Real GDP growth rates of Singapore, Taiwan and Hong Kong: An asymmetric multivariate GARCH approach

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Abstract: The economies of Hong Kong, Singapore and Taiwan have become known as "East Asian Tigers," enjoyed a remarkable record of high and sustained economic growth over three decades from 1965 to the early 1990s. Their ability to achieve a speedy development with equity has intrigued many economists who attempted to understand the drive of growth. Most of this miraculous growth is believed due to a combination of fundamentally sound development policies, tailored interventions, and an unusually rapid accumulation of physical and human capital, as well as rapid intra-regional trade integration.

Recently GARCH-type models have been applied to analyze growth rates of real gross domestic product (GDP) in developed and under-developed countries. However, few studies actually employ multivariate GARCH-type models such as the constant conditional correlation (CCC) model by Bollerslev (1990), dynamic conditional correlation (DCC) model by Engel (2002) and varying correlation MGARCH (VC-MGARCH) by Tse and Tsui (2002) for such purposes. Other studies using such models concentrate on interactions between real output and price, and between real output and stock performance. In this paper, we examine both the GARCH-type effect and the conditional correlation of the real GDP growth rates for Singapore, Taiwan and Hong Kong. We use the well-established exponential GARCH model of Nelson (1991) to capture the possibly asymmetric conditional volatility in the real GDP growth rates. And the conditional variance and covariance matrix is linked by using CCC-MGARCH and VC-MGARCH models. Our findings are consistent with findings by Ho and Tsui (2003) in which the negative real GDP shocks seem to have greater influence on future volatilities as compared to positive shocks of the same magnitude. Moreover, we apply the MISCC algorithm by Sansó et al. (2004) to identify the potential structural break points. We find support for structural breaks in conditional variance, and the quality of the estimation results will be improved if the structural breakpoints are counted in estimation,

Our findings have important implications to both academics and macroeconomic policy-makers.With the presence of asymmetric volatility, the policy-makers need to be more pro-active in formulating their economic stimulating policy during periods of negative impacts. This is because, when negative shocks happen, investors would normally have negative sentiment and over-react to the shocks, which can make the already-sinking economy even worse. In addition, the existence of persistence in volatility implies that, when the volatility is high at certain time, it is very likely that this volatility will persist. Thus, when negative shocks occur, there would be an additional effect caused by both asymmetry and persistence in volatility, namely asymmetry causes higher volatility which then, as a result of volatility persistence, would intensify the problem. During the time of positive impacts, the economies may face a quick overheating problem due to investors' over-reaction. Therefore an appropriate counter-cyclical policy measures have to been made by the government to respond to the adverse impact of negative shocks and to stabilise the macroeconomic environment. The ability to identify breakpoints would provide policy-makers with additional information to identify the causes of the volatility and help to stabilize the macroeconomy. Finally, the findings also indicate that negative economic disturbances arising from one economy may spill over to another one through the strong economic linkages. As such, international economic policy co-ordination would become imperative to ameliorate the effect of shocks originating from other economy.

Keywords: GDP growth rates, EGARCH, MGARCH, MICSS algorithm, structural changes in volatility, asymmetric volatility

