Volatility Spillovers between Equity and Currency Markets in ASEAN-5 Countries during Crises[1]

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Abstract
The interplay between equity and currency markets has attracted many researchers to study the effects of volatility spillover between them. Our paper investigates the volatility spillover effects between stock market returns and exchange rate changes within the same economy in the ASEAN-5 countries (Indonesia, Malaysia, the Philippines, Singapore, and Thailand) during two crises, namely the Asian crisis and subprime crisis, and compares the commonalities and differences between the two. We use daily data and consider the bivariate VAR(1)-GARCH(1,1) model with BEKK representation to examine the spillover effects. Although the volatility spillover effects within the economy vary during different crises for different countries, we find evidence that exchange rate fluctuations have strong influences on the volatility of stock market.

Keywords: volatility spillovers, financial crises, GARCH-BEKK, ASEAN countries
JEL codes: C32, G15

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1. Introduction

During the last two decades, countries in the South East Asian region have experienced two big crises, namely the Asian currency crisis in the 1997 - 1998 and the subprime crisis in 2007 - 2008. The first period was marked by the sharp depreciated of currencies in several countries such as Thailand, Malaysia, Indonesia, South Korea and the Philippines ranging from 33 - 74 % during the period of June 1997 to August 1998. Stock markets in this region also plunged up to 50 % within the same period (Goldstein, 1998). The recent subprime crisis which started in 2007 also adds pressures to the stock and currency markets in Asian region. However, the currencies in Asian region proved to be more durable and not depreciated greatly in the last crises compare to the 1997 - 1998 crises. But, although the currencies are more durable, the stock markets experienced quite strong impact of the crisis. During the period, Goldstein and Xie (2009) reported that Asian currencies are depreciated by only about 5%, and the stock market indices in Asia declined by 17%. This phenomenon raises questions on how currency and stock market in an economy are linked during crises. More specifically, we will focus our analysis on the countries included in Association of South East Asian Nation (ASEAN).

The interplay between stock market returns and exchange rate changes within the same economy has attracted many researchers to study the spillover effects between them. From the theoretical perspective, there are two views explaining the linkage between stock prices and exchange rates, namely the flow-oriented model proposed by Dornbusch and Fischer (1980), and the stock-oriented model of Branson (1983) and Frankel (1983). In the flow-oriented model, a country's current account and trade balance performance are assumed as two important factors of exchange rate determination, hence, stock prices are positively correlated with the exchange rate. On the other hand, stock-oriented model assumes that exchange rate is determined by the demand and supply of financial assets such as equities and bonds. Branson (1983) claims that the increase in stock prices drives up the interest rate of domestic currency and then it implies on the fall of the exchange rate. Moreover, when considering the linkage between the exchange rate and stock market, Zapatero (1995) has provided theoretical insights that relate the volatility of exchange rate with the volatility of stock market in a fully integrated two countries framework.

A number of empirical studies have examined the volatility spillover effects between stock market returns and exchange rate changes within the same economy. Kanas (2000) studied the volatility spillover effects between stock market returns and exchange rate changes for six countries, namely Canada, France, Germany, Japan, the UK, and the US, and found that except for Germany he found that the other five countries exhibit positive volatility spillover effects from stock market returns to exchange rate changes. Yang and Doong (2004) examined the effects of the mean and volatility spillover effects between stock market indices and exchange rates for the G-7 countries and found evidence of price spillovers from foreign exchange to the stock market for Canada and Japan, and from stock market to the foreign exchange market for Canada, France, Germany, Italy, and the UK. They also found significant volatility spillover effects running from the stock to foreign exchange markets for France, Italy, Japan, and the US. In a closely similar study by Fedorova and Saleem (2010), among four Eastern European countries included in their study, Poland, Hungary, and Russia show evidence of unidirectional volatility spillover effects from currency market to the stock market within the economy, and only Czech Republic that shows bi-directional volatility spillover effects between the markets.

In the Asia-Pacific region, investigation on the volatility spillover effects between stock market returns and exchange rate returns has been also done by a number of researchers. In Indian economy, Mishra *et. al.* (2007) found bi-directional volatility spillovers between stock market and foreign exchange market. Choi *et. al.* (2009) examined the volatility spillover effects between stock market returns and the changes of three foreign exchange rates in New Zealand, namely NZD/AUD, NZD/USD, and TWI index, during the period of pre-Asian crisis and post-Asian crisis. During the pre-Asian crisis period, they found bidirectional volatility spillovers between NZD/USD and TWI index changes and stock market returns, and unidirectional volatility spillovers from the NZD/AUD changes to stock market returns. While during the post-Asian crisis period, unidirectional volatility spillovers is found to run from stock market returns to NZD/AUD changes and from NZD/USD and TWI index changes to stock market returns.

