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## Article

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## ECONOMETRICS | RESEARCH ARTICLE

# Macroeconomic linkages and international shock transmissions in East Asia: A global vector autoregressive approach

Ibrahim Bakari Hassan<sup>1\*</sup>, M. Azali<sup>2</sup>, Lee Chin<sup>2</sup> and Wan N.W. Azman-Saini<sup>2</sup>

**Abstract:** The growing interdependency among East Asian countries means that there is concern not only on the way their macroeconomic variables are linked across borders, but also on the way shocks are transmitted as a consequence. This paper investigates the effect of macroeconomic linkages on international shock transmissions in selected East Asian countries. Global Vector Autoregressive model (GVAR) is used on the quarterly data of real output, inflation, equity prices, exchange rates, and short-term interest rate over the period 1979Q2–2013Q1. The result generally shows that the focus countries are more linked to global economy through equity markets, real output, and exchange rates, signifying more tendencies for contagion effects in the same way. On the other hand, result from the dynamic analysis, shows that China contributes highest shock transmission in the real sector, whereas US is the highest in the equity market. For the exchange rate; within-regional shock transmission is found to be highest. The dominance of China in the real sector implies the possibility of business cycle synchronization in the region, especially if China is triggered; however, the insignificance currency-shock transmission between China and the rest of the East Asian countries contradicts one important criterion for optimum currency area. This means that China could vanguard the

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## PUBLIC INTEREST STATEMENT

Globalization has brought about increasing interdependencies among countries. Increased trade and financial relations together with liberalized macroeconomic variables such as exchange rates, interest rate, and equity prices have resulted in increased economic linkages among countries. This work investigates the extent of such economic linkages among East Asian countries and also examines how these linkages could lead to transmission of economic crisis across borders. The finding of the work shows that East Asian countries are linked to the outside world through their respective equity markets, real output and exchange rates, implying a possibility for transmission of economic crisis in the same way. The result also shows that China contributes to the highest spillover effect in the real sector and therefore stands a better position to lead economic regionalism similar to that of Europe, especially if it could further open its currency market in the region.

economic regionalism if its currency market is more developed and liberalized. More still, the dominance of US in capital market and second to China in the real sector explained the strategic importance of US in the global economy.

**Subjects:** Economics; Political Economy; Finance; Business, Management and Accounting

**Keyword:** macroeconomic linkages; international shock transmission; East Asia; USA; GVAR

**JEL classifications:** F40; F42; F10; C32; O51; O53

## 1. Introduction

Over the years, the East Asian countries have engaged in two fundamental policy decisions; the liberalization of macroeconomic variables and the intensification of regional economic ties. Each of these decisions is considered enough to intensify economic interdependencies and inter-linkages in the region. The ultimate question is how such linkages would affect the transmission of macroeconomic shocks in the region and by implication, decisions regarding the formation of optimum currency area or monetary unionism. While this has been the concern of scholars and policy-makers, consensus on the optimum currency area or monetary unionism in the region is yet to be reached.

In the mid-1980s, most of the countries in East Asian region have initiated commitments toward open-economies by liberalizing their financial variables.<sup>1</sup> The result of the act is translated into two remarkable economic issues; the increased trade, economic growth, and market linkages (Awokuse, Chopra, & Bessler, 2009) on one hand, and on the other hand, the emergence of 1997/98 financial crisis in the region (Kawai, 2005; Yoshitomi, Shirai, & Asian Development Bank Institute, 2000). Each of these dimensions implies that a vent is created through which cross-country spill-overs can be transmitted. With credence to the Optimum currency hypothesis, the experience of the crisis necessitated the need for regional financial union starting with currency swap arrangement of the Chiang-Mai initiative.

However, as elucidated in Mundell–Fleming model, being an open-economy or incorporated into the global economy, means that a country has to adopt a strategic choice making behavior in handling volatilities of its macroeconomic variables especially the exchange rates (Fleming, 1962; Mundell, 1961, 1963). This is because volatilities in exchange rates affects returns to investment and reduce confidence in trade across borders. Thus, as proposed in the theory of optimum currency area, countries having intensified trade and similar economic fundamentals could form a currency union, where “within” exchange rate stability are reached and “between” exchange rate volatility are allowed. To that effect substantial empirical researches have investigated the feasibility for the East Asian country groups forming a monetary union, at least the optimum currency area. As a result, numbers of literature have agreed that the rate of interdependencies in ASEAN region has been on increase from the 1980s and has achieved significant linkages with the rest of the world. The engaged financial liberalization of 1990s has aided market linkages across the countries (Awokuse et al., 2009). The important channels of these linkages were identified under the context of improved external liberalization, individual domestic reforms, and market-driven integration (Awokuse et al., 2009; Kawai, 2005; Petri, 2006). The reducing share of country-specific factors and the increasing share of regional-specific factors in the determination of economic fluctuation in Asian region is also a suggestion of inter-linkages that favors monetary unionism (Lee & Azali, 2012).

However, while there is consensus on the increased level of economic interdependencies in East Asia, there is disagreement on the anchor country that could better lead the economic unionism in

the region. On this note, some empirical evidences surprisingly suggested that, US having significant trade and financial linkage with the region could best lead in the monetary unionism. Quah and Crowley (2012) investigate the anchor country to vanguard the formation of optimum currency area in East Asia. Among the three prospective candidates of US, China, and Japan, the study identified US as the favored. Hsiao, Hsiao, and Yamashita (2003) study also shows that US constitute important stock market linkages with countries in Asian-Pacific region. Large number of literatures as well supports the US economic significance in the Asian region (Mazier, Oh, & Saglio, 2008; Quah, 2012; Selover, 2004). Ozdemir, Olgun, and Saracoglu (2009) found a unidirectional relationship between equity prices in US and 15 emerging markets.

Some studies on the other hand, maintained that China is the most favored candidate to lead monetary unionism in the region. The emergence of China as a consumer economy in the region would facilitate mild extra-regional demand shocks and consequently, economic growth in the long-run (Park & Shin, 2010). Chan Leong and Felmingham (2003) show the presence of high correlation among the five East Asian economies of Singapore, Korea, Japan, Taiwan, and China. Other empirical findings pointed Japan as the most appropriate candidate to vanguard the drive to regionalism and optimum currency area in the region (Baharumshah, Chan, Wye, & Roy, 2007; Katada, 2002). Similarly, other studies such as Lee and Azali (2010) suggest inward looking for the ASEAN countries and gave evidence that the Singapore dollar could be a better candidate for common currency with-in the ASEAN countries.

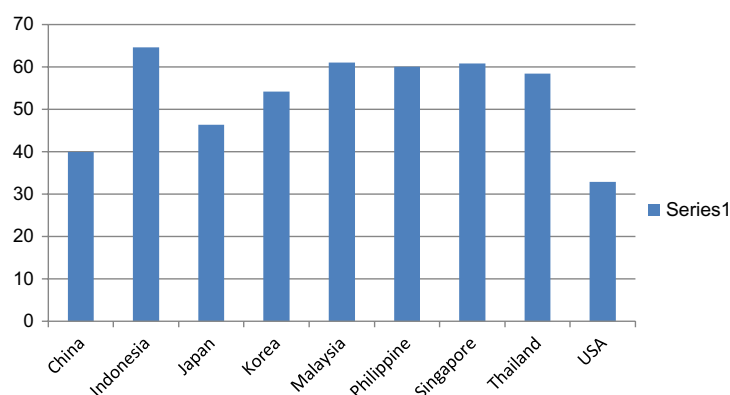
The above suggest that discordant views still exist on the suitable country to vanguard the economic regionalism in the area. Although this research explores along this line of argument, it however, differs with the available studies in some number of ways. With the established rate of country interdependencies, the effect of cross-country linkages can best be captured by the magnitude of shock they could transmit. This is because business cycle synchronization or decisions on optimum currency area are solely issues of cross-border spillovers. This study particularly observes the effect of linkages on shock transmission for the set of international macroeconomic variables. Furthermore, most of the identified literatures on the subject matter have widely ignored the global dimensions of country interdependencies in their modeling process. This could undermine the growing importance of external factors in the determination of domestic economic activities. Macroeconomic linkages is a global phenomenon requiring models of global dimensions, but as pointed by (Pesaran & Smith, 2006), most econometric models lack a coherent global dimension and allowance for interdependencies are done in an off-model manner, casting doubt on the plausibility of the estimates.

