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ASYMMETRIC FRACTIONALLY INTEGRATED VOLATILITY MODELLING OF ASIAN EQUITY MARKETS UNDER THE SUBPRIME MORTGAGE CRISIS

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Abstract

The fractionally integrated asymmetric power autoregressive conditional heteroscedasticity model has successfully captured the empirical stylized facts such as the leverage effect, power transformation and long memory in the foreign exchange markets. This study further explores the applicability of this model in the Asian equity markets under the impact of the 2008 United States subprime mortgage crisis. The empirical stylized facts of the markets are examined before and after the Lehman Brothers filed for bankruptcy protection in year 2008. The important findings of this empirical study are as follows: First, majority of the Asian equity markets are more appropriate in conditional variance representation than conditional standard deviation based on their power transformation results. Second, all the equity markets' leverage effect and magnitude appear to increase after the failing of the Lehman Brothers. Third, most of the long memory volatility intensities have the tendencies of declining across the crisis periods. From the explanation of heterogeneous market hypothesis, majority of the Asian mature markets become more efficient after the bankruptcy of Lehman Brothers whereas emerging markets with no direct investment may be affected by other factors such as political crisis or domestic economic issues and appeared to indicate fluctuating and descending long memory.

Keywords: fractionally integrated ARCH, leverage effect, subprime mortgage crisis.

JEL Classifications: C01, C58, G17

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1. Introduction

The United States (US) subprime mortgage crisis is among the worst financial catastrophes that has created global recession and steep declinations in most of the worldwide financial markets. The subprime mortgages have received considerable investments (daily with the record of USD $3 billion per trading day in year 2007) over the worldwide investors through the US treasury bills, bonds and other instruments. Thus, the collapse of this market might have direct or indirect impacts to other financial markets under the financial globalisation. Especially across the years 2007 and 2008, the US government and their financial institutes have implemented various policies and regulations to ease the severe damages by this crisis. These included lower down the Federal funds rate, improve the bank liquidities, economic stimulus packages and bailouts or merger of banks. At the same time, there are also a lot of negative news speculating the global markets such as unexpected jump in petroleum products prices, world food price crisis, high unemployment and loss of confidence in banks. Thus, it is worth to investigate the effect of subprime mortgage crisis in term of its news impact. Besides this, the volatility persistence is also an interesting stylized fact that should be taken into account in the analysis. The volatility persistency provides information regarding the market informational efficiency across the crisis period. In other words, this stylized fact indicates the predictability level of the equity markets across the crisis periods.

This study aims to examine three distinctive stylized facts, the leverage effect, power transformation and long memory of the Asian equity markets under the impact of the US subprime mortgage crisis. Stemming from the subprime mortgage market in the United States (US), the financial crisis has inevitably spread into the other regions including the Asia. The question is; how bad are Asian economies being affected? It is true that the amount of investment made by Asian countries in the subprime mortgage market is not as substantial in comparison to the US and other developed countries. However, the impact of this financial crisis has indeed significantly affected the Asian economies in certain ways. A recent study has shown that previous US recessions always entailed recessions in the emerging Asian countries (Hong et al. 2010). With many of the Asian countries becoming more active in the foreign trade (especially Malaysia, Singapore, Taipei and China), it caused their economies to be more synchronized with the US, in particular during the recessions. Besides, a report by the IMF (2008) had also shown that over the years, Asian countries have become more financially integrated with the US, which resulted from the huge rise in Asia's holdings of US securities. This scenario has led to massive investment by the Asia in US. On top, there was also increase of foreign investments in Asia which was mostly from the West. Indeed, US investors had an enormous involvement in Asian stock markets. IMF data have shown that US investors are the biggest external source of investment in several Asian countries; Hong Kong (accounting for about 36% of the total value of Hong Kong stocks held by foreign investors), Indonesia (38%), Japan (50%), Korea (50%), Malaysia (33%), Singapore (43%), and Thailand (34%) (S. Shirai 2009). Therefore, the increasingly inter-connected economy has resulted in numerous Asian countries experiencing the sharp falls in stock market prices and causing the currency depreciation due to the fact that many US financial institutions have been trying to secure needed cash and capital by deleveraging their overextended balance sheets (that is by selling both domestic and foreign assets) in Asian economies (Kawai 2008) during the crisis. Based on the previous crises, Asian countries seem to experience a more frequent, protracting and severe recessions following any

financial crisis in the US and other developed countries. It is also found that the more open Asian countries with certain initial economic conditions (e.g. high current account deficits, net government debt, depreciated currencies etc) are more susceptible to the risk. Given the fact that this latest crisis is somewhat different from the former crises, there could be other areas of implications which might not have been identified and tackled before. Therefore, it is worth for us to conduct further research on this subprime mortgage crisis impact on our Asian region. This is hopefully to shed more useful information to our respective policymakers in responding to the crisis.