JEL classification: F14; F31; P21

1. INTRODUCTION

East Asia has enjoyed a remarkable record of high and sustained economic growth over three decades from 1965 to the early 1990s. Out of the 23 countries in the region, Hong Kong, Singapore, South Korea and Taiwan emerged to be the "four tigers". Their ability to achieve speedy developments with equity has intrigued many economists who attempted to understand the drive of growth. Indeed, the World Bank named such a phenomenon as "the East Asian Miracle". Most of this miraculous growth is believed due to a combination of fundamentally sound development policies, tailored interventions, and an unusually rapid accumulation of physical and human capital, as well as rapid intra-regional trade integration. Due to data constraint, we limit our study to the economies of Hong Kong, Singapore and Taiwan only. Indeed, the recent data indicate that the trade activities between Singapore, Taiwan and Hong Kong grew tremendously in volume. According to data provided by CEIC Data Company Ltd, Singapore's exports to Taiwan grew from S$1016.7 million in January 1995 to S$4255.5 million in October 2007 on the monthly basis alone. Singapore's exports to Hong Kong grew from S$464.1 million to S$1327.4 million during the same period. Taiwan's trade volumes with Hong Kong and Singapore also grow well. Taiwan's exports to Singapore grew from US$279.6 million in January 1998 to US$1091.9 million in October 2007. Meanwhile, Taiwan's export to Hong Kong is even more spectacular with volume of US$1627.4 million in Jan 1998 growing to US$3243.6 million in October 2007. More trade activities between these economies would further enhance collaborations and interdependency.Studies on output co-movement and volatility dynamics of the real GDP growth across countries have important implication for regional economic integration. To our knowledge, there is no study focusing on the volatility dynamics of the real GDP growth in these economies. The closely related one is Ho and Tsui (2003) who employed the exponential GARCH model by Nelson (1991) to investigate conditional variances of GDP series of Greater China – the Mainland China, Hong Kong and Taiwan. However, the drawback of this study is that they use only a single GARCH-type model in their analysis, and their approach do not capture the possible cross effects among the economies in the Greater China region. In this paper, we employ a multivariate GARCH framework to investigate the asymmetric conditional volatility in the real GDP growth rates and the structural breaks in conditional variance in the economies of Hong Kong, Singapore and Taiwan. There are a few study applying the multivariate models to macroeconomic variables. For example, Ahn and Lee (2006) and Lee (2006) attempted to incorporate output into multivariate GARCH models. However, their studies investigate the interactions between real output and price, and between real output and stock performance rather than the real output growth rates across countries. Our choice of multivariate GARCH-type models includes the constant conditional correlation (CCC) model by Bollerslev (1990) and the time-varying conditional correlation MGARCH (VC-MGARCH) by Tse and Tsui (2002). Our findings suggest that the CCC-MGARCH model is more adequate.

The rest of this paper is organized as follows. In section 2, we discuss the theoretical framework and methodology for this study along with Nelson (1991) and Tse and Tsui (2002). Section 3 describes the data used in the study and the empirical results. Diagnostic test will be conducted and discussed for model adequacy checking,. Section 5 concludes the paper.

2. ARMA-EGARCH-CCC-MGARCH MODEL

Since the seminal ARCH model by Engle(1982) and later its extension to the Generalized Autoregressive conditional heteroscedasticity (GARCH) by Bollerslev (1986), there has been a growing literature of GARCH-type models. For asset returns, it is well-known that the negative shocks may have greater impacts on the volatility than the positive shocks of the same magnitudes. However, the simple GARCH(1,1) model is unable to account for this leverage effect because it assigns the same degree of importance to both negative and positive shocks. Nelson (1991) proposes the Exponential GARCH model (EGARCH) to account for such leverage effects. Under the EGARCH(p,q) model with the assumption of normal distribution, we have:

$$\ln(h_t) = \alpha_o + \sum_{h=1}^{p} \alpha_h \ln(h_{t-h}) + \sum_{h=1}^{q} \theta_h g\left(\frac{\varepsilon_{t-h}}{\sigma_{t-h}}\right) \tag{1}$$

where $g\left(\frac{\varepsilon_{t-h}}{\sigma_{t-h}}\right) = \beta_h \frac{\varepsilon_{t-h}}{\sigma_{t-h}} + \gamma_h \left[\left|\frac{\varepsilon_{t-h}}{\sigma_{t-h}}\right| - \mathrm{E}\left(\left|\frac{\varepsilon_{t-h}}{\sigma_{t-h}}\right|\right)\right]$ and $E\left(\left|\frac{\varepsilon_{t-h}}{\sigma_{t-h}}\right|\right) = \sqrt{\frac{2}{\pi}}$.

The EGARCH approach is able to capture asymmetric volatility through the parameter β. If β is less than 0, a negative shock will add more volatility. In addition, EGARCH places no restrictions on parameters β, α and γ. For details, see Nelson (1990).

As Hong Kong, Singapore and Taiwan have a close economic tie and share many similarities, it is natural to apply multivariate GARCH models to study the dynamic pattern of the real output together. There are well-known multivariate GARCH-type models like the VEC model and the BEKK model by Engel and Kroner (1995). However, there is no guarantee that these multivariate GARCG-type models could be able to secure the requirement of positive definiteness in the variance-covariance matrix and thus convergence during estimation. Moreover, the relatively fewer data points for GDP growth rate series could also cause unwanted divergence in estimation.