Against this background, this research work investigates how the ASEAN5+3<sup>2</sup> economies are linked among themselves and with the rest of the world and how macroeconomic shocks are consequently transmitted, using the Global vector Autoregressive Model (GVAR). The overall significance is the better understanding on how the increased trade and financial linkages within the ASEAN5+3 affect the transmission of macroeconomic shocks in the region and by implication, decisions regarding the formation of optimum currency area or monetary unionism. More also, looking at the important trading relation among the ASEAN5+3 countries as shown in Figure 1, pertinent question will also be on how would that influence decisions regarding regional optimum currency area? Categorically, the work investigates both the contemporaneous effects and dynamic (GIRF) analysis of the impact of foreign variables on their domestic counterparts using the GVAR model developed in Dees, Mauro, Pesaran, and Smith (2007). Although, the work focuses on the most developed eight Asian countries refers to as ASEAN5+3, the estimation reflects a global dimension and covers 33 countries that accounts for 90% of the global output.

With introduction in section one above; section two discusses the methodology of the Global Vector Autoregressive (GVAR). Data description is presented in section three. While result are presented and discussed in section four, summary and concluding remarks are given in section five.

**Figure 1. Percentage volume of trading activities within the ASEAN+3 countries.**

Source: Computed by the Author from the direction of trade statistics of GVAR database obtained in (Smith & Galesi, 2014).



## 2. Global vector autoregressive model

This work uses the Global Vector Autoregressive models of Pesaran, Schuermann, and Weiner (2004) and subsequent improved version in Dees et al. (2007). Accordingly the model has the following advantages over other global models in modeling interdependencies and inter-linkages across borders. Firstly, the creation of foreign variables out of the trade or financial matrices in the model caters for the individual cross-country interdependencies and at the same time reduces the problem of parameter instability. Secondly, stacking of individual augmented country-specific equations in a system reduces the problem of over-parameterization in the model. Thirdly, using average pairwise correlation accounts for common factor interdependencies among the country-specific variables. Lastly the sieve bootstrap procedure developed from the simulation of the model as a whole is used in creating error bounds for the generalized impulse responses (GIRF) and also serves as critical values in the test of over-identifying restriction and in structural stability test making inferences from the model more efficient. The GIRF measures the cross border shock while in cognizance of the global dimension of the relationships.

### 2.1. GVAR model specifications

The primary difference between GVAR and ordinary VAR models is the fact that foreign variables created as a weighted averages are included in the GVAR model. Simply put, GVAR model is an augmented VAR model (VARX) which include the domestic variables and their foreign counterpart (created as a weighted averages of the trade relations among the countries). Following the work of Dees et al. (2007) version the model can be specified as follows:

$$\chi_{it} = \theta_{i0} + \phi_{i1t} + \eta_i \chi_{i,t-1} + \Omega_{i0} \chi_{it}^* + \Omega_{i1} \chi_{i,t-1}^* + \varepsilon_{it} \quad \text{for } i = 0, 1, \dots, N; t = 1, 2, \dots, T \quad (1)$$

where  $\eta_i$  is a  $k_i \times k_i$  matrix of lagged dependent variables  $\chi_{i,t-1}$ ,  $\Omega_{i0}$  and  $\Omega_{i1}$  are  $k_i \times ki^*$  matrices of coefficient of foreign specific variables  $\chi_{it}^*$  and  $\chi_{i,t-1}^*$  (contemporaneous and lagged values)<sup>3</sup>, and  $\varepsilon_{it}$  is a  $k_i \times 1$  vector of idiosyncratic shocks and is assumed to be serially uncorrelated with zero mean and nonsingular covariance matrix  $\varepsilon_{it} \sim iid(0, \Sigma_{ii})$ , while  $\theta_{i0}$  and  $\phi_{i1t}$  are the coefficient of deterministics; intercept and trend, respectively. More detailed of the GVAR specification is shown at the Appendix A.

### 3. Data descriptions

The data used in estimation include quarterly variables (1979Q2–2013Q1) of real output, price levels or rate of inflation ( $p_{it} - p_{i,t-1}$ ), real equity prices, real exchange rates and short-term interest rate obtainable in GVAR database of Smith and Galesi (2014). Although the sample countries in the database is 33 (accounting for over 90% of the global output), the analysis here focussed on the eight (8) East Asian economies (ASEAN5+3) including: China, Japan, South Korea, Malaysia, Singapore, Thailand, Indonesia, and Philippines. Furthermore, unlike the Dees et al. (2007), here Euro Area is not aggregated as a single economy but rather treated in their respective individual units in the model. This in line with Bussière, Chudik, and Sestieri (2009), is to enable adequate analysis on the pre-Euro

periods. The variables in the model are selected for the fact that they represent available macroeconomic variables and constitutes important channel through which goods and financial markets are related. However, other macroeconomic variables such as the long-run interest rate whose data are not available for most of the focus countries, are excluded from the analysis.

In addition, the cross country linkages in GVAR modeling is accounted for by a weight matrix created from trade or financial flows among countries. In this study, trade flow data inbuilt Smith and Galesi (2014) is used as a weight matrix in the model. Fixed weight is selected for the construction of country-specific foreign variables and the solution of the GVAR model. The weight is computed from the direction of trade statistics. This is for the fact that unlike the capital flows, trade statistics is readily available and can relatively explain cross-border output and exchange linkages. More also this same scarcity of data on capital flows hindered the use of capital flow matrix for robust check of the estimated GVAR model. However, the fact that postestimation test of model fitness, stability test and test on the underlying assumption are carried out, may be appealing.

#### 4. Empirical results

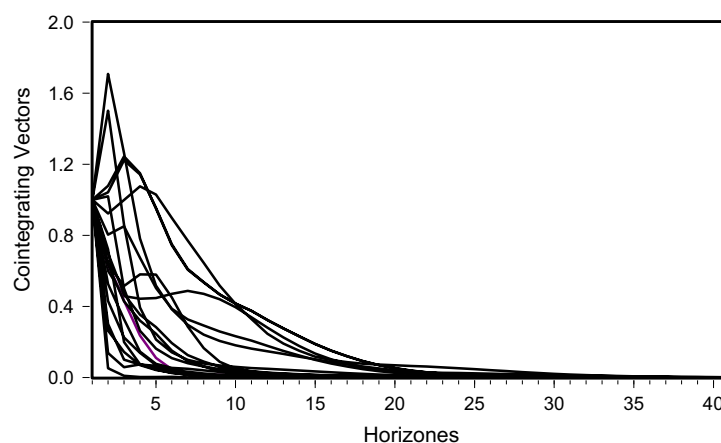
At the beginning, GVAR model stability and fitness tests are conducted alongside the model underlying assumptions. This according to Dees et al. (2007) is essential in making inferences from the estimated GVAR result. Importantly, three features are observed; the eigenvalues, the model persistence profile and the graphs of the generalized impulse responses. On the other hand, the weak exogeneity test of foreign variables and average pairwise cross-sectional correlation tests are also carried-out.