A flexible model introduced by Tse (1998) which combined the asymmetric power ARCH model (Ding et al. 1993) and integrated differencing operator (Granger and Joyeux 1980) in fractionally integrated ARCH model (Baillie et al. 1996), is used to capture all the aforementioned stylized facts. The fractionally integrated technique has been introduced by Baillie et al. (1996), Ding et al. (1993), Granger (1980), Lo (1991) and Mandelbrot (1997) in the literature of finance. The worldwide financial time series include stock market, foreign exchange, commodity markets and macroeconomic indicator indicating the evidence of long memory with slow hyperbolic decaying shocks. The presence of long memory financial time series is important in informationally efficient market and risk management analysis. With the evidence of long memory, the time series is claimed to be consisted of predictability components which to some extents against the efficiency market hypothesis (Fama 1998). This statistical property is also one of the essential stylized facts in time series modelling where it is crucial for estimation as well as forecast especially in the market risk determination such as value-at-risk (Jorion 2002). For the *first* stylized fact, asymmetric volatility sometimes refers to leverage effect in finance. In short, the conditional volatility tends to respond higher to negative shocks ('bad' news) than positive shocks ('good' news) of the same magnitude. This phenomenon has been evidenced (Brooks 2007; Cheong et al. 2007; Selcuk 2005) in the global equity markets. The explanation by Black (1976) stated that the debt-to-equity ratio of an asset is highly sensitive to 'bad' news where negative information most likely will cause a negative return. When this ratio increases, the equity becomes riskier with higher volatility (Campbell and Hentschel 1992). Other factors that influence the magnitude of asymmetric volatility are such as individual or corporate gain taxes (Jayasuriya et al. 2009 named it as transaction costs) and short selling activities (Bris et al. 2004) in a particular equity market. *Second*, the Cox-Box power transformation in condition volatility provides the most appropriate volatility representation which often restricts to the Bollerslev's conditional variance (1986) or the Taylor's conditional standard deviation (1986) representations. Under this power transformation, the volatility representation is more flexible and at the same time able to improve the model specification. Finally, the *third* stylized fact is the long memory or fractionally integrated volatility. The discovery of long memory in financial time series has enriched the market efficiency literature with fractal market hypothesis (Aleksander and Rafal 2000; Peters 1994) and heterogeneous market hypothesis (Dacorogna et al. 2001; Mullier et al. 1997). Some studies related the intensity of long memory with the market efficiency (Cajueiro and Tabak 2004; Cheong et al. 2007) in emerging and mature markets. This is because higher long memory intensity implied better predictability of a time series.

In the empirical study, this study investigates the impact of 2007-2008 US subprime mortgage crisis to seven Asian equity markets. In order to isolate the impact of this crisis, the data are divided into four sub-periods during the crisis from year 2008 to 2009. The analysis

focuses on the aforementioned three distinctive stylized facts across the crisis periods. The remainder of this study is organized as follows. In Section 2 we describe the background of US subprime mortgage crisis, data source and data handling. Section 3 explains the conditional heteroscedasticity models and estimation procedures. In Section 4, the estimation results are reported. The three stylized facts are examined and discussed across the subperiods. Finally, some conclusions are given in Section 5.