In more country - specific focus, Caporale *et. al.* (2002) studied the causality relationship between stock prices and exchange rates volatility in several East Asian countries namely Indonesia, Thailand, South Korea and Japan during the period of 1987 to 2000. Their finding indicates that during the pre-crisis period, stock prices lead exchange rate negatively in Japan and South Korea while it goes positively for Indonesia and Thailand. They also found that during the 1997 crisis, the spillover effect goes bidirectionally for Indonesia and Thailand. Later, Wu (2005) studied the volatility transmission effects between stock market returns and exchange rate changes during Asian crisis and recovery periods for Indonesia, Japan, South Korea, Phillipines, Singapore, Taiwan, and Thailand. The results indicate that there is a two-way feedback relationship between the volatility of stock returns and exchange rate changes during the period of recovery of the Asian countries. Furthermore, the results also suggest that the interactions of stock and foreign exchange markets of Asian countries are affected by the Asian financial crisis, and the impact is greater for Indonesia, Japan, the Philippines and especially Thailand, which are more vulnerable during the financial crisis. Using more recent data that covers the period from January 1997 to July 2006, Morales and O'Donnell (2006) examined the volatility spillovers between stock market returns and exchange rate changes for Hong Kong, Singapore, South Korea, Taiwan, and Thailand. They found significant volatility spillovers between stock market returns and exchange rate changes during the Asian crisis period for Singapore, South Korea, and Thailand. They also found no significant volatility spillovers in any direction during the post-Asian crisis period for all countries, with Taiwan being the exception that shows significant volatility spillovers from exchange rate changes to stock market returns.

While these literatures on ASEAN-5 countries focus the attention on the period of Asian crisis and post-Asian crisis, little works have been done to examine the impact of the recent subprime crisis on the dynamic relationship between stock market returns and exchange rate changes. Although a recent study by Walid *et. al.* (2011) addresses a closely related issue to four emerging countries, namely Hong Kong, Singapore, Malaysia, and Mexico, the present paper employs substantially different model and focuses the analysis on ASEAN-5 countries.

The aim of this paper is to investigate the extent of volatility spillovers between stock market returns and exchange rate changes for major five countries included in The Association of South East Asian Nations (ASEAN), namely Indonesia, Malaysia, the Philippines, Singapore, and Thailand during the Asian crisis in 1997 and the recent subprime crisis in 2007. Our objective is to identify whether the spillover effects between stock market returns and exchange rate changes within the same economy vary during different crises.

The paper is organized as follows. The next section describes the data and methodology used in this study. Section 3 presents the empirical results and the last section concludes the paper.

2. Data and Methodology

2.1 Data

The dataset consists of daily closing stock markets indices and exchange rates of ASEAN-5 countries: Indonesia, Malaysia, the Philippines, Singapore, and Thailand. The stock market indices are stated in local currency and the exchange rates are also in local currency per unit of US dollar. The sample period runs from 1 July 1997 to 26 April 2010. All data were taken from Datastream International. Based on exchange rates (e) and stock market indices (s), the percentage of exchange rate change ($r_{e,t}$) is calculated as $r_{e,t} = 100\times\log(e_t/e_{t-1})$ and stock market return ($r_{s,t}$) at time t is calculated as $r_{s,t} = 100\times\log(s_t/s_{t-1})$. Appendix 1 displays the graphical representation of the series.

To investigate the volatility spillover effects during crises, we divide our sample into three sub-periods which cover the period of Asian crisis, non-crisis, and subprime crisis. The Asian crisis period spans from 1 July 1997 to 30 September 1998, the post-Asian crisis period starts from 1 October 1998 to 25 July 2007, and the subprime crisis period starts from 26 July 2007 to 26 April 2010. This division is based on the analysis of financial crises by Jang and Sul (2002) and Fry *et al.* (2011). Note that, because Malaysia changed its currency regime to a fixed rate on 2 September 1998, we limit our sample of Malaysian exchange rate and stock market index during the first sub-period until the introduction of fixed exchange rate regime and do not include Malaysia in our analysis during the non-crisis period.