In a stable GVAR model, we expect to have all eigenvalues to lie within the unit circle with a certain number fallen on the unit circles<sup>4</sup>, the persistence profile to converge to zero within 40 periods and the impulse responses to stabilize at about 40 horizons. The result obtained satisfied these conditions; none of the eigenvalue lie outside the unit circle, the persistence profiles as can be seen in Figure 2 converge to zero within short horizons, conforming to the a priori expectation, and the displayed GIRFs graphs are stable within reasonably few quarters. In addition, the Weighted Symmetric ADF tests (WS) used for the unit root test shows that the series are non-stationary integrated of order one. Similarly, the result for the cointegration also confirmed the presence of long-run relations among the country variables.<sup>5</sup>

##### 4.1. Weak exogeneity test of foreign variables

One of the important assumptions of the GVAR model is the weak exogeneity of the foreign variables ( $x^*$ ) specified in the context of VECMX in the conditional equation of the model. Satisfaction of weak exogeneity assumption of foreign variables in the GVAR model is therefore essential. The Table B1 at Appendix B shows result for the weak exogeneity test at 5% significance level for the focus

**Figure 2. Persistence profile of the effect of system-wide shocks to the cointegrating relations of the GVAR model.**





countries. None of the focus countries (i.e. ASEAN5+3) failed the weak exogeneity test; the test statistics are less than the critical values for all series. However, for the overall result (which will be provided on request), only 10 out of the 165 total number of country variables rejected the null of weak exogeneity of the foreign variables. This is a clear indication that the foreign variables in our model are weakly exogenous, satisfying the underlying assumption of the GVAR model. In the case of US, evidence of weak exogeneity in the equity prices the interest rate is not found. Thus, following Dees et al. (2007) and Cesa-Bianchi, Pesaran, Rebucci, and Xu (2012) the two foreign variables are excluded in the US model. As a big economy and the *numeri* country in the model, allowing variables that does not satisfy weak exogeneity assumption would affect the result.

#### 4.2. Average pairwise cross-section correlation

Among the important assumptions of GVAR modeling also the fact that the idiosyncratic shocks of country models should be cross-sectionally weakly correlated in such a way that  $\text{Cov}(x_{it}^*, u_{it}) \rightarrow 0$ , with  $N \rightarrow \infty$ . As established in Dees et al. (2007), the specification of country-specific foreign variables in GVAR approach appeared effective in reducing cross-sectional correlation among individual country errors in the model, and thus helps in dealing with the problems of common factor interdependence. The Average pairwise cross-section correlation (APCC) test is used to validate such claim by observing the level and first difference of the endogenous variables in the model. The procedure compares average pairwise correlations for the estimated residuals from VAR and VARX models<sup>6</sup>. It is then observed if residual from the VARX model have relatively very lower correlation values than the ordinary VAR model. In that case, GVAR model is said to have minimized the problem of cross-sectional dependence among variables across countries. Table B2 at Appendix B provides result for the average pair-wise cross-section correlation. As can be seen, the respective APCC of VARX residuals are very negligible and lower than the corresponding VAR residuals. This indicates absence of significant cross-sectional dependence in the estimated model. For example, the APCC of VAR errors in China is 0.071. This is large if compared to the corresponding value for VARX errors (−0.066). The test of weak exogeneity assumption earlier done, partly confirmed the existence of weakly correlated idiosyncratic shocks.

#### 4.3. Contemporaneous effects of foreign variables on domestic counterparts

Having identified the properties of the GVAR model with regard to its stability and some underlying assumptions, the estimates of the contemporaneous effects of foreign variables on their domestic counterparts is employed to identify the level of contemporaneous inter-linkages among the variables across countries. The estimates are obtained from the cointegrating VECMX<sup>7</sup> models and are interpreted as impact elasticity. The magnitudes of this elasticity show the extent of contemporaneous inter-linkages among country variables. Robust t-ratios, computed using White's Heteroscedasticity-Consistent variance estimators are used for decisions on the significance.

Table 1 presents the estimates of the contemporaneous effects of foreign variables on their domestic counterparts. The equity market and real output appeared to have higher correlations in their respective domestic and foreign variables, signifying higher international linkages through these channels. While for output; 7 out of the 9 focus countries are significant, the equity prices show significance in all the 6 available countries. Output in China responds to global impact in a given quarter to a tune of 0.56% in every 1% change in the global productivity. This shows that the country is highly linked with the rest of the world, the fact which may not be unconnected with the giant role the country is playing in the global trade. In the like manner, the effects of foreign influence on Japan real output is also high at about 0.67% to every 1% change in a global output in a given quarter. Similarly, 1% positive change to a foreign output results to increase in South Korea real output by 0.52%, Thailand real output by 0.80%, Singapore by 1.26%, and Malaysia by 1.42% in a given quarter. Malaysia and Singapore appeared to have been over-reacted to the change in the external output. This could mean high tendency of output contagion in these countries.

On the part of inflation, only South Korea and Malaysia appeared to have significant contemporaneous effect of foreign variables on their domestic counterpart in the group. The result for South Korea

**Table 1. Contemporaneous effects of foreign variables on domestic counterparts**

	Real GDP	Inflation rate	Real equity prices	Short-term interest
China	0.56* [2.96]	0.07 [0.03]	–	0.01 [0.37]
Indonesia	0.30 [1.24]	0.58 [1.26]	–	0.06 [0.25]
Japan	0.67* [3.48]	–0.11 [–1.39]	0.71* [7.07]	–0.03 [–0.15]
Korea South	0.52* [2.38]	0.38* [2.58]	0.80* [4.11]	–0.14* [–2.16]
Malaysia	1.42* [5.21]	0.77* [5.33]	1.23* [7.05]	0.01 [0.08]
Philippines	0.07 [0.24]	–0.24 [–0.77]	1.04* [7.05]	0.62 [1.78]
Singapore	1.26* [5.48]	0.19 [1.47]	1.22* [10.91]	0.21* [1.91]
Thailand	0.80* [2.05]	0.46 [1.82]	1.01* [7.82]	0.23 [1.33]
USA	0.53* [4.78]	0.09 [1.36]	–	–

Note: Figures in brackets are White's adjusted t-ratio.

\*Indicate significance.

shows that 1% change in foreign inflation in a given quarter would trigger 0.77% increase in Korea's general price level and 0.38% for that of Malaysia. The result points to the fact that inflation could be imported into these countries, especially when it emanates from an important trading partner.

Interestingly, except for China and Indonesia whose data on equity prices not available; the remaining estimated focus countries have all shown significant contemporaneous effects of foreign variables with their domestic counterpart and except for Japan and South Korea, all have over-reacted to these contemporaneous changes. This explained the increasing importance of Asian equity markets in the global capital market. It is an indication that these countries are highly integrated in the global equity markets. It could also explain the increasing interest on the countries' stocks as portfolios to other investors or as complement to the outside stock markets. Concurrently, these contemporaneous effects could as well mean excessive contagion effects to these countries, implying that shocks emanating from equity prices abroad could easily be contagious to the domestic stock markets within a short period of time and with higher magnitude. For the short term interest rate, only Korea and to some extent Singapore show significant contemporaneous correlation with the rest of the world.