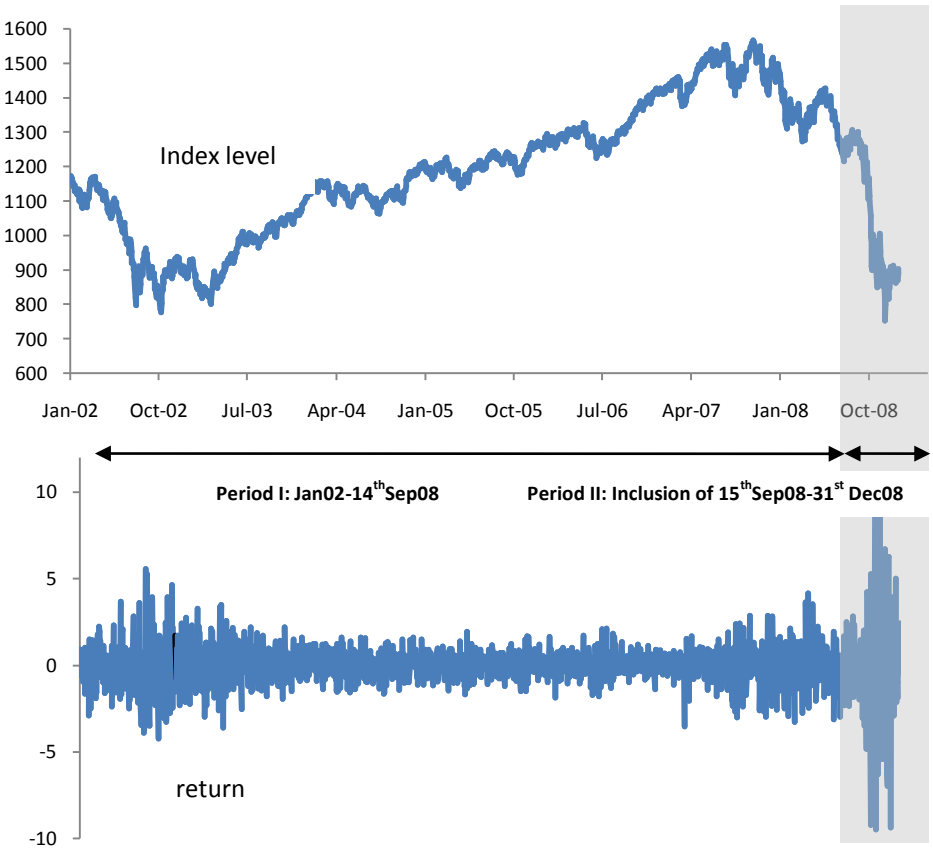
2. Data Source

All the daily indices are collected from the Datastream database from January 2002 until March 2009. Seven Asian countries and the US S&P500 are selected in this study. The Asian equity markets are from Hong Kong (Hang Seng Index), Singapore (Strait Time Index), South Korea (Korea Composite Price Stock Index), Taiwan (Taiwan Stock Exchange), Malaysia (FTSE-Kuala Lumpur Composite Index), Indonesia (Jakarta Stock Exchange) and Thailand (Stock Exchange of Thailand). The S&P500 index is selected for data division and comparison purposes. Their numbers of observations are differed depending on their public holidays and trading days. For Asian countries and the US, the numbers of observations are 1789, 1804, 1789, 1786, 1786, 1758, 1776 and 1823 respectively. According to the Dow Jones classification (http://www.djindexes.com), these equity markets can be classified as mature markets (Hang Seng Index, Strait Time Index, Korea Composite Price Stock Index and Taiwan Stock Exchange) and emerging markets (FTSE-Kuala Lumpur Composite Index, Jakarta Stock Exchange and Stock Exchange of Thailand). The data point is selected from year 2002 and not earlier due to the recession of US economy. In order to examine the impact of US subprime mortgage crisis, the overall observations are divided into *before*-crisis (Jun 2008- 14th September 2008) and *after*-crisis (Jan 2002– Dec 2008) respectively. The stylized facts (estimation results) are expected not to differ significantly across the periods if the crisis effect is not dramatic.

Figure 1 illustrates the timeframe divisions for the S&P500 index level and return series. In general, there is a downward drift started in year 2008 and the US market is relatively more volatile after the bankruptcy of Lehman Brothers. The expansion of the US housing bubble is the greatest in the middle of year 2006. At the end of July 2007, the bubble burst after the collapses of two Bear Stearns hedge funds which caused significant increases in mortgage delinquencies and foreclosures in the subprime mortgage. This crisis spread further until a boiling point in September 2008 when the Lehman Brothers filed for bankruptcy protection and also the US Federal Reserve announced to insure the American International Group (AIG). Figure 2 indicates similar downward drift pattern in all the seven Asian equity markets. Table 1 reports significant drops in all the Asian markets *after*-crisis if compares with *before*-crisis. In order to investigate the information (bad news especially) effect, volatility power transformation and volatility persistence across the crisis periods, we firstly look into the immediate impact of S&P500 index. Later, we examine the spread of this crisis to the selected Asian equity markets.

3. Methodology

Let $\{r_{i,t}\}$ be a set of individual continuously compounded returns series. For a given information set, $I_{i,t-1}$, available at time t–1, the individual conditional expected return r_t is defined as:



