others and the respective policies have to be implemented to improve the situation.

Regarding the debt management, overall ASEAN-5 countries reduce their debts year by year (Appendix 3, Figure 9).

C. Reduction of restrictions on foreign investment and investors

Reducing restrictions on foreign investment, especially in the banking system could facilitate the entry of foreign banks, other financial institutions, and other forms of direct investment. For example, Bank Negara Malaysia liberalized its licensing policies to foreign banks.

In addition, governments may implement strong macroeconomic policy measures such as lowering interest rates and supplying banks with sufficient liquidity and others.

As financial integration continues to increase around the world, even without crises, international financial markets will remain volatile. Therefore, government officials, investors, and policymakers should continue to take steps as proposed to strengthen individual country economies and investment strategies in order to reduce the risks from contagion in the future.

Of course, there are limitations in this paper, such as the paper only selects one Islamic stock market and to compare with its counterpart; the study period (data length) could extend to the current year; the paper assumes the cause of contagion among ASEAN-5 is solely from the US sub-prime crisis; not all cross-border correlations are discussed in this paper mainly due

[9] Data source: Asian Development Bank, Key Indicators for Asia and the Pacific 2010 (Manila, 2012).

to our research focus. These limitations could be the future research for those who are interested.

7. Summary findings and implications

We attempted to investigate the impact of the US sub-prime crisis on the volatility of the ASEAN-5 stock markets [including Malaysia (conventional and Islamic), Thailand, Singapore, Indonesia, Philippine] by applying MGARCH-DCC through the period of January 1, 2004 to July 5, 2012 on daily stock indices returns, and also, Continuous Wavelet Transform coherence method from January 1, 2006 to December 31, 2009 on daily stock indices returns. We found the evidence that there is statistically significant volatility transmission and spillover effect from the US sub-prime crisis to ASEAN-5 countries and the contagion occurs probably around mid-2008.

We also found the conditional volatility is the highest in Indonesia market returns (.0082549) and lowest for Malaysia market (.0047155). In the cross return correlations, the results suggest that Singapore and Malaysia are highly positively correlated (.63433) among all pairs.

Our results tend to indicate that the co-movement during a financial crisis was unstable over time and across timescale. Moreover it indicates the consistent co-movement between most of the ASEAN-5 stock markets and the US stock market in the long run. We also uncovered evidence of a wide variation in co-movement across different timescales during the financial crisis. For most of the ASEAN-5 stock markets, the co-movement concentrates at the 1-32 day timescale prior to the US sub-prime crisis, while the co-movement extended to a 32-128 day timescale during the crisis, where around mid-2008 is the time point we can observe the sudden increase in volatilities and correlation of all markets. The US stock market dominated the leading position with all the ASEAN-5 stock markets despite they were shocked by the global financial crisis originating from the US. This intuitively makes sense because after all the US market is big and matured among all. We also acknowledge there is contagion taking place during the US sub-prime crisis on the other ASEAN-5 stock markets. This could be indicated by the evidence that all cross-border markets investigated have one similarity in their conditional correlation: a raise-up pattern since around mid-2008. It could suggest that the US sub-prime crisis has the impact on the volatility transmission and spillover effect across ASEAN-5 markets with slight variation. Overall, the co-movement between each pair was unstable over time and across timescale during a financial crisis. The results suggest

various lead-lag relationships: Singapore and Malaysia is weak; most of time Thailand led Malaysia; Malaysia switching leading role with Indonesia; and Malaysia led Philippines market.