In general, the result shows that equity markets and the real output are the prominent channels through which sudden external crises are transmitted to ASEAN5+3 countries. While the output channel explained the expanding trade relation among these countries, the equity market channel signifies the increasing integration with the global developed stock markets. All in all the result show evidence of contemporaneous linkages in equity and output and less in short-term interest and inflation in the ASEAN5+3 countries.

#### **4.4. Result from the generalized impulse response functions**

Generalized Impulse response function is a dynamic analysis which captures the time profile of the effects of variable-specific shocks on all the variables in the model. While the contemporaneous



correlation estimated above observed the instantaneous linkages across the countries, it is, nevertheless limited in identifying the inter-linkages over a time horizon and also not adequate in identifying the specific cross-variables shocks. On this note, GIRF is used to verify which among the country variables explained more, the link between the domestic variables and its foreign counterpart so identified contemporaneously? Does the effect lapse within the identified quarter or extend over longer periods? However, while the cross-variables shock transmission could be numerous, this study relies on the within-variable but cross-country shocks.<sup>8</sup>

The results for the generalized impulse response functions for the individual variables (real output, real equity prices, short-term interest rate, inflation, and real exchange rate) are presented in Figures 3–7 (graphs). It is important to note that due to space constraint; only graphs that are significant are presented here. Any country or variable not showed in the figures means that it is not significant.

**Figure 3. Graphs of one standard error negative shock to RGDP and their effects on ASEAN+3.**

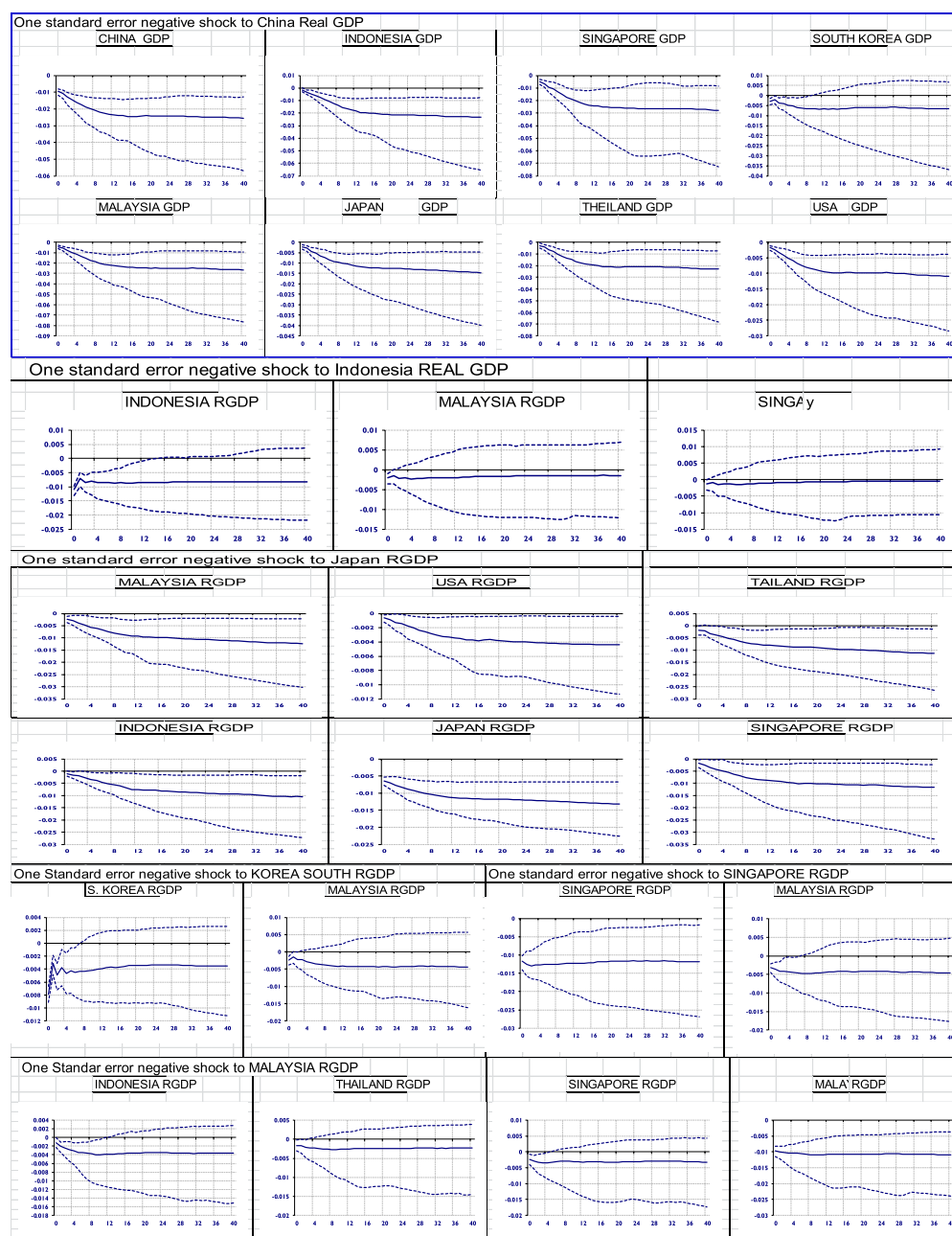
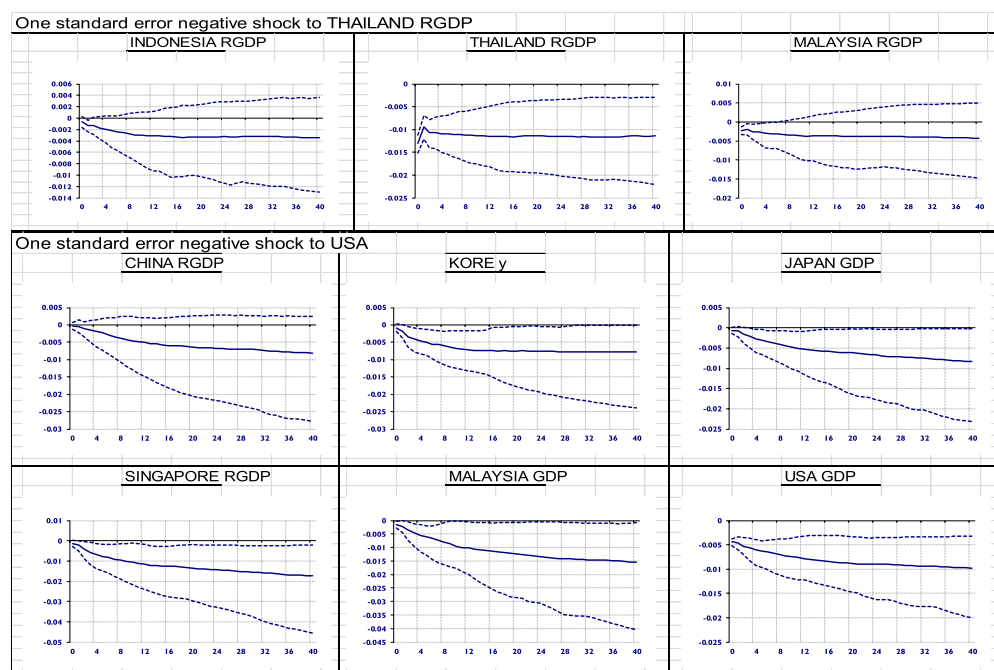


Figure 3. (Continued).