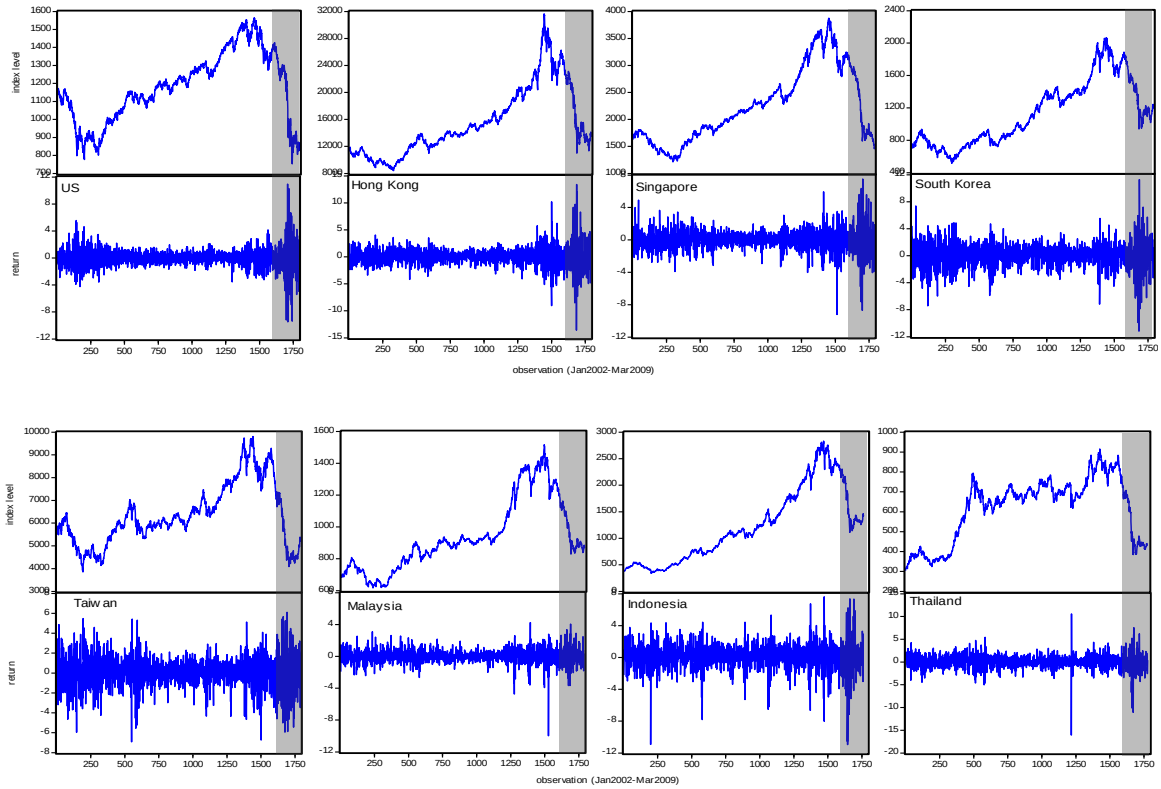
Notes: Data divisions: *Before*-crisis (Jan 2002- 14th September 2008) and *after*-crisis (Jan 2002– Dec 2008)

Figure 1. Index Level and Return Series for the S&P500

Table 1. The Stock Market Performances

	Mature market index level				*Emerging market index level*			
Date	*US*	*Hong Kong*	*Singapore*	*Korea*	*Taiwan*	*Malaysia*	*Indonesia*	*Thailand*
Jan2002	1148.08	11397.21	1625.69	693.7	5551.24	696.09	392.03	303.85
Before crisis	1251.70	19352.90	2570.67	1477.92	6310.68	1044.03	1804.06	654.34
After crisis	931.80	14387.48	1761.56	1124.47	4591.22	876.75	1355.40	449.96

Notes: Data divisions: *Before*-crisis (Jan2002- 14th September 2008) and *after*-crisis (Jan 2002– Dec 2008)



Notes: The shaded area includes *before*-crisis (Jan 2002- 14th September 2008), a*fter crisis* (Jan 2002– Dec 2008)

Figure 2. Index Level and Return Series for the Asian Equity Markets

$$r_{i,t} = \mu_{i,t} - a_{i,t}$$

$$a_{i,t} = \sigma_{i,t}\varepsilon_{i,t},\ \varepsilon_{i,t} \overset{i.i.d}{\sim} f(\cdot); \qquad \ldots (1)$$

where f(·) is the density function of $\varepsilon_{i,t}$ and the conditional mean $E(r_{i,t} \mid I_{i,t-1}) = E_{i,t-1}(r_{i,t}) = \mu_{i,t}$, normally follows a stationary ARMA model. For conditional volatility modelling, Tse (1998) used the power asymmetric generalized ARCH model (Ding et al. 1993) and incorporates the fractionally integrated filter (Granger and Joyeux 1980; Baillie et al. 1996)) results in the following specification:

$$\sigma_{i,t}^{\delta} = \frac{\alpha_{i,0}}{1-\beta_i(B)} + \left\{1 - \frac{\varphi_i(B)(1-B)^d}{1-\beta_i(B)}\right\}(|a_{i,t}| - \gamma_i a_{i,t})^{\delta}, \qquad \ldots (2)$$

where $\alpha(B) = (\alpha_1 B + \ldots + \alpha_q B^q)$, $\beta(B) = (\beta_1 B + \ldots + \beta_p B^p)$ and $\varphi(B) = \frac{1-\alpha(B)-\beta(B)}{1-B}$ represent the lag polynomials. The operator $(1-B)^d = \sum_{n=0}^{\infty}(-1)^n \frac{d(d-1)\ldots(d-k+1)}{k!} B^d$ with $d \in [0,1]$ denotes the fractional integrated operator. The leverage effect is captured by $\gamma \in (-1,1)$. For example, a

positive γ means that negative shocks give rise to stronger volatility than positive shocks with a same magnitude. In addition, the magnitude of relative leverage effect (Jayasuriya et al. 2009) among the indices is calculated using $\gamma = \left(\frac{1+\gamma}{1-\gamma}\right)^{\delta}$. Finally, the coefficient δ indicates the Box-Cox transformation with the most common δ=2 for conditional variance and δ=1 for conditional standard deviation.