Moreover, applying multivariate GARCH-type models like the CCC-MGARCH and VC-MGARCH models would be computationally efficient in the estimation as these models are more stable, especially in satisfying the positive definiteness condition and free from the curse of dimensionality as there are they fewer number of parameters to be estimated. Under the VC-MGARCH model, the conditional correlation matrix of standardized residuals $\frac{\varepsilon_t}{\sigma_t} = (\frac{\varepsilon_{1t}}{\sigma_{1t}}, \ldots\ldots, \frac{\varepsilon_{Kt}}{\sigma_{Kt}})'$ is assumed to be time-varying. The conditional correlation between ε_{it} and ε_{jt} evaluated at time t-1 is given by the expression $\rho_{ij} = h_{ijt} / \sqrt{(h_{iit} h_{ijt})}$. In general, both ρ_{ij} and H_t vary with time. Hence, the time-varying conditional covariances can be expressed as the product of conditional correlation and square root of the product of the corresponding two conditional variances,

$$h_{ijt} = \rho_{ij} (h_{iit} h_{jjt})^{\frac{1}{2}} \qquad j = 1,\ldots\ldots, K,\ i = j+1,\ldots\ldots,K \tag{2}$$

The conditional variance-covariance matrix will become:

$$H_t = D_t R\, D_t \qquad \text{or}$$

$$H_t = diag(\sqrt{h_{11,t}},\ldots,\sqrt{h_{KK,t}})\ \ R\ diag(\sqrt{h_{11,t}},\ldots,\sqrt{h_{KK,t}}) \tag{3}$$

We note in passing that each conditional variance still follows the univariate GARCH-type specifications, for example EGARCH.

Tse and Tsui (2002) propose the VC-MGARCH model to allow for time-varying conditional correlations. Specifically, the time-varying conditional correlation matrix R_t is generated from the recursive ARMA structure:

$$R_t = (1 - \theta_1 - \theta_2) R_0 + \theta_1 R_{t-1} + \theta_2 \varphi_{t-1}, \tag{4}$$

The covariance-variance matrix is specified as:

$$H_t = D_t R_t D_t \qquad \text{or}$$

$$H_t = diag(\sqrt{h_{11,t}},\ldots,\sqrt{h_{KK,t}})\ \ R_t diag(\sqrt{h_{11,t}},\ldots,\sqrt{h_{KK,t}}) \tag{5}$$

where θ_1 and θ_2 are assumed to be non-negative and $\theta_1 + \theta_2 < 1$. $R_0 = \{\rho_{ij}\}$ is a time invariant K x K positive definite parameter matrix with unit diagonal elements and φ_{t-1} is a K x K matrix whose elements are functions of the lagged observations of ε_t. As R_t is a standardized measure, φ_{t-1} is thus also standardized into a correlation matrix of the lagged standardized residuals ε_i.

Denoting $\varphi_{t-1} = \{\varphi_{ijt}\}$, Tse and Tsui (2002) proposed the following specification for φ_{t-1}:

$$\varphi_{t-1} = \frac{\sum_{h=1}^{M} e_{i,t-h} e_{j,t-h}}{\sqrt{(\sum_{h=1}^{M} e_{i,t-h}^2)(\sum_{h=1}^{M} e_{j,t-h}^2)}},\ 1 \le i \prec j \le K \tag{6}$$

where $e_{it} = \varepsilon_{it} / h_{it}$. When θ_1 and θ_2 are confined to zero, the VC-MGARCH model is reduced to the CCC-MGARCH model. We apply both models to the three GDP growth series. However, we often find that estimates of θ_1 are so close to zero that the VC-MGARCH estimation did not converge.

As it will be seen, our study of data series indicates the possible presence of structure breaks. In order to identify the location of breakpoints, we use the iterated cumulative sum of squares (ISCC) algorithm developed by Inclan and Tiao (1994) and Sanso et al. (2004). The program treats the series of growth rates for the initial period to have stationary variance and then captures a change in variance when it occurs. Then, the variance is again treated as stationary until another change is captured. If there is leptokurticity and conditional heteroskedasticity, the structural breaks in volatility may occur more often, generating spurious breaks. As such, Sanso et al. (2004) improve the procedure by accounting for the kurtosis and the conditional heteroskedasticity, using a nonparametric adjustment based on the Bartlett kernel. Another advantage of this modified ICSS is that it allows for multiple break points to be detected by dividing and examining different parts of the series. We use dummy variables in the conditional variance equations to capture the structural changes in volatility. As such, the conditional variance equation with breakpoints is specified as below:

$$\ln(h_t) = \alpha_o + \sum_{h=1}^{p} \alpha_h \ln(h_{t-h}) + \sum_{h=1}^{q} \theta_h g\left(\frac{\varepsilon_{t-h}}{\sigma_{t-h}}\right) + \sum_i \omega_i \times B_{(Country)i} \quad (7)$$