#### 4.4.1. Result of the GIRF on one standard error negative shock to Real Output (RGDP)

Figure 3 presents the results for the effect of one standard error negative shock to real output (RGDP) on the nine focus countries. It shows the effect of shock to RGDP in each country on the remaining countries. From the graph, it can be seen that a one standard error negative shock to real output in China would negatively affect real output in all the countries under study with the exception of Philippines. Among the affected countries only South Korea whose effect is in the short-run, the effects on the remaining countries are persistent; both in the short-run and long-run. This is not surprising, considering China's growing trade linkages with these countries and its importance in the regional output growth. For Indonesia, however, negative shock to its real-output can only affect real-output in Malaysia and Singapore marginally at their first quarters. This finding partly supports the contemporaneous result which shows insignificant international linkage in Indonesian real output. On the other hand, one standard error negative shock to Japan real-output would lead to significant negative effects on the real output of USA and Malaysia in both its short and long runs, while Thailand, Indonesia, and Singapore in the long-run. This also indicates the importance of Japan next to China in output linkages in the region. Similarly, while a negative shock to South Korea can only affect Malaysia in the short-run, a negative 1% shock to Malaysia real output, affects outputs in Indonesia, Singapore, and Thailand. Although the effect did not persist, it dies quickly at Q12, Q4, and Q4, respectively; it signifies the important trading linkage Malaysia has with its immediate neighbors. Similar shock to Philippines's real-output does not have significant effect on any of the countries. On the other hand, negative shock to Singapore shows negatives effect on Malaysia alone portraying high economic relation between the two countries. For Thailand, negative shock to its real-output affects Indonesia and Malaysia slightly. In the same line, USA shock appeared to affect Korea, Malaysia, Singapore, and Japan. It is therefore important to note that while China's real-output shock affects USA, the opposite is not the case.

#### 4.4.2. Result of the GIRF on one standard error negative shock to equity prices (EQ)

The GIRF of one standard error negative shock to equity prices is presented in Figure 4. It can be seen that one standard<sup>9</sup> error negative shock to Japan's equity prices (equivalent to 5% in this case) would have negative effect on all the six countries in the region (whose data on equity prices are available). Although, the identified effect is in the short-run (the effect dies at quarters not greater than four for all the affected countries). This shows the importance linkages Japan's equity market has with other stock markets in the region. For Korea, a 7% negative shock to equity prices impacts negatively on

**Figure 4. Graphs of one standard error negative shock to real equity prices and their effects on ASEAN+3.**

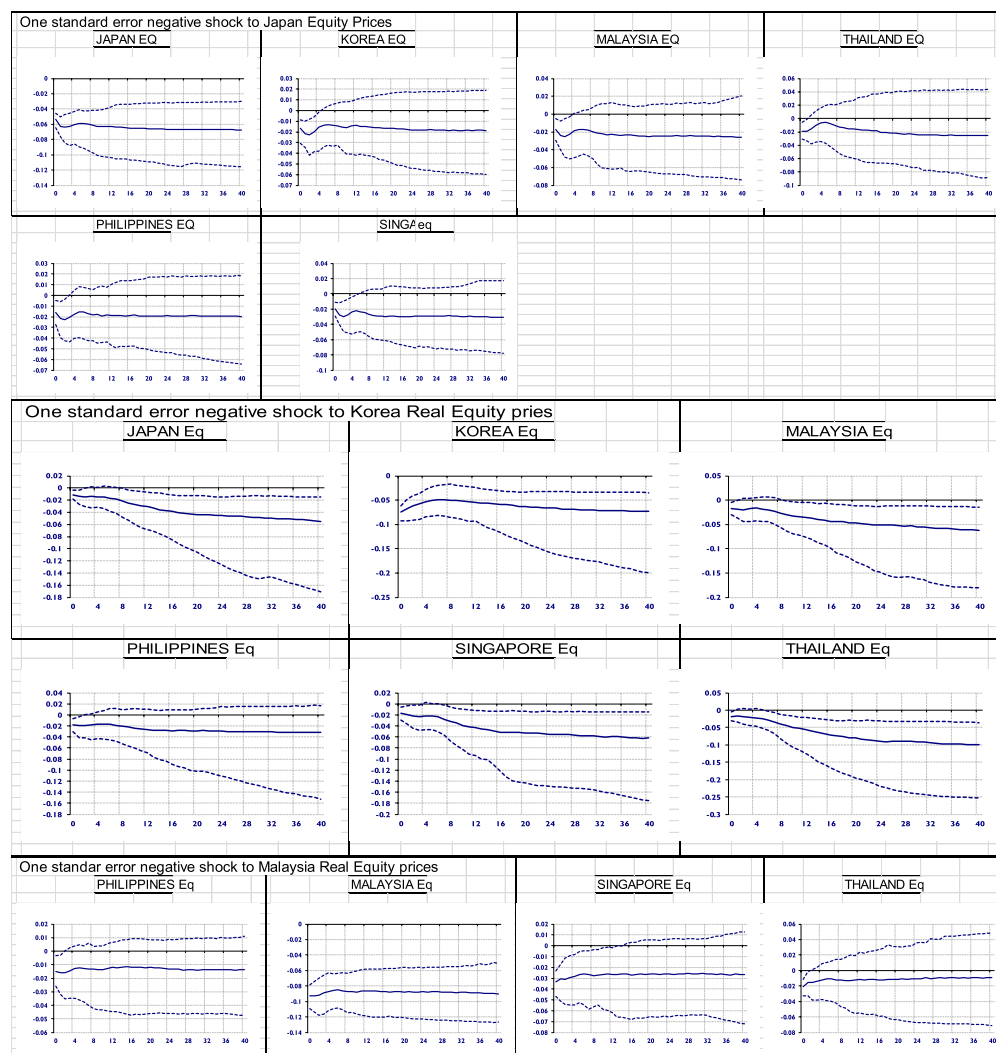
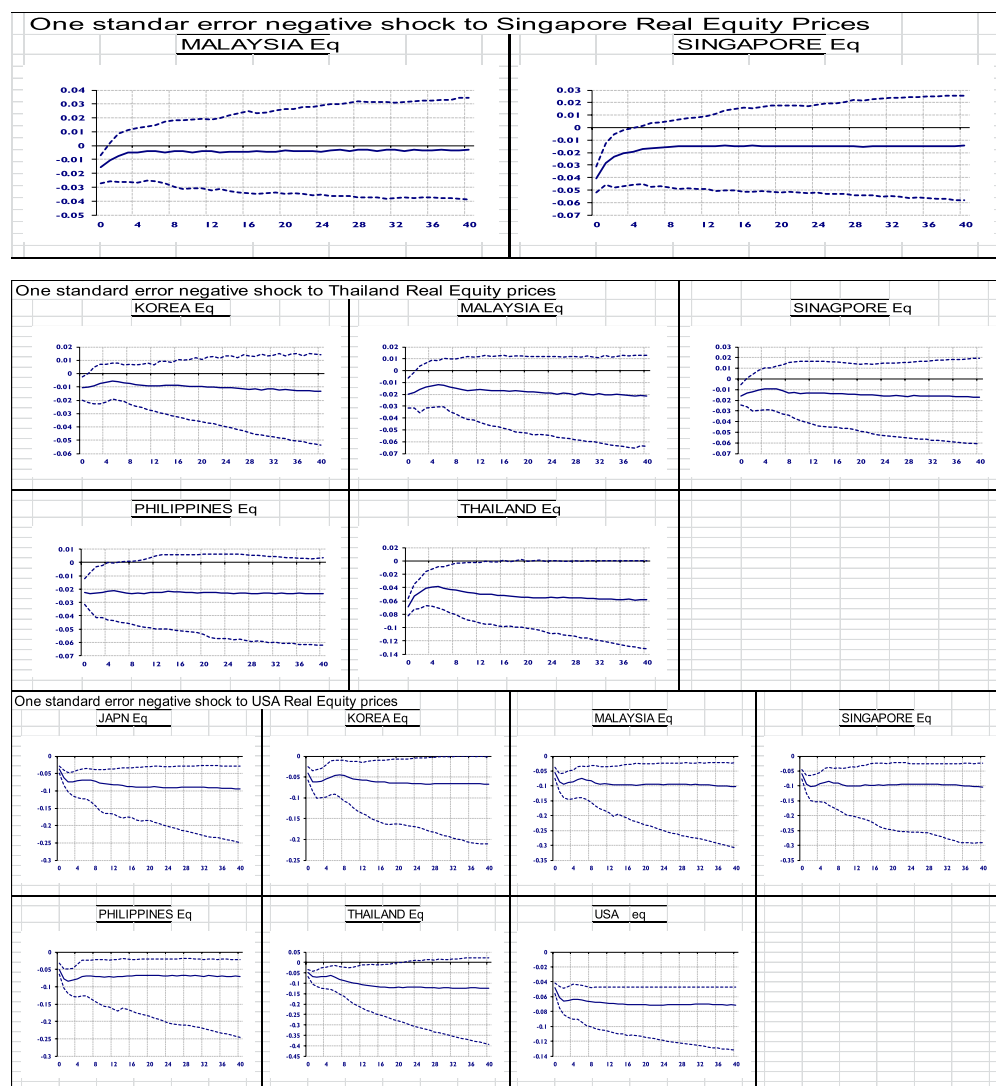