In estimation procedures, the truncation lag of the slow decaying fractional differencing operator $(1\text{-}B)^d$ is set to 1000 to account for the possible long-run dependencies which is in line with the common setting (Baillie et al. 1996). More precisely, $(1-B)^d = \sum_{n=0}^{1000} (-1)^n \frac{d(d-1)...(d-k+1)}{k!} B^d$. Due to the large number of parameters, the iterative optimization algorithm is used instead of the analytical derivative approach. Consider a log-likelihood function L_N with overall joint estimator

$$\frac{\partial L_N}{\partial \psi} \approx \frac{\partial L_N}{\partial \psi^{(0)}} + \left(\psi - \psi^{(0)}\right) \frac{\partial^2 L_N}{\partial \psi^{(0)} \partial \psi'^{(0)}}, \quad \text{... (3)}$$

where $\psi^{(0)}$ denotes the trial values of the estimates (θ, α_0, α_1, β_1, γ, δ, d, v) that involve conditional mean parameters and conditional variance parameters. Rearranging the terms as in the Newton-Raphson algorithm, the $(k+1)^{th}$ vector set of parameter values is defined as

$$\psi^{(k+1)} = \psi^{(k)} - \left(\frac{\partial^2 L_N}{\partial \psi^{(0)} \partial \psi'^{(0)}}\right)^{-1} \frac{\partial L_N^{(k)}}{\partial \psi}. \quad \text{... (4)}$$

This study has selected the Marquardt (1963) approach to improve the speed of the estimations. For heavy-tailed ε_t, we use the standardized student-t distribution with between three to six degrees of freedom with the following representation:

$$f(\varepsilon_t; v) = \frac{\Gamma\left[(v+1)/2\right]}{\Gamma[v/2]\sqrt{\pi(v-2)}} \left(1 + \frac{\varepsilon_t^2}{v-2}\right)^{-(v+1)/2}, \quad \text{... (5)}$$

where $\Gamma[\bullet]$ is the gamma function. The student-t distribution with v>2 exceeds the normal kurtosis which indicates fat-tailed behaviour.

4. Empirical Study

4.1 Descriptive Statistics

Table 2 reports the descriptive statistics for all the equity markets. The lowest (negative) mean daily return is observed in US, Singapore and Taiwan whereas the rest of the countries indicated positive returns. All the markets have high standard deviations (excess 1%) compared with their average returns with the exception of Malaysia with 0.87%. This finding implies that overall risk of investing in both the mature and emerging markets are almost the same in the Asian equity markets. All the markets indicate negative skewness except for Hong Kong market. The unconditional returns tend to be skewed to left which may due to numerous negative extreme values during the crisis. For the tail behaviour, all the unconditional returns are leptokurtic.

Based on these statistics, we have conducted the Jacque-Bera normality tests for all the unconditional returns. The tail distributions for all the unconditional returns are heavier than the normal distribution. For Jacque-Bera test, the joint tests of skewness (0 for normal distribution) and kurtosis (3 for normal distribution) are both significantly different from a normal distribution. In conclusion, heavy-tailed innovations may be more suitable in the model specification.

Table 2. Statistics Summary

	Mature market					*Emerging market*		
Statistics	*US*	*Hong Kong*	*Singapore*	*Korea*	*Taiwan*	*Malaysia*	*Indonesia*	*Thailand*
Mean	-0.018326	0.009778	-0.005031	0.030925	-0.003537	0.012651	0.073773	0.019748
Std. Dev.	1.378814	1.655745	1.279693	1.696516	1.490273	0.873115	1.570093	1.471662
Skewness	-0.196982	0.059583	-0.454108	-0.433555	-0.281778	-1.030982	-0.818616	-0.989884
Kurtosis	13.45062	13.73829	9.456369	7.447068	5.248968	14.98031	9.918432	16.76943
Jarque-Bera	8152.675	8596.516	3168.733	1530.213	400.6952	10997.26	3702.438	14320.23

* indicates significant at 5% level.

4.2 Estimation Results

Tables 3 and 4 report the overall estimation[5] results of the FIAPARCH model. First, the tail indices represented by the degree of freedom, v, are all statistically significant at 5% level ranging from 6.358892 to 11.222088. For $v>2$, the conditional error distribution is heavier than a normal distribution. Most of the mature and emerging markets indicate heavy-tailed behaviour with the degree of freedom around 7.0000 except for the South Korea market (10.0000). This implies that the South Korea market's error term is tended toward normal distribution as compared to other markets.

Second, the first order lag autoregressive coefficients θs of conditional returns are all statistically insignificant in Asian mature markets in Table 1. On contrary, three of the emerging markets indicate significant serial correlation in their first lag conditional returns. Emerging markets often exhibit infrequent trading (Antoniou et al. 1997; Miller et al. 1994) with serial correlation in the return series. In addition, Urrutia (1995) also claimed that the potential growth of emerging market also tended to generate this correlation in the return series. However, Miller et al. (1994) reported that this spurious autocorrelation can be adjusted by using a first order autoregressive or moving average. This approach has also been implemented in this study. On the other hand, most of the mature markets are highly liquid and consist of trivial non-synchronous (Engle and Lee 1999) closing prices. Thus, there are no serial correlations observed in the Asian mature markets.