3. DATA AND RESULTS

Our data set consists of the quarterly real GDP of Singapore, Taiwan and Hong Kong taken from CEIC data manager. The GDP series for Singapore and Hong Kong are adjusted to year 2000 price whereas for Taiwan is adjusted to price in year 2001. For uniformity, we also adjust the data to start from 1977Q3 to 2007Q2. Our choice of period would cover the "miracle period" in 1965-1990 and the post-miracle period. This helps to examine the volatility dynamics and the structural changes in volatility in both periods. Moreover, the raw GDP data is seasonally adjusted by the Cencus-X11 (Multiplicative) procedure. We compute the continuously compounded growth rates of the seasonally adjusted quarterly real GDP by 100 times of the difference of the natural logarithm of the quarterly seasonally adjusted real GDP for each country:

$$r_t = (\ln Y_t - \ln Y_{t-1}) * 100$$

where Y is the seasonally adjusted real output measured in the respective country's currency. For each return series, we use autoregressive (AR) specification for mean equations with lag order up to m

$$r_t = \phi_0 + \sum_{i=1}^{m} \phi_i r_i + \varepsilon_t$$

We first assess the statistical features of the real growth rates series in these economies (the results are not reported but available upon request). It is found that Singapore enjoys the highest mean growth rates, and Hong Kong has the most volatile growth rates during the sample period. Singapore growth rates are negatively skewed, whereas those of Hong Kong and Taiwan are positively skewed. And all three growth series have excess kurtosis with Taiwan registering the highest at 6.31. Normality checking by the Jacque-Bera test reveals that they are not normally distributed, thereby reflecting high kurtosis and non-zero skewness. As regards the Q statistics for checking possible correlation in the variance, we find that Q statistics of the squared growth rates for Singapore and Taiwan are not significant at the 5% level, and Hong Kong is just barely significant, which indicates the absence of autocorrelation in the variance. However, we find support for high sample kurtosis and the rejection of the null hypothesis of normal distribution by the Jarque-Bera tests. They may indicate the presence of conditional heteroskedasticity.

Following Sanso et al. (2004), we employ the iterated cumulative sum of squares (ISCC) algorithm to identify structural breaks in volatility. The results indicate that there two possible breaks points for Taiwan respectively in 1987 and 1998, and two for Hong Kong and Singapore in 1997 and 2003, coinciding with the Asian Financial crisis and SARS outbreak. We then adopt correspondingly dummy variables in the conditional variance equations for each economy to capture the structural changes in volatility. We have employed the augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests to check the stationarity of the GDP growth rate series. Our findings, available upon request, show that all ADF and PP test statistics are significant at the 1% level, indicating that all are stationary.

We now turn to the discussion of the evidence of persistence and asymmetry in volatility as reflected by the estimated values of parameters in the conditional variance equations, and then we compare the difference between models that accounts for structural changes in variance and the one that does not, and alsodiscuss the time-varying conditional standard deviations for each real output series, justifying the behaviors of each time series of conditional standard deviation.

We report in Table 1 the estimation results of the conditional variance both with and without the breakpoints. As can be seen in Table 1, there is marked difference in term of persistence between cases "with breakpoints" and "without breakpoint". The persistence is indicated by the estimated value of α in the variance equations. For the latter case, the persistence is higher than that of the "with breakpoint" case. For example, the estimated value of α for Taiwan is 0.8453 in the absence of breakpoints, but it is reduced to 0.4252 when breakpoints are present in the variance structure. The possible explanation is that, when dummy variables are included into the variance equation, they account for the excess volatility that is otherwise treated as persistence. Moreover, consistent with Ho and Tsui (2003), we find that the degree of persistence for the growth rates is the highest for Taiwan, and the growth rates for Singapore and Hong Kong show a lesser degree of persistence.