Table 1. Summary Statistics

Country	Statistic	All sample		Asian crisis		Non-crisis		Subprime crisis	
		EX	R	EX	R	EX	R	EX	R
Indonesia	Mean	0.0405	0.0430	0.4587	-0.3016	0.0117	0.0647	-0.0016	0.0307
	Std dev.	1.7952	1.7988	4.8277	2.9195	0.7708	1.3180	0.6643	1.9532
	Skewness	1.5812	-0.1484	0.6025	0.1497	-0.3144	-0.7516	0.5384	-0.5261
	Exc. Kurtosis	47.70	6.59	6.19	3.23	14.47	4.95	51.97	4.64
	JB	307,993.0	5,871.9	534.7	141.5	16,708.0	2,132.7	75,893.6	634.8
	LB (12)	152.92 *	102.02 *	23.28 *	34.61 *	43.99 *	62.05 *	38.10 *	29.07 *
	LB $(12)^2$	2688.70 *	587.07 *	148.60 *	20.86	1377.29 *	206.47 *	19.94	203.16 *
	ADF test	-50.23 *	-48.66 *	-15.70 *	-14.75 *	-41.07 *	-39.22 *	-24.16 *	-22.47 *
Malaysia	Mean	-	-	0.1405	-0.4461	-	-	-0.0108	-0.0043
	Std dev.	-	-	1.8580	3.2786	-	-	0.4271	1.0835
	Skewness	-	-	-0.5881	1.1453	-	-	-0.0270	-1.2166
	Exc. Kurtosis	-	-	6.20	7.99	-	-	0.69	11.57
	JB	-	-	482.6	837.3	-	-	13.5	3,955.0
	LB (12)	-	-	31.48 *	9.56	-	-	13.21	12.38
	LB $(12)^2$	-	-	79.05 *	12.70	-	-	49.94 *	32.88 *
	ADF test	-	-	-13.78 *	-15.10 *	-	-	-26.00 *	-23.55 *
The Philippines	Mean	0.0159	0.0048	0.1577	-0.2506	0.0052	0.0277	-0.0028	-0.0151
	Std dev.	0.6300	1.5861	1.4456	2.3930	0.4443	1.3065	0.4531	1.7426
	Skewness	1.2872	0.3338	2.3779	0.2337	-9.0636	1.5449	-0.0056	-0.6917
	Exc. Kurtosis	89.67	10.81	17.68	2.77	221.23	22.98	-0.36	7.27
	JB	1,087,124.0	15,832.8	4,483.8	105.5	3,943,780.0	43,016.3	3.6	1,535.9
	LB (12)	136.26 *	102.26 *	40.62 *	27.13 *	47.59 *	54.70 *	12.49	25.23 *
	LB $(12)^2$	43.16 *	188.63 *	1.50	26.73 *	14.24	31.95 *	156.67 *	160.56 *
	ADF test	-51.41 *	-48.82 *	-14.70 *	-14.26 *	-23.20 *	-39.06 *	-25.06 *	-22.39 *
Singapore	Mean	-0.0013	0.0135	0.0509	-0.2226	-0.0050	0.0222	-0.0140	-0.0269
	Std dev.	0.3888	1.4868	0.8150	2.2560	0.2633	1.0989	0.3977	1.7758
	Skewness	-0.6581	0.1764	-0.7831	0.9733	-0.1737	-0.5807	-0.0477	-0.0311
	Exc. Kurtosis	11.41	7.93	3.41	8.75	3.56	5.22	3.38	2.78
	JB	18,144.9	8,671.3	188.6	1,078.5	1,036.1	2,317.6	337.9	229.0
	LB (12)	44.17 *	36.02 *	22.97 *	25.75 *	16.77 *	34.31 *	15.67	13.25
	LB $(12)^2$	1216.08 *	772.31 *	48.68 *	36.16 *	78.90 *	375.59 *	96.65 *	461.97 *
	ADF test	-59.48 *	-52.96 *	-19.08 *	-15.05 *	-44.20 *	-43.15 *	-27.27 *	-26.01 *
Thailand	Mean	0.0069	0.0118	0.1358	-0.2374	-0.0056	0.0344	-0.0068	-0.0216
	Std dev.	0.6192	1.7964	1.6487	2.7378	0.3474	1.4373	0.2510	1.7678
	Skewness	0.2582	0.0970	-0.0857	0.9590	0.2985	-0.7570	0.0182	-0.6364
	Exc. Kurtosis	28.52	6.58	3.00	2.46	26.53	11.39	2.16	5.08
	JB	106,724.3	5,685.8	116.2	124.6	53,988.7	10,118.1	131.2	768.3
	LB (12)	171.90 *	78.59 *	31.69 *	28.39 *	14.29	28.31 *	46.45 *	33.35 *
	LB $(12)^2$	1491.86 *	682.09 *	45.28 *	77.21 *	393.86 *	267.26 *	150.78 *	308.60 *
	ADF test	-47.40 *	-51.28 *	-12.09 *	-14.06 *	-44.38 *	-27.93 *	-21.48 *	-24.51 *

Notes: * denotes significant at the 5% level. Exc. Kurtosis is Kurtosis - 3. JB denotes the Jarque-Bera statistics and ADF test is the statistic of the Augmented Dickey-Fuller test

Source: Author's calculation based on data from Datastream.

