Modelling the Dynamic Relationship between U. S.' and Malaysia's Stock Market Volatility

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***Abstract*—A number of previous studies have been devoted to investigate properties of volatility in emerging markets. Rather than focusing on the stock market volatility alone, we examine the dynamic inter-relationship of stock market volatility between two markets, namely the U. S. and Malaysia. The GARCH model is used to generate the volatility series for these two markets. Later, the system equation of VAR model is used to investigate the inter relationship between the volatility of stock market of U. S. and Malaysia using the volatility series generated from GARCH model. The results are compared between three sub-periods, i.e. pre-crisis, crisis and post-crisis periods. Our results reveal very low or insignificance impact of stock market volatility from Malaysia on the stock market volatility in U. S. On the other hand, stock market volatility of U. S. has relatively low impact on the stock market volatility in Malaysia in the pre- and post-crisis periods. The impact is larger during the crisis period. Exchange rate and oil price shocks have very low explanatory impact on the volatility of stock markets in both markets.**

***Index Terms*—Exchange rate, GARCH model, inflation targeting, stock market volatility.**

I. Introduction

The study on the volatility of stock market is one of the main interests to academic researchers and market practitioners. The volatility can be directly considered as a measurement of risk. Higher volatility implies higher risk of assets. The study on the volatility of stock market provides evaluation on the performance of stock market. Many models are used in modelling the stock market volatility, ranging from the ARCH model proposed by [1] in early 1980's, followed by the introduction of GARCH model by [2], [3] in mid- 1980 and other GARCH-type models. These models include GARCH-M, IGARCH, EGARCH models in [4] Threshold GARCH [5] asymmetric GARCH model or AGARCH by [6] and Fractionally Integrated or FIGARCH by [7]. Rather than focusing on the volatility of stock market for a group of countries, previous studies are also interested in examining the co-movements and bi-directional relationship of two international stock markets. The results provide information on how shocks are transmitted from one market to another. Indeed previous studies reveal strong linkage and correlation of international stock markets and some studies found U.S. as the global factor affecting the developed and developing markets [8].

In this study, we use GARCH (1, 1) model to model the volatility of stock market for U.S. and Malaysia separately. Our intention is not to forecast the movement of stock market or to compare the performance of stock market of these two countries. Rather, we seek to generate the volatility series using GARCH model so that we can proceed in examining the inter-relationship of these two series using the system equation of VAR analysis. We take into account the impact of 1997 financial crisis of Asia and divide the data into three main periods, i.e. the pre- crisis, crisis and post-crisis periods. Our results show limited interactions of stock market volatility between the two countries. The stock market volatility of U. S. has larger impact on the stock market volatility in Malaysia during the crisis period but the stock market volatility of Malaysia has very low or insignificance impact on the market of U. S. in the pre and crisis periods, the impact is larger in the post crisis period. Besides, both exchange rate and oil price shocks have very small impact on the stock market volatility in these two countries.

The paper is organized as follows: Section II discusses the literature review; Section III explains the data and methodology; Section IV summarizes the results and Section V concludes.

II. Literature Review

A large number of studies have been conducted to investigate the linkage and correlation of international financial markets mainly focused in developed markets for instance [9], [10]. But after the Asian crisis, more studies are focused on emerging Asian markets. Among them are [11] and [12]. Previous studies reported different results but a number of studies reveal co-movements of international stock markets. For instance, [13] detected bi-directional in returns, shocks and volatilities among Asian countries. [7] detected two-way directional volatility spillovers between U. S. and Indian stock market through trade and investment. [14] studied the volatility spillovers and linkage between U.S. and European stock markets. The results detected strong cointegration relationship between these two stock markets. However, [15] found minimal co-movements between Malaysia stock market and other markets and that Asian markets are vulnerable to the impacts of U.S. market.

Besides, there are studies investigate the volatility transmission of international markets. Some results reveal significance volatility spillovers from the U.S. and Japan markets to other markets, for instance see [7], [16], [17]. On the other hand, some studies find weaker or no volatility impacts from U.S. to international markets, for instance, [15].

III. Data and Methodology

The data sets used in this study are daily closing indices of

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KLCI, NASDAQ, crude oil, and exchange rate (RM/1USD). These series are obtained from Yahoo Finance (http://finance.yahoo.com) and crosschecked with the data downloaded from OANDA and FOREXPROS.