[5] In diagnostic checking tests, the serial correlation tests and Engle's Lagrange multiplier tests are performed on all the models. All the Ljung-Box tests faiedl to reject the null hypothesis of no serial correlation in the standardized residuals. Due to space scarcity, the diagnostic results will be provided upon request.

Third, we focus on the power transformation for all the Asian markets.[6] Based on the test statistics ($\frac{\delta-1}{se}$ and $\frac{\delta-2}{se}$), two markets (South Korea[7] and Thailand) indicate that the power parameter δs are not significantly different from unity suggesting the conditional standard deviation representation (Taylor 1986) for volatility. On the other hand, Hong Kong, Singapore, Malaysia and Indonesia are found to be more favourable to conditional variance models (Bollerslev 1986). It is worth noting that the volatility representation for Taiwan's market cannot be distinguished between neither the Taylor's nor the Bollerslev's representation. Knowing the type of volatility representation (either standard deviation or variance) has an advantage in market forecast and market risk determination.

Fourth, the leverage effect coefficients, γs, are all significant at 5% level across crisis periods. These findings imply that the leverage effect occurs in all the selected markets. The magnitude of leverage effect indicates the intensity of volatility and the risk condition of a market. Normally, the leverage effect magnitude is proportional to the risk level. Overall, the selected Asian markets are more volatile to 'bad news' (negative shock) than positive shocks with the same magnitude. These results are similar to Brooks (2007) and Jayasuriya et al. (2009). Among the selected Asian markets, South Korea and Indonesian markets indicate strongest leverage effect with average values 0.762 and 0.700 across the periods. On the other hand, the Malaysian market shows the least impact to the 'bad' news across the periods. Besides the news impact related to subprime mortgage, gain tax rates (Jayasuriya et al. 2009) are among the factors that influence the magnitude of leverage effect. For instance, the implementation of 20% equities gain tax rate in South Korea is among the factors that cause the high leverage effect as compared to other Asian countries that do not impose taxes. Short selling activity is another reason that affect the magnitude of leverage effect.

Finally, the estimates for long memory parameter, *d*s, for all the markets are statistically significant at 5% level (except for Indonesian market). The presence of long memory property provides additional information regarding how the markets behave and consequently improve the model specifications for the selected markets. With the inclusion of this stylized fact, the forecast and market risk can be better determined for some finance applications. This stylized fact can be explained using the concept of heterogeneous market hypothesis (Dacorogna et al. 2001; Mullier et al. 1999). Real financial markets consist of heterogeneous market participants with different endowments, interests, risk profiles, geographical location, degree of information and contractual constraints, among others. The different time reactions among the investors have created a unique cascade volatility under the fluctuating price movements. The combinations of these dissimilar volatilities (due to reaction times) are believed to produce hyperbolic autocorrelation decays or long memory in the financial return volatility. On the other hand, the randomness of the market has an inverse relationship with the strength of long memory return volatility.

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[6] These findings are slightly different from Brooks (2007) due to the variation of sample coverage (1995-2005).

[7] Exceptional for *before*-crisis period.