Table 1 presents the summary statistics of the stock market returns and exchange rate changes for the complete sample and for three sub-samples, Asian crisis, non-crisis, and subprime crisis periods. The exchange rate changes of all countries exhibit positive sample means during the Asian crisis period and negative sample mean during the subprime crisis period. In terms of standard deviations, the volatility of stock market returns is higher than the exchange rate changes for all countries. In all sample and all sub-samples, exchange rate changes and stock market returns are leptokurtic for all countries except for the exchange rate changes of Malaysia and The Philippines during the subprime crisis period. The Jarque-Bera test statistic shows that the data are non-normal

except for The Philippines during the subprime crisis period. The Ljung-Box statistic shows that there are both linear and nonlinear serial correlations in the series except for Malaysia during the Asian crisis period. The augmented Dickey-Fuller test (Dickey and Fuller, 1979) indicates that all exchange rate changes and stock market returns are stationary.

2.2 Methodology

To study the linkages between exchange rate changes and stock market returns, we consider the following bivariate VAR(1) – GARCH (1,1) model with BEKK representation of Engle and Kroner (1995):

$$\begin{bmatrix} r_{e,t} \\ r_{s,t} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} + \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix} \begin{bmatrix} r_{e,t-1} \\ r_{s,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix} \tag{1}$$

with

$$\boldsymbol{\varepsilon}_t \mid I_{t-1} \sim N(0, \mathbf{H}_t)$$

$$\mathbf{H}_t = \mathbf{C}'\mathbf{C} + \mathbf{A}'\boldsymbol{\varepsilon}_{t-1}\boldsymbol{\varepsilon}'_{t-1}\mathbf{A} + \mathbf{B}'\mathbf{H}_{t-1}\mathbf{B} \tag{2}$$

where α and β are parameters and **C**, **A**, and **B** are parameter matrices to be estimated. Specifically, **C** is a 2×2 lower triangular matrix, and **A** and **B** are 2×2 unrestricted parameter matrices. The term $\boldsymbol{\varepsilon}_t = (\varepsilon_{1,t}, \varepsilon_{2,t})'$ is the vector of residuals which is assumed to follow a bivariate conditional normal distribution with mean zero and conditional variance-covariance matrix $\mathbf{H}_t \equiv E(\boldsymbol{\varepsilon}_t\boldsymbol{\varepsilon}'_t \mid I_{t-1})$, where I_{t-1} represents the information available at time t-1.

Moreover, the equation (2) is the GARCH (1,1) - BEKK representation of the conditional variance-covariance matrix. The advantage of using the BEKK representation is that it guarantees a symmetric and positive definite conditional variance-covariance matrix. To see the dynamic relationship of the elements of the variance-covariance matrix of equation (2), we can expand it as a system of equations and express them as follows:

$$h_{11,t} = c_{11}^2 + (a_{11}\varepsilon_{1,t-1} + a_{21}\varepsilon_{2,t-1})^2 + b_{11}(b_{11}h_{11,t-1} + b_{21}h_{12,t-1}) + b_{21}(b_{11}h_{12,t-1} + b_{21}h_{22,t-1}) \tag{3}$$

$$\begin{aligned} h_{12,t} = {} & c_{11}c_{21} + a_{12}(a_{11}\varepsilon^2_{1,t-1} + a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1}) + a_{22}(a_{11}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}\varepsilon^2_{2,t-1}) \\ & + b_{12}(b_{11}h_{11,t-1} + b_{21}h_{12,t-1}) + b_{22}(b_{11}h_{12,t-1} + b_{21}h_{22,t-1}) \end{aligned} \tag{4}$$

$$h_{22,t} = c_{21}^2 + c_{22}^2 + (a_{12}\varepsilon_{1,t-1} + a_{22}\varepsilon_{2,t-1})^2 + b_{12}(b_{12}h_{11,t-1} + b_{22}h_{12,t-1}) + b_{22}(b_{12}h_{12,t-1} + b_{22}h_{22,t-1}) \tag{5}$$

where the parameters $h_{ij,t}$, $c_{i,j}$, $a_{i,j}$, and $b_{i,j}$ are the i^{th} row - j^{th} column element of matrix $\mathbf{H}_t$, **C**, **A**, and **B** respectively. As can be seen in equation (3), (4), and (5), the dynamic process of $\mathbf{H}_t$ is modelled as a linear function of its own past values $\mathbf{H}_{t-1}$ and the past values of the squared error terms ($\varepsilon^2_{1,t}$, $\varepsilon^2_{2,t}$), hence allowing for both self influences and cross influences in the conditional variances and covariances of the two series. Moreover, to estimate the model, we use the VARMAX procedure implemented in SAS® that estimates the model by maximizing the log-likelihood function of our bivariate VAR(1) – GARCH (1,1) with BEKK representation.