Figure 4. (Continued).



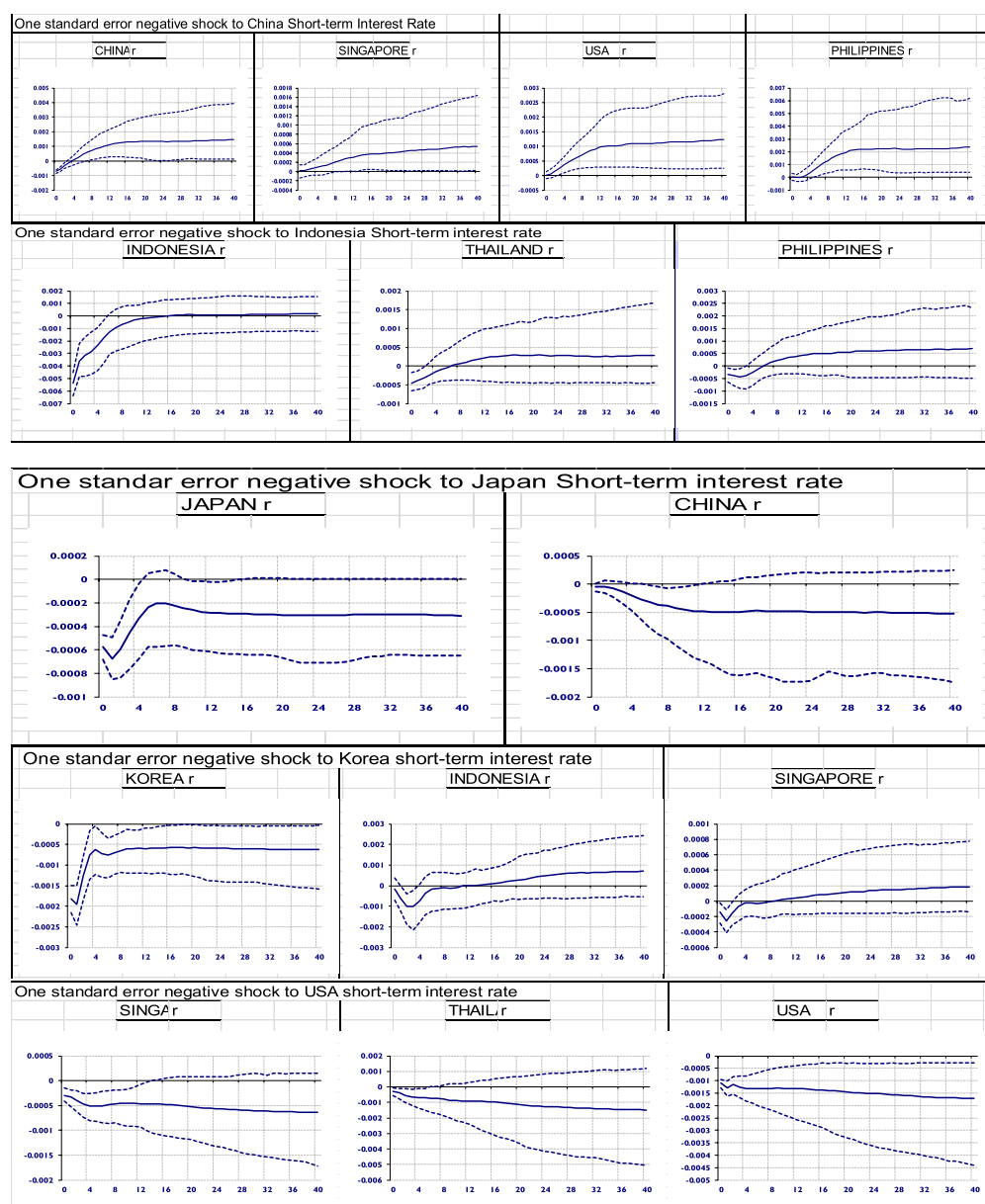
Philippines equity prices to the tune of 2% in the short-run and to Japan, Malaysia, Singapore, and Thailand equity prices in the long-run. A negative shock to Malaysia's equity prices results to negative effects on equity prices of Philippines, Singapore, and Thailand in the short-run. Shock to Singapore equity prices only affects Malaysia's equity prices in the short-run. Similarly, a -7% shock to Thailand equity prices results to -1% (-1.2% on average) respond in Korea, -2% in Malaysia, Singapore, and Philippines all in the short-run, with the effects dying quickly after third quarters.

Interestingly, a shock to USA equity prices appeared different. It affects stock prices in all the study countries with higher magnitudes and over longer time periods. One standard error negative shock to USA equivalently impacted on Malaysia and Singapore equity prices in the short-run and to Japan, Korea, Thailand, and Philippines in the long-run. However, on the contrary, none of the study countries show significant influence on USA equity prices. This is a clear indication that USA stock market plays an important role in the determination of equity prices in ASEAN5+3 markets.

#### 4.4.3. Result of the GIRF on one standard error negative shock to short-term interest rate ( $r$ )

Unlike the equity prices and real output, shocks to short-term interest rate have fewer significant spillover effects across the countries as show in Figure 5. This supported the findings in the

**Figure 5. Graphs of effects of one standard error negative shock to short-term interest rate on ASEAN+3.**



contemporaneous correlation where only Korea and Singapore show contemporaneous linkages, with the outside world in their short-term interest rate. The GIRF result shows that, while Shock to China's interest rate affects Singapore, Philippines, and USA in the long-run, the shock to Indonesia short-term interest has short-run significant influence on Philippines, and Thailand. Negative shock to Japan, on the other hand affects China and Japan's interest rate marginally in the short-run. While negative shock to Korea's short-term interest rate affects Singapore and Indonesia in the short-run, shock to Malaysia, Philippines, and Singapore short-term interest rates does not have significant effects on any of the countries under study. Lastly shock to US short-term interest rate appeared to have significant effect only on Singapore and Thailand in the short-run. The weaker impact of shock to short-term interest rate may be related to different respond to interest policy by the constituting monetary authorities in these countries. This may not be much surprising as short-term interest rate is bank-based that are localized in these countries.