Table 3. Estimation results

		θ	γ	Y	δ	δ=1	δ=2	v	d
US	Before	-0.07981 (0.02668)	0.88215 (0.35084)	58.88	1.47086 (0.20414)	2.3065	-2.5920	11.06941 (2.08970)	0.32224 (0.10163)
	After	-0.08482 (0.02595)	0.84675 (0.29549)	35.38	1.43263 (0.17909)	2.4157	-3.1680	11.03803 (2.0264)	0.37629 (0.098838)
Hong Kong	Before	0.01321 (0.02506)	0.25361 (0.09558)	2.69	1.90757 (0.32394)	2.8016	-0.2853	7.91353 (1.78960)	0.39055 (0.12629)
	After	0.01573 (0.02537)	0.36156 (0.10492)	3.70	1.72718 (0.25578)	2.8430	-1.0666	8.06757 (1.8002)	0.41386 (0.11583)
Singapore	Before	-0.01116 (0.02545)	0.32248 (0.12277)	3.40	1.83110 (0.26763)	3.1054	-0.6310	7.73923 (1.3434)	0.39133 (0.12096)
	After	-0.00958 (0.02517)	0.36136 (0.12608)	3.94	1.81210 (0.23474)	3.4595	-0.8004	7.94287 (1.3972)	0.38998 (0.11073)
Korea	Before	0.02358 (0.02700)	0.67333 (0.20551)	9.18	1.35735 (0.22998)	1.5538	-2.7943	9.84838 (2.47350)	0.33812 (0.09398)
	After	0.02419 (0.02676)	0.72839 (0.20430)	12.16	1.34999 (0.19488)	1.7959	-3.3354	9.83209 (2.4940)	0.34792 (0.09057)
Taiwan	Before	0.03077 (0.02487)	0.48225 (0.15468)	4.74	1.47906 (0.28415)	1.6859	-1.8333	7.35948 (1.3273)	0.36934 (0.10577)
	After	0.03669 (0.02433)	0.48409 (0.15554)	4.93	1.50981 (0.26662)	1.9121	-1.8385	7.60208 (1.3822)	0.37919 (0.10757)
Japan	Before	-0.00430 (0.02734)	0.34563 (0.10442)	2.06	1.45811 (0.30762)	1.4892	-1.7615	14.52758 (4.6308)	0.57600 (0.16782)
	After	-0.00578 (0.02705)	0.45910 (0.11555)	2.70	1.37095 (0.24068)	1.5769	-2.8687	14.25307 (4.5863)	0.52353 (0.13689)
Malaysia	Before	0.12749 (0.02555)	0.20352 (0.08307)	1.95	1.62319 (0.27133)	2.2968	-1.3887	6.52585 (1.0095)	0.42191 (0.11766)
	After	0.12872 (0.02472)	0.23368 (0.08195)	2.27	1.72146 (0.24416)	2.9548	-1.1407	6.542795 (1.0145)	0.38680 (0.09951)
Indonesia	Before	0.13529 (0.02642)	0.78702 (0.38061)	41.26	1.74877 (0.33809)	2.2147	-0.7430	7.61268 (1.4750)	0.05095 (0.04509)
	After	0.13765 (0.02596)	0.74785 (0.40887)	49.34	2.01369 (0.33603)	3.0166	0.0407	6.71505 (1.0674)	0.06216 (0.05369)
Thailand	Before	0.07537 (0.02444)	0.31401 (0.10292)	2.27	1.25820 (0.21329)	1.2105	-3.4778	7.91312 (0.73182)	0.36967 (0.07700)
	After	0.08329 (0.02409)	0.35118 (0.10154)	2.72	1.36152 (0.19281)	1.8750	-3.3114	7.45355 (0.69235)	0.40317 (0.08816)

Notes: The AR(1) model: $\mu_{i,t} = \theta_{i,0} + \theta_{i,1}r_{i,t-1}$. The coefficients are: γ - news impact; δ - power transformation; v – tail distribution; d – long memory volatility. Test statistics for H_0: δ=1 and δ=1 are $\frac{\delta-1}{se}$ and $\frac{\delta-2}{se}$. Value in parentheses denotes standard error.

4.3 The Impact of the US Subprime Mortgage Crisis

Based on Figure 2, all the periods begin from January 2002 and end according to their respective crisis periods. The inclusion of approximately three months of trading days in each consecutive period is intended to examine the behaviour of leverage effect, volatility power transformation and volatility persistence across the crisis periods from year 2008 to 2009.

Table 4 summarizes the asymmetric coefficient (γ) and magnitude (Υ) for the selected markets *before*- and *after*-crisis periods. Surprisingly the US market indicates highest leverage effect in *before*-crisis (0.882158), and tends to reduce in *after*-crisis (0.846757). The relative magnitude of these leverage effects can also be represented by Υs with the values of 58.88 and 35.38 in the two respective periods. As the origin of this crisis, the US investors are the most well-informed groups that provide with accurate and up to date information regarding the actual condition of the subprime markets. At the end of July 2007, the mortgage bubble burst after the collapses of two Bear Stearns hedge funds which cause significant increases in mortgage

delinquencies and foreclosures in the subprime mortgage. This crisis spread further until a boiling point in September 2008 with the bankruptcy of Lehman Brothers. In other words, the US market has already encountered the most intense leverage effect before the declaration of bankruptcy by the Lehman Brothers on 15th September 2008. With the commitments of the US government to handle the crisis especially across the year of 2008, various significant actions have been taken such as banning the shorting activities by the securities and exchange commission (SEC) in 17th September 2008, approval of USD $700 billion for the Troubled assets relief program (TARP), Public-private partnership investment program, bail-out for banks (Bear Stearns and Merrill Lynch) and USD$600 billion program to take over the mortgage backed securities (MBS) for the government sponsored enterprises (GSE). These announcements ('good' news) to some extent have lessened this financial turmoil from further crashing of the US overall financial markets.

For Asian equity markets, overall the leverage effect indicates tendency of increment from *after*-crisis to *before*-crisis (except for Indonesian markets). This implies that the 'bad' news in general causes higher volatility in the selected Asian markets. Although some arguments claim that the Asian regional economics should be decoupled (Dooley and Hutchison 2009) from the subprime crisis, the global recession (reduction in export demand), decline of commodities price (export reduction) and high inflation problem, poverty and unemployment are among the contributors to the leverage effect in the Asian equity markets. These global and domestic economic issues have the deepest impact on Indonesian market where the magnitude of leverage effect is the greatest among the seven Asian markets. It is also worth noting that the Malaysian stock market indicates the least leverage effect across the crisis periods. Since the Malaysian mortgage markets do not have direct or indirect investments to US subprime mortgages, the negative news regarding this turmoil has considerably less impact on this market than other Asian equity markets.