Table 1: Estimates of Conditional Variance with vs without breakpoints: Eq (2) and (8)

	Conditional Variance with breakpoints			Conditional Variance without breakpoints		
	HK	Spore	Taiwan	HK	Spore	Taiwan
α_0	-4.2267 (1.276)	-4.5951 (1.360)	-5.0902 (2.396)	-2.8362 (1.5899)	-4.5951 (1.389)	-1.4275 (0.810)
α_h	0.5305 (0.139)	0.4994 (0.152)	0.4252 (0.274)	0.6655 (0.1862)	0.5096 (0.158)	0.8453 (0.0897)
γ_h	0.3662 (0.272)	0.1930 (0.195)	0.2232 (0.273)	0.6873 (0.1361)	0.2184 (0.201)	0.3676 (0.263)
β_h	-0.5649 (0.116)	-0.4024 (0.180)	-0.1599 (0.143)	-0.3409 (0.1398)	-0.4086 (0.174)	-0.169 (0.108)
ω_1		0.2706 (0.212)	0.0009 (0.217)			
ω_2	-0.1906 (0.276)	0.4316 (0.233)	-0.6830 (0.397)			
ω_3	-0.0037 (0.318)					

Note: The Bollerslev-Wooldridge robust, heteroskedastic-consistent standard errors are reported in parentheses.

3.1 Discussion of asymmetry and constant correlations:

As regards asymmetry in the conditional volatility, we need to examine estimates of β of Eq. 2 to see whether it is negative or not and whether it is statistically significant. As it can be seen in Table 1, the coefficient of volatility asymmetry for Singapore and Hong Kong are all negative and significant at the 5% level, and the corresponding value for Taiwan, though negative, is insignificant at the 5% level. In particular, the coefficient suggests that negative shocks have a greater impact on future volatilities than positive shocks of the same magnitude. This is consistent with the findings of Ho and Tsui (2003), who have detected significantly negative volatility asymmetry in the real GDP of the US.

It is generally believed that volatility of the GDP growth rates in particular and those of macroeconomic variables in general is higher during the time of recession (see Brunner, 1992 and French and Sichel, 1993). Casual observation suggests that real output volatility apparently increase during economic downturns, and in particular, increases in the conditional deviation usually occur after the contractions (recessions) in the US economy. According to the NBER, during or shortly after the recessions, the conditional standard deviations have been significantly higher for sectors such as the Consumer Good, Investment Good and Manufacturing sectors. Ho and Tsui (2003) also observe that in the period after the 1973/74 and 1979 oil price shocks, the world economy plunged into a global recession and the conditional standard deviation of the overall US IIP is relatively higher.

Indeed, Engle (1982) has noted that, in the chaotic 1970s when economies were plagued by stagflation, estimated variances of inflation increase substantially. Ho and Tsui (2002) have also suggested that episodes of high conditional standard deviation of Hong Kong's real GDP are associated with economic downturns and political uncertainty Another noteworthy feature is that the level of IIP conditional volatility is generally lower in the late 1980s and the 1990s. This could be partly ascribed to the generally accepted view that the US economy is more stable in the years after World War II than in the pre-war period (Diebold and Rudesbusch (1992)). This consensus is reinforced by formal examinations of postwar stabilisation, such as De Long and Summers (1986). These studies have focused on the changing volatility of business fluctuations, and they have uniformly concluded that the variability of various macroeconomic aggregates about trend have diminished during the post-war period. Also, according to the NBER's Business Cycle Dating Committee, the period from March 1991 onwards marks the beginning of a 10-year expansion that is the longest in the NBER's chronology (NBER (2002)). This protracted period of expansion, partly spurred by substantial productivity gains arising from advances in technological advances, has probably helped to reduce economic uncertainty and contributed to the low conditional standard deviations of the sectoral IIP series.

Both Singapore and Hong Kong are well known for being entrepot traders as well as international financial centers with few restrictions on trade and capital flows, and also both have a heavy reliance on international trade, with Hong Kong being the important intermediary serving Mainland China and Singapore being the international hub linking the East and West. It is therefore not surprising to see the high volatility in the real output growth in these two economies. This is further evidenced by the insignificantly negative volatility asymmetry in the real growth rate.