Based on the specification of equation (1), to examine the return spillover effects between exchange rate changes and stock market returns within the economy, we test the significance of the parameters. The evidence of return spillover effects is found to run from stock market returns to exchange rate changes (exchange rate changes to stock market returns) if the parameter β_{12} (β_{21}) is significant.

The specifications described in the equations (3) – (5) also allow us to test the presence of volatility spillover effects in one or both directions. The volatility spillover effects between exchange

rate changes and stock market returns within the same economy is examined by testing the significance of the estimated parameters. To examine the presence of volatility spillover effects from stock market returns to exchange rate changes (exchange rate changes to stock market returns), we test the joint significance of the estimated coefficients of a_{12} and b_{12} (a_{21} and b_{21}) using the Wald test specification.

3. Empirical Results

Tables 2-4 display the results of estimations of the bivariate VAR(1)-BEKK(1,1) model for each country during the Asian crisis, non-crisis, and subprime crisis periods, respectively. Panel A and B present the estimation results of the equation (1), and (3) – (5) respectively. Panel C and D show the diagnostic tests of the innovation series of the model based on Ljung-Box test statistic and the results of the Wald tests for volatility spillover effects, respectively.

Table 2. Estimation results of the bivariate BEKK model during Asian crisis period

	Indonesia	Malaysia	The Philippines	Singapore	Thailand
Panel A: Mean equation					
α_1	0.3153 *	0.0984	0.1713 *	0.0417	0.1055
α_2	-0.3820 *	-0.4095 *	-0.1434	-0.1244	-0.2891 *
β_{11}	0.1946 *	0.0429	0.0916	-0.0122	0.1496 *
β_{21}	0.0793 *	0.1761	-0.3922 *	-0.4817 *	0.1174
β_{12}	0.0137	-0.1205 *	-0.1109 *	-0.0167	-0.0586
β_{22}	0.1498 *	0.1652 *	0.0306	0.1431 *	0.1742 *
Panel B: Volatility equation					
c_{11}	0.0000	0.0000	0.0000	0.0000	0.0000
c_{12}	0.9625 *	-1.0261	0.1457	0.2513	0.0167
c_{22}	2.9650 *	9.9678 *	1.7318 *	3.1128 *	3.2931 *
a_{11}	0.7676 *	-0.0779	0.3064 *	0.4107 *	0.3043 *
a_{21}	-0.0339	-0.1775 *	0.0132	0.0371	-0.2015 *
a_{12}	-0.0003	0.4728 *	0.5952 *	-0.6958 *	0.3330
a_{22}	-0.2212 *	0.2738 *	0.6475 *	0.4323 *	0.4184 *
b_{11}	0.1566 *	0.9990 *	-0.1536	0.3656 *	-0.8017 *
b_{21}	1.1568 *	0.2411	0.5558 *	-0.2574 *	-0.3166 *
b_{12}	-0.4349 *	-0.1455	0.8681 *	-0.1058	-0.1992
b_{22}	-0.3516 *	0.0010	-0.1100	0.3740 *	0.5246 *
Panel C: Diagnostic tests					
$LB_1(12)$	8.16	17.84	20.71	14.60	11.67
$LB_1(12)^2$	13.85	16.78	1.42	5.12	7.36
$LB_2(12)$	16.34	5.26	17.58	13.29	8.20
$LB_2(12)^2$	12.34	6.24	8.36	3.76	17.78
Panel D: Test of volatility spillover effects					
Volatitility spillovers from stock market to exchange rate					
Wald (a_{12}=b_{12}= 0)	124.66 *	11.11 *	45.16 *	67.53 *	3.17
Volatitility spillovers from exchange rate to stock market					
Wald (a_{21}=b_{21}= 0)	290.90 *	33.49 *	54.70 *	40.32 *	32.61 *

Notes: * denotes significant at the 5% level. $LB_i(n)$ is the Ljung-Box statistic of the innovation series i at lag n. $LB_i(n)^2$ is the Ljung-Box statistic of the squared innovation series i at lag n.

Source: Author's calculation

For the first moment interdependencies during the Asian crisis, we find significant unidirectional mean spillovers from currency to stock market for Indonesia and Singapore, from stock to currency market for Malaysia, and bi-directional mean spillovers between currency and stock

market for The Philippines. During the non-crisis period, the mean spillover effects are persistent for The Philippines, reversed for Singapore, stronger for Thailand for the direction from stock to exchange market, and weaken for Indonesia. Comparing the mean spillover effects during the two crises, we find that the direction of the mean spillover effects for Malaysia and Singapore persists during both crises, but the effects weaken for Indonesia and The Philippines during the subprime crisis.