#### 4.4.4. Result of the GIRF on one standard error negative shock to exchange rate (EXC)

Figure 6 show the results of shock to real exchange rates for the eight focus countries excluding US; being the reference country. From the table, it can be seen that exchange rate highly transmit cross-border shocks within the ASEAN5. Negative shock to currency market in China would slightly affect respective currency markets of Korea, Indonesia, and Malaysia with the effects disappearing within few quarters. This finding shows that despite China's significant linkages in real output, its currency market is not highly linked with currencies in the region. This could pose a serious question, especially with regard to optimum currency area decisions in the region. For Indonesia, negative shock could affect exchange rates in Malaysia persistently, Singapore, and Thailand in the long-run and Japan slightly in the short-run. For Japan, shocks to exchange rate only affect Singapore exchange rate and in the short-run. Surprisingly however, shock to Korea's exchange rate has an effects on

**Figure 6. Graphs of effects of one standard error negative shock to exchange rate on ASEAN+3.**

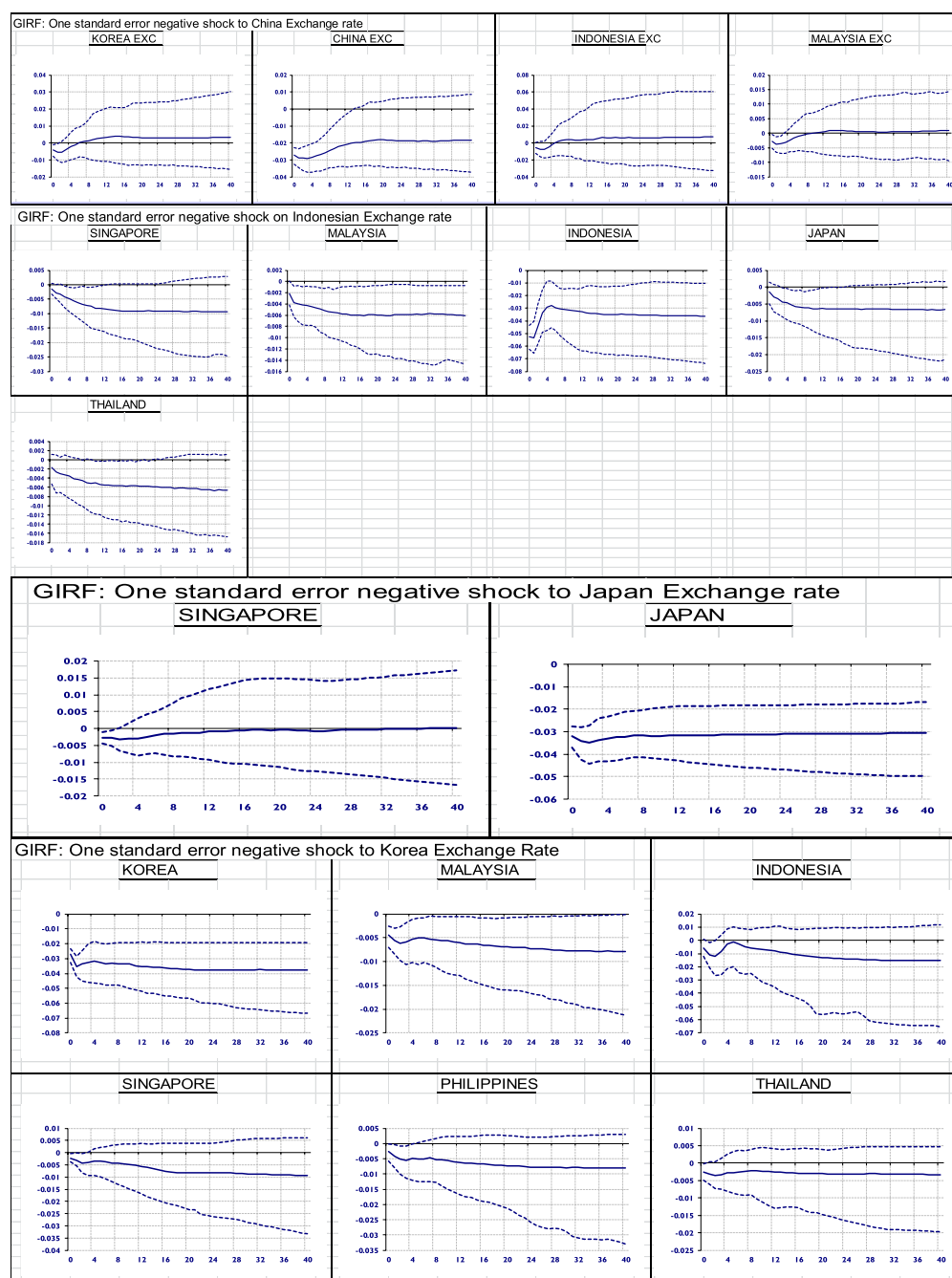
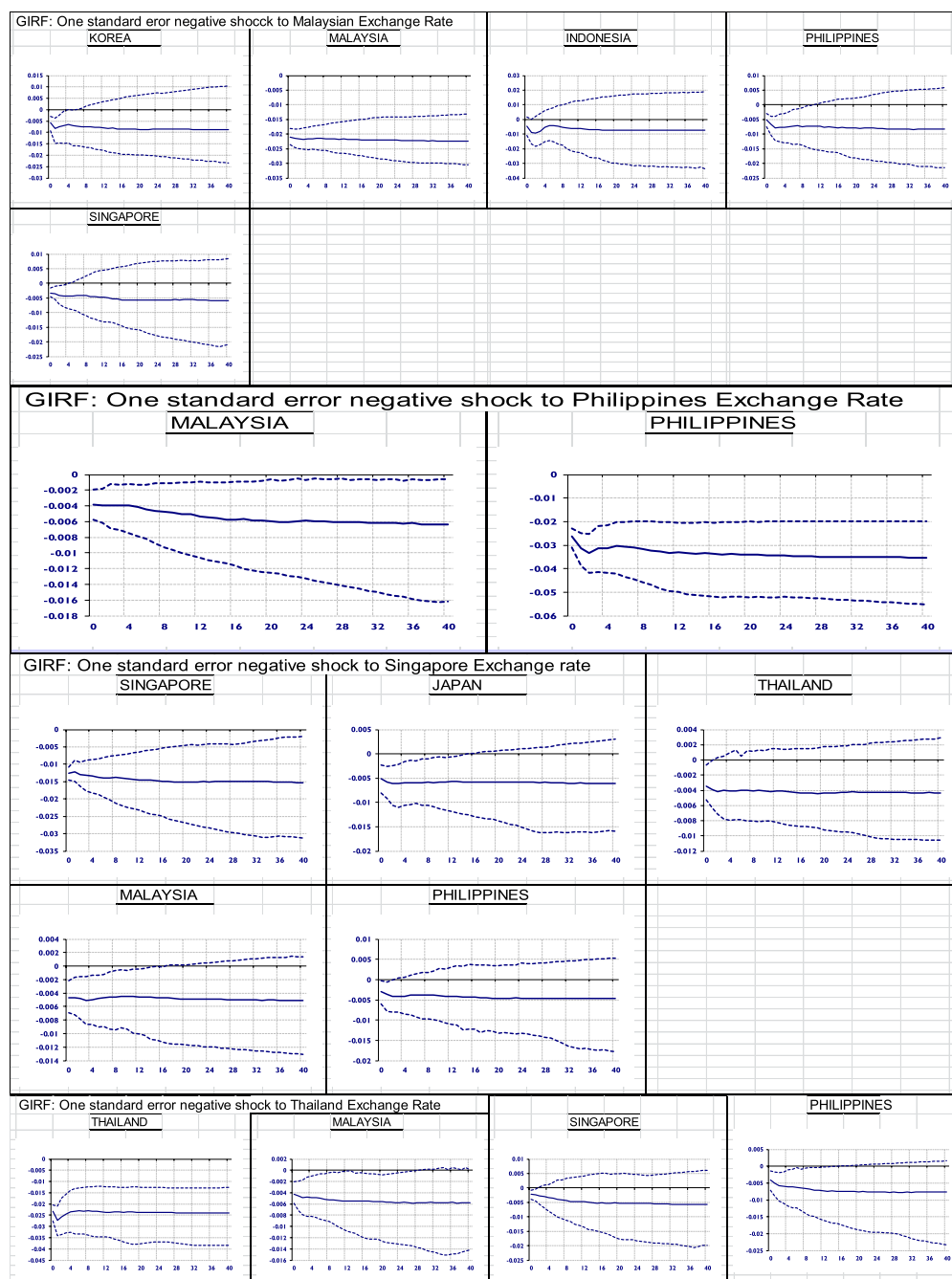