Table 4. Leverage Effect and Its Magnitude

Country	*coefficient*	*Before crisis*	*After crisis*
US	γ	0.882158	0.846757
	Magnitude, Y	58.88	35.38
Hong Kong	γ	0.253619	0.361568
	Magnitude, Y	2.69	3.70
Singapore	γ	0.32248	0.361368
	Magnitude, Y	3.40	3.94
Korea	γ	0.673336	0.72839
	Magnitude, Y	9.18	12.16
Taiwan	γ	0.482257	0.484097
	Magnitude, Y	4.74	4.93
Malaysia	γ	0.203527	0.233682
	Magnitude, Y	1.95	2.27
Indonesia	γ	0.787025	0.747855
	Magnitude, Y	41.26	49.34
Thailand	γ	0.314015	0.351185
	Magnitude, Y	2.27	2.72

Notes: γ - leverage effect. Y -magnitude of leverage effect, $\left(\frac{1+\gamma}{1-\gamma}\right)^{\delta}$

Next, we turn to long memory volatility of the markets across the periods as indicated in Table 3. First, the US market indicates ascending estimates of long memory coefficients[8] (*d*) with 0.322240 and 0.376297 in both the periods. From the viewpoint of market informational efficiency analysis (Cajueiro and Tabak 2004; Cheong et al. 2007), the intensity of long memory in financial markets is inversely proportional to market efficiency. In other words, stronger long memory means stronger predictable component in a particular market. From the US long memory behaviour across the crisis periods, the market becomes more efficient (increase in randomness) at *after*-crisis period. The investment activities based on various durations (such as short-term, medium-term and long-term) by the heterogeneous market participants have generated long memory volatility under the cascade volatilities for each duration. During *before*-crisis period, most of the market participants still optimistic and believe that the recovery of the mortgage industry is in near future. However, this crisis spread further until a boiling point in September 2008 when the Lehman Brothers filed the bankruptcy protection. In after-crisis period, huge numbers of panic-stricken investors react simultaneously by withdrawing their capitals on a large scale from the mortgage markets. These synchronize actions among the heterogeneous investors to some extent have reduced the nature of heterogeneity in the US equity markets. Thus, the long memory intensities are less in *after*-crisis as compared to *before*-crisis.

Similar patterns also have been observed in most of the mature markets such as Hong Kong, Korea and Taiwan while the Singapore STI has indicated consistent long memory behaviour across the crisis periods. For emerging markets, only the Malaysian and Thailand markets have showed long memory volatility. The Malaysian market has encountered political chaos (Channel News Asia 2008) in March 2008[9] and caused severe plunge (9.5% of KLCI) to Malaysian capital markets. This event can be considered as one of the most influential factors to Malaysian economic growth. Most of the government linked companies and government bonds have recorded negative performance during this period. This political instability has reduced and stopped foreign and domestic investments in Malaysia. However, this condition becomes less critical when the opposition parties fail their deadline for power transition in September 2008. Thus, the long memory intensities are less in *before*-crisis and become stronger in *after*-crisis when the investors are more optimistic with the Barisan Nasional government. For Thailand market, the long memory intensity decreases from *before*-crisis to *after*-crisis period. Part of the randomness in market may be due to the instable political issue. Since 2008, Thailand has encountered political crisis between the People's Alliance for Democracy (PAD) and the National United front of Democracy against Dictatorship (UDD). In September, Thailand has declared a state of emergency in Bangkok due to the clashes between these supporters. Due to this, the long memory behavior varies across the crisis periods.

4. Conclusion

This study examines seven Asian equity markets in terms of their leverage effects, volatility power representation and long memory behaviour during the US subprime mortgage crisis. The dynamics of these stylized facts are observed from year 2002 to June 2008 at the first

[8] The strength of long memory is stronger from 0.5 towards 0.0 ($0<d<0.5$).

[9] It is the first time since 1969 Malaysian general election that the coalition of Barisan Nasional failed to secure 2/3 majority in the parliament.

place and then with the inclusion of approximately three months for the next three consecutive periods. Overall, the stylized facts are more responsive in *after*-crisis period when the Lehman Brothers filed the bankruptcy protection from US government. The key findings of this study are: First, the conditional variance representations are more preferable under the Box-Cox power transformation in the seven Asian return volatilities. Second, majority of the markets indicate significant increment of leverage magnitude after the announcement of Lehman Brothers bankruptcy. It is worth noting that the global events (such as food and energy prices crises, among others) have also contributed to the leverage effect in the studied markets which are not considered in this study. Finally, most of the mature Asian markets have the tendencies of declining long memory volatilities across the crisis periods whereas the emerging markets are more affected by the political crisis and appeared to indicate fluctuating and descending long memory. From the market efficiency analysis, the reduction of long memory implies that a market become more efficient with less dependency in the underlying time series.

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