The volatility spillover effects are significant for all countries during the three periods we consider except for Singapore during the non-crisis and subprime crisis period. During the Asian crisis period, we find that all countries exhibit significant bi-directional volatility spillovers between stock and currency market except for Thailand that exhibits unidirectional volatility spillovers from currency to stock market. Except for Singapore during Asian crisis period, our result appears to be different with Wu (2005), but closely similar to the results obtained in Caporale *et al* (2002).

Table 3. Estimation results of the bivariate BEKK model during non-crisis period

	Indonesia		The Philippines		Singapore		Thailand	
Panel A: Mean equation								
α_1	-0.0048		0.0062		-0.0046		-0.0071	
α_2	0.1089	*	0.0397		0.0220		0.0736	*
β_{11}	-0.0281		-0.0454	*	-0.0072		0.0724	*
β_{21}	0.0426		-0.3528	*	0.0220		-0.1274	
β_{12}	0.0069		-0.0171	*	-0.0211	*	-0.0119	*
β_{22}	0.0839	*	0.1353	*	0.0528		0.1107	*
Panel B: Volatility equation								
c_{11}	0.0153	*	0.0022		0.0524	*	0.0060	*
c_{12}	-0.0218	*	0.0004		-0.0092		-0.0541	
c_{22}	0.0616	*	0.6961	*	0.1275	*	0.2059	*
a_{11}	0.6623	*	0.4292	*	0.2476	*	0.5572	*
a_{21}	-0.1057	*	-0.0189	*	-0.0008		0.0550	*
a_{12}	-0.1398	*	0.7264	*	-0.0077		-0.2463	*
a_{22}	0.3463	*	0.3292	*	0.2656	*	-0.3157	*
b_{11}	0.7997	*	0.9151	*	0.9510	*	0.8042	*
b_{21}	0.0256	*	0.0195		0.0011		-0.0210	
b_{12}	0.0849	*	-0.5802	*	0.0019		-1.1859	*
b_{22}	0.9262	*	0.6256	*	0.9581	*	-0.9091	*
Panel C: Diagnostic tests								
$LB_1(12)$	42.30	*	39.06	*	11.40		13.17	
$LB_1(12)^2$	5.59		16.31		9.05		1.44	
$LB_2(12)$	16.17		13.87		19.12		16.54	
$LB_2(12)^2$	17.83		15.72		9.00		3.93	
Panel D: Test of volatility spillover effects								
Volatitility spillovers from stock market to exchange rate								
Wald (a_{12}=b_{12}= 0)	18.13	*	46.24	*	2.30		18.70	*
Volatitility spillovers from exchange rate to stock market								
Wald (a_{21}=b_{21}= 0)	77.99	*	6.67	*	0.01		215.34	*

Notes: * denotes significant at the 5% level. $LB_i(n)$ is the Ljung-Box statistic of the innovation series *i* at lag *n*. $LB_i(n)^2$ is the Ljung-Box statistic of the squared innovation series *i* at lag *n*.

Source: Author's calculation

Comparing the volatility spillover effects during Asian and subprime crises, in general, we find that the volatility spillover effects from the exchange rate fluctuations strongly affect the stock market volatility in ASEAN-5 countries as can be seen from the presence of unidirectional volatility spillovers from exchange rate changes to stock market returns for all countries except for Singapore.

Moreover, we find that the volatility spillover effects betweeen currency and stock markets for Indonesia and Thailand are persisted during both crises. While for Malaysia and The Philippines, the volatility spillover effects become to be unidirectional from currency to stock maket. During the non-crisis period, we find that Indonesia, The Philipppines, and Thailand exhibit bi-directional volatility spillover effects between currency and stock markets while Singapore does not show significant volatility spillover effects in any direction.

Table 4. Estimation results of the bivariate BEKK model during subprime crisis period