In addition, our finding also suggests that the Malaysian Islamic stock market (.0048239) is slightly more volatile than its conventional counterpart (.0047155), but the Malaysian conventional stock market was found more contagious in response to the US subprime crisis than the Malaysian Islamic stock market during the global financial crisis period. Not surprisingly, it is found that Malaysian Islamic stock market is negatively correlated (-.8446E-3) with the US stock market overall since mid-2006. During the global financial crisis period, the pattern persisted and even the correlation declined further. Figure 9 indicates that the Malaysian conventional stock market and US stock market co-moved relatively stronger at 4-32 day time scales till early 2008, and since then with the increase of co-movement between this pair, they co-moved at 64-128 day a longer time scale as well. It suggests that the global financial crisis does have a fundamental impact on Malaysian conventional stock market's stability. Given this co-movement pattern, it shows unstable over time and inconsistent over time scales. Compared with the co-movement between Malaysian conventional stock market and US market, co-movement between Malaysian Islamic stock market and US stock market is much weaker. Furthermore, the negative correlation between this pair could indicate policy implications for portfolio diversification. Prior to January 2008, the co-movement was concentrated at 4-32 day time scales. The negative correlation coefficient probably is evidenced by a decrease in co-movement between this pair at 4-32 day time scales. Besides, this pair co-moved at 64-128 day time scales after mid-2008 but the dependency is weak. As we mentioned earlier, US market led Malaysian conventional stock market positively, whereas the negative lead-lag could be found in the co-movement between Malaysia Islamic stock market and US market, around October 2007 and July 2008 for instance. It is indicated that before August 2006 US led Malaysian Islamic stock market, however it turned to be unstable since then. Nevertheless, the dependency is weak and the co-movement is found unstable over time and inconsistent over timescales.

Knowing the dynamic changes of correlations, time-variation and timescale-variation in co-movements among these studied stock markets, these would have important implications for not only the policy makers and but also the investors. It is especially true for the investment portfolio optimization. In order to cope with the challenges in constructing a well-diversified

portfolio in today's highly correlated markets and together with the contagion not going away, James et.al. (2012) have proposed good tips for the investors: appropriate risk management, slightly longer-term views, and careful choice of the most liquid instruments may well all help push investors back into the black. Moreover, we would like to add one more: investors would benefit from the inclusion of Shariah-compliant stocks into their portfolios.

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Appendix 1: Testing Results in Tables

Table 3: Estimation of the MGARCH-DCC model on stock indices daily return (Model 1, t-istribution)

Multivariate GARCH with underlying multivariate t-distribution

Converged after 29 iterations

Based on 1566 observations from 01-Jan-04 to 31-Dec-09.

****

Parameter	Estimate	Standard Error	T-Ratio[Prob]
lambda1_DOWJ	.93796	.010157	92.3498[.000]
lambda1_DJMY	.91694	.015051	60.9234[.000]
lambda1_IDX	.85564	.033197	25.7743[.000]
lambda1_PHIP	.85664	.033386	25.6587[.000]
lambda1_SIG	.92673	.011753	78.8508[.000]
lambda1_THD	.84291	.032744	25.7427[.000]
lambda2_DOWJ	.051452	.0074918	6.8678[.000]
lambda2_DJMY	.061650	.010232	6.0250[.000]
lambda2_IDX	.080709	.016004	5.0432[.000]
lambda2_PHIP	.069904	.014490	4.8245[.000]
lambda2_SIG	.051021	.0075911	6.7212[.000]
lambda2_THD	.10450	.019875	5.2579[.000]
delta1	.97033	.0067832	143.0496[.000]
delta2	.013198	.0020543	6.4246[.000]
df	8.3475	.51350	16.2562[.000]

****

Maximized Log-Likelihood = 37272.3 df is the degrees of freedom of the multivariate t distribution

Table 4: Estimation of the MGARCH-DCC model on stock indices daily return (Model 2, t-istribution)

Multivariate GARCH with underlying multivariate t-distribution

Converged after 27 iterations

Based on 1566 observations from 01-Jan-04 to 31-Dec-09.