The data is divided into three sub-periods, taking into account the impact of 1997 financial crisis in Asia. The three periods are: pre-crisis (2nd January 1990 to 30th June 1997), crisis (1st July 1997 to 30th September 1998) and post-crisis (1st October 1998 to 30th Dec 2010). Following [18], the natural log return is computed as

$$R_t = \ln(\frac{P_t}{P_{t-1}}) \quad (1)$$

where R_t is the daily returns and P_t is the daily prices.

A. GARCH (1, 1)

We apply VAR model to examine the dynamic inter-relationship between the stock market volatility of U. S and Malaysia. Before conducting the VAR analysis, we need to generate the stock market volatility series by running the GARCH (1, 1) model for both countries separately. Following [19], we assume that the conditional mean equation of stock return is constructed as the constant term plus residuals term, i.e. $r_t = \mu + \varepsilon_t$

$$\varepsilon_t = z_t \sigma_t \qquad z_t \sim \text{iid } (0, 1)$$

Under GARCH specification, the time-varying conditional volatility is a function of its own past lag one term plus the past innovations. The conditional variance equation in GARCH (1, 1) process is assumed to be a function of its lag one term plus lag one of innovations and it is determined by the movement of exchange rate an crude oil price:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 + a_1(ex\_rate) \quad (2)$$

The condition of $\alpha_1 + \beta_1 < 1$ should hold to gain the weakly stationarity of GARCH process. α_1 implies the short-run persistency of shocks or the volatility clustering while β_1 as indicator for the long-run persistency.

B. VAR (p)

For a set of *K* time series variables, $y_t = (y_{1t}, ..., y_{kt})'$, VAR model captures their dynamic interactions. The basic model of order p (VAR (*p*)) has the form

$$y_t = A_1 y_{t-1} + ... + A_p y_{t-p} + u_t \quad (3)$$

where the y_t is the conditional volatility of stock market for Malaysia and U.S. respectively, A_k 's are ($k \times k$) coefficient matrices and $u_t = (u_{1t}, ..., u_{kt})'$ is an unobservable error term (see [20]). In this study, the constant term and two exogenous variables, i.e. exchange rate and crude oil price are added in the VAR (*p*) model.

C. IRF and FEVD

VAR analysis provides two tools for interpretation, i.e. impulse response function (IRF) and forecast error variance decomposition (FEVD). The IRF is a useful tool for determining the magnitude, direction, and the length of time that the variables in the system are affected by a shock to another variable. According to [20], if the process of y_t is *I*(0), the effects of shocks in the variables of a given system are most easily seen in its World moving average (MA) representation

$$y_t = \phi_0 u_t + \phi_1 u_{t-1} + \phi_2 u_{t-2} + ... \quad (4)$$

where $\phi_0 = I_k$ and the

$$\phi_s = \sum_{j=1}^{s} \phi_{s-j} A_j$$

can be computed from the reduced-form coefficients of the VAR in levels. The coefficients of this representation may be interpreted as reflecting the responses to impulses hitting the system. The (*i, j*) elements of the matrices ϕ_s, regarded as a function of *s*, trace out the expected response of $y_{j,t+s}$ to a unit change in y_{jt}, holding constant all past values of y_t .Since the change in y_{jt} ,given { y_{t-1}, y_{t-2} ….}, is measured by the innovation u_{jt} , the elements of *s* represent the impulse responses of the components of y_t with respect to the u_t innovations. Occasionally, the main interest is focused on the accumulated effects of the impulses. They are easily obtained by adding up the ϕ_s matrices.

$$\phi = \sum_{s=0}^{\infty} \phi_s = (I_K - A_1 - ... - A_p)^{-1} \quad (5)$$

According to [20], forecast error variance decompositions are also popular tools for interpreting VAR models. The corresponding forecast error variance is

$$\sigma_k^2(h) = \sum_{n=0}^{h-1} (\psi_{k1,n}^2 + ... + \psi_{kK,n}^2) = \sum_{j=1}^{K} (\psi_{kj,0}^2 + ... + \psi_{kj,h-1}^2) \quad (6)$$

The term $(\psi_{kj,0}^2 + ... + \psi_{kj,h-1}^2)$ is interpreted as the contribution of variable j to the h-step forecast error variance of variable *k*. This interpretation makes sense if the errors term can be viewed as shocks in variable.