Table 2: Constant conditional correlations and log-likelihoods

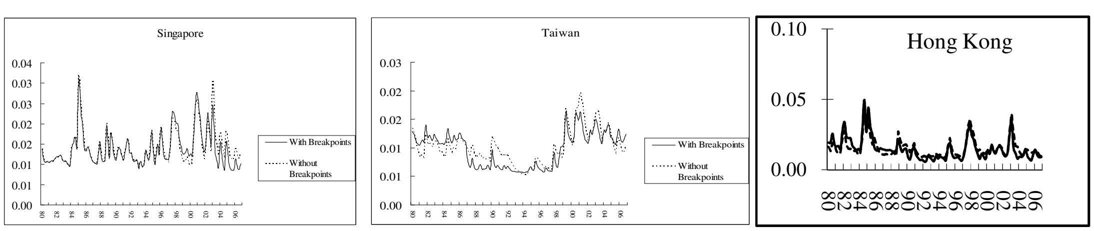
	Correlations			Model adequacy comparison
	Spore-Taiwan	*Spore-HK*	*Taiwan-HK*	Log-likelihood
With breakpoints	0.3045**	0.3124**	0.3306**	1223.94
	(0.0846)	(0.0927)	(0.1009)	
Without breakpoints	0.3129**	0.3380**	0.4083**	1212
	(0.0814)	(0.0897)	(0.0916)	

As it can be seen in Table 2, all the estimated values of conditional pair-wise correlation coefficients are significant at the 1% level, indicating that dynamic correlations probably exist among these three economies. It is interesting to note that the pattern of conditional correlations and the magnitude differ between the model with and without breakpoints. The magnitude of the correlation coefficients is generally smaller in the estimations including the breakpoints than without the breakpoints. The possible explanation is that, when we included the dummy variables to account for the structural breaks, we might improve estimation of the conditional standard deviations, which otherwise is absorbed in the constant conditional correlation.

Figures 1-3 present the conditional standard deviations of the real GDP growth rates for the three economies. The dashed lines denote estimates of conditional standard deviations without accounting for structural changes in volatility. The solid lines indicate the conditional standard deviations in the estimation with structural breakpoints in volatility. As can be seen from the figures, the structural breaks are very visible, and consistent with the historical events in each country. It is interesting to note that the volatility decreases in 1987 for Taiwan. This could be due to the government's anti-overheating measures implemented in the 1987 and anti-inflationary stance since the beginning of 1980s. The finding of the breakpoints in Hong Kong and Singapore is associated with the economic downturns and political uncertainty.

On the diagnostics front, we have conducted the Ljung-Box Q statistic and Jarque-Bera test for normality to check for model adequacy (the results are available upon request). It is found that the Jarque-Bera test statistics for series "with breakpoints" is smaller than those without breakpoints. As such, we cannot reject the null hypothesis of normality. Also, the Q-Statistics for squared series with the breakpoints are smaller than that without. As such, we may conclude that it is more adequate to accommodate break points in the multivariate GARCH-type models to account for structural changes in conditional volatility. In addition, the log-likelihood values generated from models with structural breakpoints are larger than those without breakpoints. This provides further support for including structural breakpoints in volatility estimations.

Figure 1: Conditional standard deviation of real GDP growth rates: Singapore, Taiwan and Hong Kong (1980Q1 – 2007 Q2)



4. CONCLUSION

We have employed two multivariate GARCH-type models to capture the volatility dynamics and persistence of the real GDP growth rates for the economies of Singapore, Hong Kong and Taiwan. We find evidence of asymmetry and persistence in volatility. The results also indicate that asymmetric volatility is sensitive to the structure of the conditional variance. The detection of structural breakpoints of volatility corresponds well to the historical economic and political events such as the Tiananmen event, Asian Financial crisis and SARS outbreak. Moreover, when the structural breakpoints are included in estimation, we find that the quality of the estimation results has been improved.

Our findings have important implications to both academics and macroeconomic policy-makers. With the presence of asymmetric volatility, the policy-makers need to be more pro-active in formulating their economic stimulating measures during periods of negative impacts. This is because, when negative shocks happen, investors would normally have negative sentiment and over-react to the shocks, which can make the already-sinking economy even worse. In addition, the existence of persistence in volatility implies that, when the volatility is high at certain time, it is very likely that this volatility will persist. Thus, when negative shocks occur, there would be an additional effect caused by both asymmetry and persistence in volatility,, namely asymmetry causes higher volatility which then, as a result of volatility persistence, would intensify the problem. During the time of positive impacts, the economies may face a quick overheating problem due to investors' over-reaction to their optimistic expectation. Therefore an appropriate counter-cyclical policy measures have to been made by the government to respond to the adverse impact of negative shocks and to stabilise the macroeconomic environment. The ability to identify breakpoints would provide policy-makers with additional information to identify the causes of the volatility and help to stabilize the economy. Finally, the findings also indicate that negative economic disturbances arising from one economy may spill over to another one through the strong economic linkages. As such, international economic policy co-ordination would become imperative to ameliorate the effect of shocks originating from any economy.

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