	Indonesia	Malaysia	The Philippines	Singapore	Thailand
Panel A: Mean equation					
α_1	-0.0113	-0.0236	-0.0072	-0.0363 *	-0.0088
α_2	0.1014	0.0602 *	0.0154	0.0631	0.0604
β_{11}	0.1115 *	0.0101	0.0137	-0.0333	0.1581 *
β_{21}	-0.2285	-0.0836	-0.2196	-0.3102 *	-0.3133
β_{12}	0.0098	-0.0543 *	0.0105	0.0072	-0.0153 *
β_{22}	0.0248	0.1526 *	0.1218 *	-0.0147	0.0209
Panel B: Volatility equation					
c_{11}	0.0017	0.0325 *	0.0036	0.0031 *	0.0007
c_{12}	-0.0389 *	-0.0411	0.0543	-0.0115 *	0.0226
c_{22}	0.2659 *	0.0323 *	0.1250	0.0341	0.0532
a_{11}	-0.2218 *	0.3640 *	0.3240 *	0.1966 *	0.5181 *
a_{21}	0.0407 *	0.0289	-0.0425 *	0.0091	0.0160 *
a_{12}	-0.3602 *	0.0207	-0.5210 *	-0.3512	-0.3090
a_{22}	-0.4547 *	0.4406 *	0.3812 *	0.3492 *	-0.3308 *
b_{11}	0.9921 *	-0.8691 *	0.9575 *	0.9646 *	0.8914 *
b_{21}	0.0283 *	-0.1961 *	0.1491 *	-0.0048	0.0308
b_{12}	-0.1277 *	0.3871	-0.5865	0.1272	-1.4755 *
b_{22}	0.8587 *	0.9449 *	-0.9231 *	0.9345 *	-0.9532 *
Panel C: Diagnostic tests					
$LB_1(12)$	9.84	17.92	13.53	12.66	22.45 *
$LB_1(12)^2$	18.88	9.23	18.69	2.76	8.43
$LB_2(12)$	7.81	4.30	4.06	9.67	19.93
$LB_2(12)^2$	9.21	4.53	18.42	13.73	7.26
Panel D: Test of volatility spillover effects					
Volatitility spillovers from stock market to exchange rate					
Wald (a_{12}=b_{12}= 0)	23.51 *	2.48	4.91	4.25	5.66
Volatitility spillovers from exchange rate to stock market					
Wald (a_{21}=b_{21}= 0)	68.32 *	37.63 *	16.46 *	1.9	8.36 *

Notes: * denotes significant at the 5% level. $LB_i(n)$ is the Ljung-Box statistic of the innovation series i at lag n. $LB_i(n)^2$ is the Ljung-Box statistic of the squared innovation series i at lag n.

Source: Author's calculation

The Ljung-Box test statistics of the innovation series from the estimation of the model show that most of them are linearly independent and the statistics on the squared innovation series show that the innovation series are non-linearly independent. Hence, in general, the model we consider works quite well for our data.

4. Conclusions

In this paper, we examine the linkages between stock market returns and exchange rate changes of five ASEAN countries, namely Indonesia, Malaysia, The Philippines, Singapore, and Thailand. The sample period is from July 1997 to April 2010 and then we devide it into three sub-

samples that explains the period of Asian crisis, non-crisis, and subprime crisis. We use VAR(1) – GARCH (1,1) with BEKK representation of Engle and Kroner (1995).

Analyzing the mean spillover effects between stock market returns and exchange rate changes during the two crises, we find evidence of the persistence of mean spillover effects for Malaysia and Singapore. In this study, we also find significant volatility spillover effects between the stock market and exchange rate within the economy during the three periods we consider. Although the direction of the volatility spillover is not similar among countries, we find evidence that the currency fluctuation in ASEAN-5 countries during the crisis strongly affects the volatility of the stock market in the economy except for Singapore during the subprime crisis period. During the non-crisis period, we also find similar results of significant bi-directional volatility spillovers between exchange rate changes and stock market returns except for Singapore that shows weak spillover effects. Overall, our results show evidence of strong influence from exchange rate fluctuations to stock market volatility in ASEAN-5 countries.