IV. Results

We obtain the conditional stock market volatility series for U. S. and Malaysia by running the GARCH (1, 1) model. Testing with Johansen cointegration test fails to detect any cointegration relationship between the two series. Also, testing with Augmented Dicky-Fuller unit-root test shows that these series are stationary. Therefore, we proceed with the VAR estimation. Following the suggestion by Akaike Information Criterion, we optimum lag length selected are 5, 1 and 6 for pre-crisis, crisis and post-crisis periods estimation

respectively. Table I summarizes the results of VAR. The results show that the interaction between the volatility stock market of U. S. and Malaysia is very low. The movement of stock market volatility for each country is mostly determined by its own lagged volatility. However, comparing the results across periods, we observe higher impact from the volatility of stock market from U.S. on Malaysia's in the pre and crisis periods. The impact is decreasing in the post-crisis period. Conversely, there is almost no significance impact of stock market volatility of Malaysia on U.S.'s in the pre- and crisis periods. But we observe some significance impact from Malaysia's on U.S.'s. Besides, the results also show that exchange rate and oil price show some significance impacts on the stock market volatility of these two countries, the impact is very small and close to zero, indicating very limited impact of these two variables on the stock market volatility in Malaysia and U.S.

TABLE I: RESULTS FROM VAR ESTIMATION

	Pre Crisis Period		Crisis period		Post-crisis period	
Variable	VAR01	VAR02	VAR01	VAR02	VAR01	VAR02
	0.827383**	3.67E-05	0.812433*	0.005419	0.890008*	0.073644*
VAR01(-1)	(0.02388)	(0.00301)	(0.03535)	(0.00530)	(0.02159)	(0.02871)
	-0.091975**	0.006166			0.073018*	-0.107640*
VAR01(-2)	(0.03088)	(0.00389)	-	-	(0.02878)	(0.03826)
	0.089648**	-0.004792			-0.039829	0.010581
VAR01(-3)	(0.03090)	(0.00389)	-	-	(0.02885)	(0.03836)
	-0.124483**	-0.000812			0.018521	0.029315
VAR01(-4)	(0.03089)	(0.00389)	-	-	(0.02885)	(0.03836)
	0.077199**	-0.001588			-0.039101	0.039020
VAR01(-5)	(0.02386)	(0.00300)	-	-	(0.02877)	(0.03825)
					0.000799	-0.065572*
VAR01 (-6)	-	-	-	-	(0.02157)	(0.02868)
	0.331028*	0.842948**	0.598298*	0.740931*	0.037903*	0.952640*
VAR02(-1)	(0.18964)	(0.02387)	(0.28808)	(0.04316)	(0.01619)	(0.02153)
	0.068761	0.095177**			-0.032395	0.124595*
VAR02 (-2)	(0.24773)	(0.03119)	-	-	(0.02231)	(0.02966)
	-0.453385*	-0.090697**			-0.001023	-0.008430
VAR02 (-3)	(0.24765)	(0.03118)	-	-	(0.02235)	(0.02972)
	0.011318	0.005663			-0.027210	-0.091880*
VAR02 (-4)	(0.24738)	(0.03115)	-	-	(0.02233)	(0.02969)
	0.032352	0.024207			0.019487	0.057712**
VAR02 (-5)	(0.18922)	(0.02382)	-	-	(0.02223)	(0.02955)
					0.006190	-0.051656*
VAR02 (-6)	-	-	-	-	(0.01613)	(0.02145)
	-0.000196*	-2.83E-05**	-0.000573	-0.000178	0.000188*	8.41E-05
C	(0.00010)	(1.3E-05)	(0.00074)	(0.00011)	(4.7E-05)	(6.3E-05)
	9.62E-05**	8.65E-06*	0.000112	4.17E-05*	-4.24E-05*	-1.75E-05
EX_RATE	(3.9E-05)	(4.9E-06)	(0.00012)	(1.8E-05)	(1.2E-05)	(1.6E-05)
	-7.83E-07	7.92E-07**	1.65E-05	4.48E-06	-4.52E-07*	-2.61E-07*
OIL	(1.2E-06)	(1.5E-07)	(2.2E-05)	(3.3E-06)	(8.7E-08)	(1.2E-07)
R square	0.6276	0.8306	0.7504	0.6423	0.8873	0.9782

Note: Standard errors are given in parentheses. **, * Significant at 5% and 10 %respectively; VAR01 and VAR02 denote the conditional volatility of stock market for Malaysia and U. S. respectively.