****

Parameter	Estimate	Standard Error	T-Ratio [Prob]
lambda1_DOWJ	.93934	.010293	91.2557[.000]
lambda1_DJIMY	.91018	.014666	62.0592[.000]
lambda1_IDX	.84292	.036684	22.9779[.000]
lambda1_PHIP	.82387	.039954	20.6206[.000]
lambda1_SIG	.91557	.013755	66.5617[.000]
lambda1_THD	.81656	.037914	21.5375[.000]
lambda2_DOWJ	.050242	.0075652	6.6412[.000]
lambda2_DJIMY	.070003	.010669	6.5614[.000]

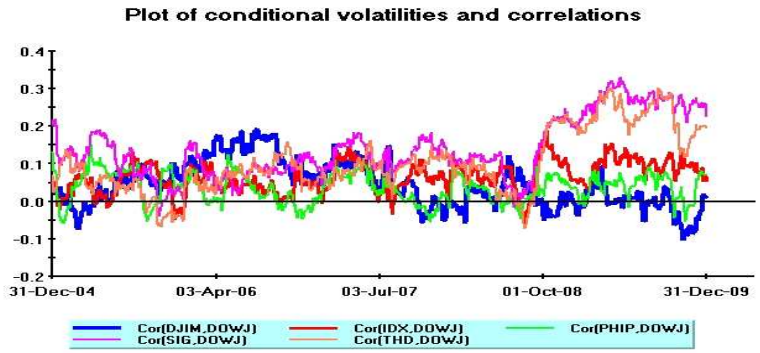
lambda2_IDX	.088663	.017592	5.0399[.000]
lambda2_PHIP	.084170	.016930	4.9717[.000]
lambda2_SIG	.058199	.0088169	6.6008[.000]
lambda2_THD	.12256	.022707	5.3974[.000]
delta1	.96883	.0093050	104.1186[.000]
delta2	.011635	.0021655	5.3727[.000]
df	9.3521	.60716	15.4031[.000]

****

Maximized Log-Likelihood = 36953.2 df is the degrees of freedom of the multivariate t distribution

Appendix 2

Figure 7: Conditional correlation of variables: Model 2, corr (DOWJ,X)



Appendix 3

Figure 8 Fiscal balance of ASEAN-5

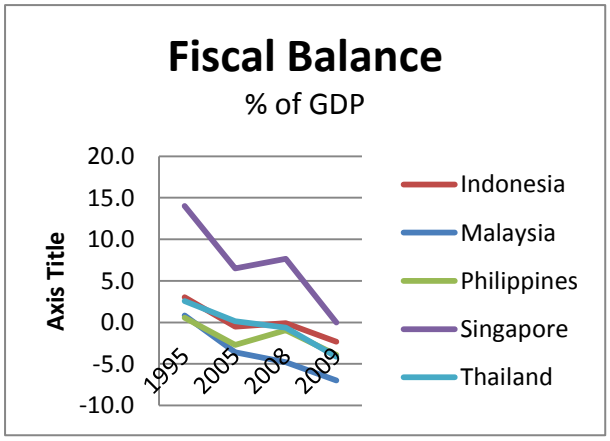
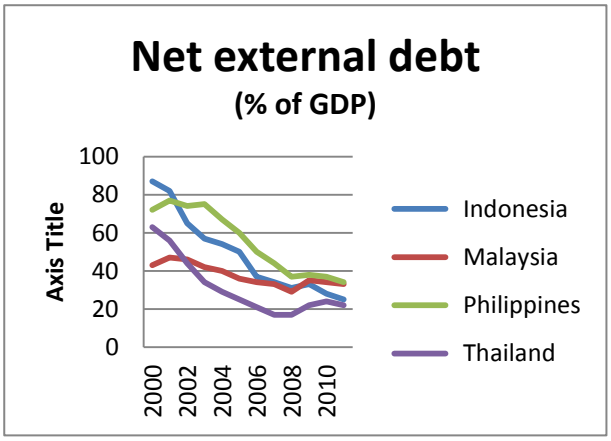


Figure 9 Net external debt



Data source: Asian Development Bank, Key Indicators for Asia and the Pacific 2010 (Manila, 2012).