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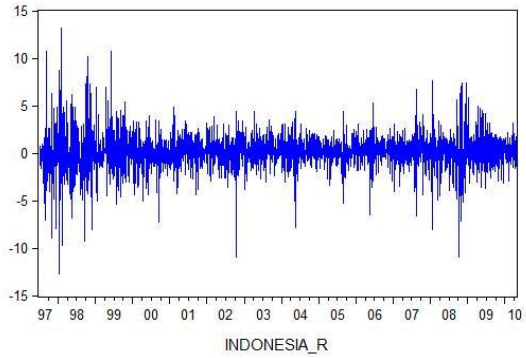
Appendix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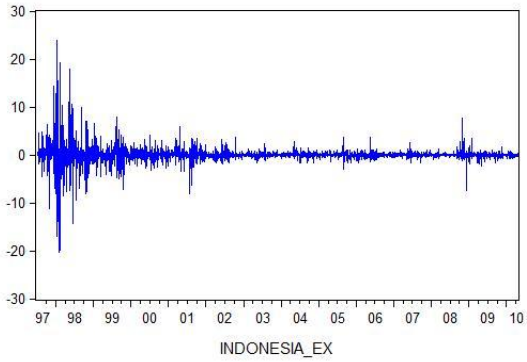
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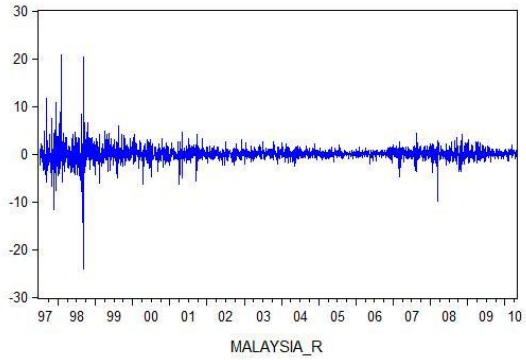
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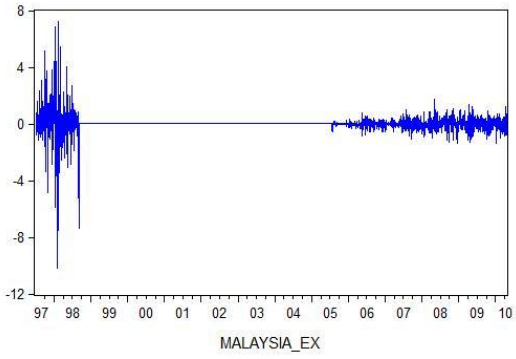
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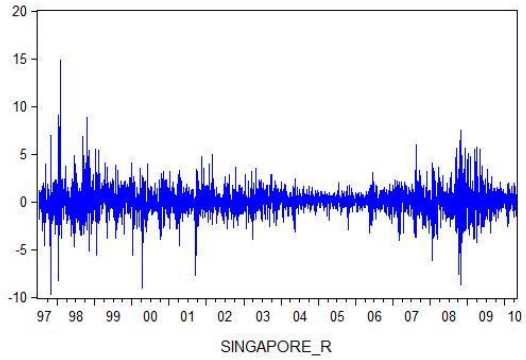
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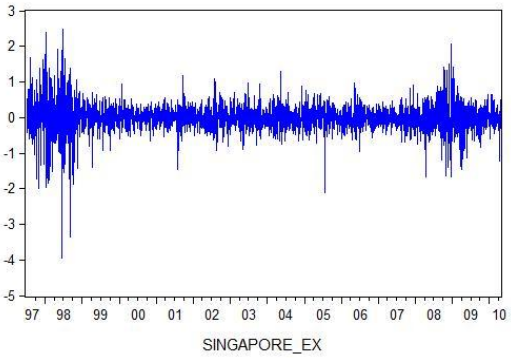
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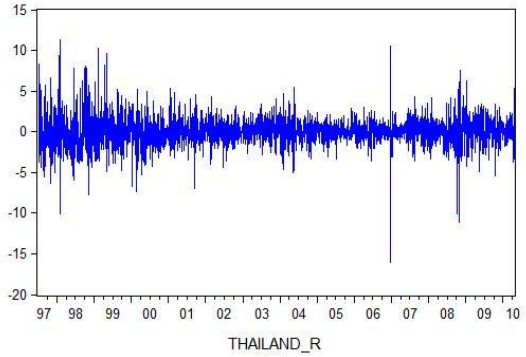
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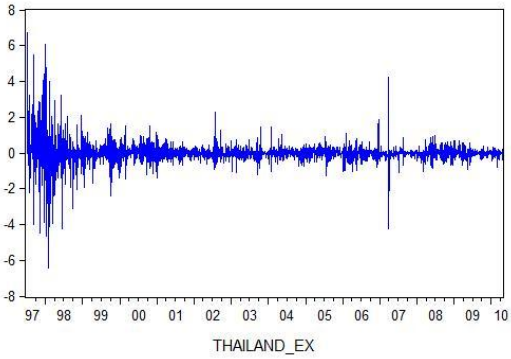
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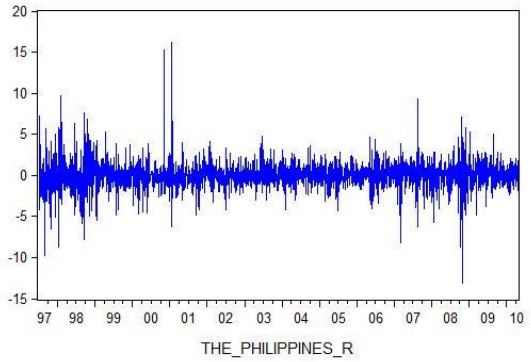
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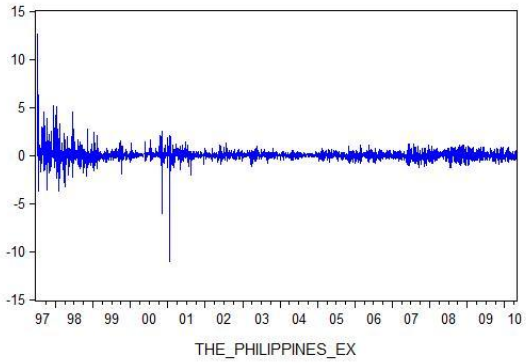
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