TABLE II: FORECAST ERROR VARIANCE DECOMPOSITION

	Variance Decomposition of VAR01:			Variance Decomposition of VAR02:		
(A) Pre-crisis period						
	S.E.	VAR01	VAR02	S.E.	VAR01	VAR02
1	0.000154	100.0000	0.000000	1.94E-05	1.850664	98.14934
2	0.000201	99.89947	0.100532	2.54E-05	1.854500	98.14550
3	0.000222	99.62639	0.373612	2.99E-05	2.403088	97.59691
4	0.000235	99.58448	0.415520	3.27E-05	2.661977	97.33802
5	0.000241	99.58280	0.417199	3.46E-05	2.771433	97.22857
(B) Crisis period						
1	0.000651	100.0000	0.000000	9.76E-05	10.88070	89.11930
2	0.000853	99.58270	0.417299	0.000122	11.95993	88.04007
3	0.000974	98.90711	1.092887	0.000134	12.88310	87.11690
4	0.001054	98.16540	1.834599	0.000141	13.64549	86.35451
5	0.001109	97.46071	2.539290	0.000145	14.25681	85.74319
(C) Post-crisis period						
1	4.08E-05	100.0000	0.000000	5.42E-05	1.727966	98.27203
2	5.48E-05	99.86185	0.138148	7.52E-05	2.593056	97.40694
3	6.54E-05	99.80838	0.191619	9.40E-05	2.485176	97.51482
4	7.32E-05	99.74530	0.254700	0.000111	2.345399	97.65460
5	7.95E-05	99.76619	0.233811	0.000126	2.297588	97.70241

Note: VAR01 and VAR02 denote the conditional volatility of stock market for Malaysia and U. S. respectively.

Turning to the results of forecast error variance decomposition (see Table II), we observe very similar results. The stock market volatility of Malaysia is mainly determined by its own shock, i.e. stock market volatility shocks of

Malaysia can forecast the variance of volatility in Malaysia almost 100%, and the explanatory power is slightly declines over time across three periods. The same results hold for the case of U. S. However, it is observed that the shock of stock market volatility in U.S. has higher explanatory power on the movement of stock market volatility in Malaysia in the pre and during the crisis periods relative to the post-crisis period.

Table III summarizes the impulse response function for each variable in the system equation. Again, the accumulated impulse response function also reported very similar result, i.e. the accumulated effect of each shock on its own stock market volatility is relatively very large compare to the other country. The results re-confirm that the stock market volatility of each country is mainly determined by its own lagged values.

TABLE III: IMPULSE RESPONSE FUNCTION

period	Pre-crisis			
	Impulse of VAR01		Impulse of VAR02	
	VAR01	VAR02	VAR01	VAR02
1.	0.0002**	0.0000**	2.64E-06**	1.92E-05**
2.	0.0003**	6.37E-06**	4.87E-06**	3.55E-05**
3.	0.0004**	1.83E-05**	7.96E-06**	5.10E-05**
4.	0.0004**	2.52E-05**	1.06E-05**	6.39E-05**
5.	0.0005**	2.85E-05**	1.28E-05**	7.49E-05**
	Crisis			
1.	0.0006**	0.0000**	3.22E-05**	9.21E-05**
2.	0.0012**	5.51-05**	5.96E-05**	0.0002**
3.	0.0017**	0.0001**	8.28E-05**	0.0002**
4.	0.0020**	0.0002**	0.0001**	0.0002**
5.	0.0024**	0.0003**	0.0001**	0.0003**
	Post-crisis			
1.	4.08E-05**	0.0000**	7.10E-06**	5.39E-05**
2.	7.73E-05**	2.05E-06**	1.68E-05 **	0.0001**
3.	0.0001**	4.04E-06**	2.54E-05**	0.0002**
4.	0.0001**	6.34E-06**	3.40E-05**	0.0002**
5.	0.0002**	7.37E-06**	4.27E-05**	0.0003**

Note: VAR01 and VAR02 denote the conditional volatility of stock market for Malaysia and U. S. respectively.

V. CONCLUSION

Applying the GARCH (1, 1) and VAR(*p*) approaches, we conduct empirical investigation on the dynamic inter-relationship between stock market volatility if U.S. and Malaysia. The results are compared across pre-crisis, crisis and post-crisis periods. In general, our results reveal limited interactions between the two variables. The stock market volatility of each country is mainly determined by its own past values. Comparing the results across periods, it is observed that the volatility of stock market in U.S. has larger impact on the volatility of stock market in Malaysia in the pre and crisis periods. On the other hand, the volatility of stock market in Malaysia has very limited impact on the volatility of U.S. Both exchange rate and oil price have almost no impact on the volatility of stock market of both countries.

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