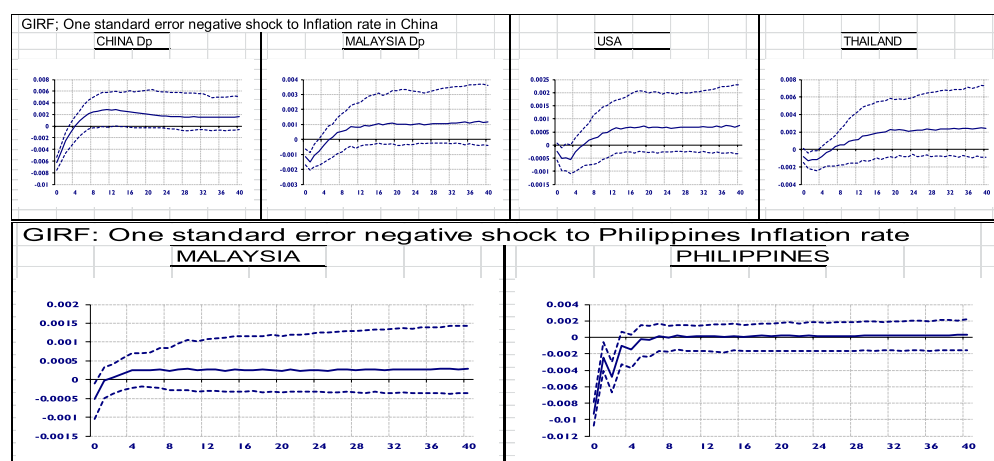


Figure 6. (Continued).



Indonesia, Philippines, Singapore, and Thailand exchange rates in the short while affects Malaysia both in the short-run and long-run. This explains a significant currency market linkage between Korea and countries in the region. On the other hand, while one standard error negative shock to Malaysia's exchange rate affect exchange rates in Korea; Philippines, and Singapore over few horizons, similar shock to Philippines affect only Malaysia persistently over longer time period. Shock to Singapore has significant effect marginally on Thailand and Philippines and substantially on Japan and Malaysia. Similarly shock to Thailand exchange rate affects Singapore and Philippines exchange markets in the short-run and on Malaysia over longer time horizon. In general, the fact that ASEAN5 shows significant exchange shock transmissions within them, revealed that their currency are still linked together nearly as they were pre-1997 crisis period. As such tendency for excessive spillovers

**Figure 7. Graphs of effects of one standard error negative shock to inflation rate on ASEAN+3.**



in the event of currency crisis in the region cannot be rule out. It also revealed a weak China's currency integration with the remaining countries in the region.

#### 4.4.5. Result of the GIRF on one standard error negative shock to Inflation rate ( $\Delta P$ )

Unlike other macroeconomic variables observed above, shock to countries price levels does not show much significant effects across borders thus underscoring the cases of imported inflation. As can be seen in Figure 7, one negative sock to inflation rate in China appeared to affect the price levels in Malaysia and Thailand negatively over short time period. It can also affect prices in US marginally. More also shock to Philippines inflation could affect Malaysia's prices in the short-run.

### 5. Summary and concluding remarks

The growing interdependencies among East Asian countries mean that there is concern not only on the way their macroeconomic variables are linked across borders, but also on the way shocks are transmitted as a consequence. Shock transmission and business-cycle synchronization are among the important criteria for optimum currency area. This research investigates the effects of macroeconomic linkages on shock transmission in the global economy with particular reference to ASEAN5+3. The global dimension of the analysis is captured by the GVAR model. Two important analyses are undertaken: the contemporaneous correlation to measure the level of cross-country linkages with the outside world and the dynamic analysis of the generalized impulse response functions which is used to identify the channel of transmissions of shocks across borders. In both the two, the analysis limits to within-variable cross country study.<sup>10</sup>

The contemporaneous results show significance in equity prices and output for most of the study countries, suggesting that the ASEAN5+3 are more linked to global economy through these channels, and thus could be more prone to shock transmission through the same way. This is considered a reflection of the increasing trade relations and developments in the equity markets. The dynamic analysis on the other hand, identified four important findings; (i) highest shock transmission to ASEAN5+3 countries comes from equity prices, exchange rates and real output and low shocks from short-term interest rates and inflation rates. (ii) On the equity prices, shock to US has the highest effect on the ASEAN5+3. The finding is similar to the result in Hsiao et al. (2003) and Ozdemir et al. (2009). A unidirectional shock transmission from US is an indication that the ASEAN5+3 equities are more correlated to US equity markets and only marginally with one another. By implication this means that disturbances in the US equity markets could be highly contagious to capital markets in ASEAN5+3, suggesting a strategic behavior in policy response to capital investments in the region, especially through boosting indigenous participation in the market and encouraging diversification to minimize the apparent high risk of international shock transmissions. (iii) On the real output, shock to China's real output transmits highest shock to ASEAN5+3. Contrary to equity market, result

from the real output shock (representing the real sectors) shows that China is more significant than US in shock transmission portraying the growing significance of China's real sector in the region. (iv) Result on the exchange rates shows that within regional shocks transmission is highest (within the ASEAN5) similar to the period of financial crisis in 1997/98.

Furthermore, unlike equity prices (capital market), shocks to short-term interest rate and inflation rate (money markets) have fewer significant spillover effects, signifying low linkages in the markets. The weaker international linkages in money market than capital market may be a reflection of the varied monetary policy implementations in the region.

Summarily, the findings show mixed results for optimum currency area. The dominance of China in the real sector implies the possibility of business cycle synchronization in the region especially if the downturn emanate from China. On the other hand, the insignificance currency shock transmission between China and the rest of the ASEAN5+3 countries, disqualify an important criterion for optimum currency area. Thus, in addition to China's advantage in real-sector linkages, its currency market need to be more developed and liberalized to assume leadership in the region. More still, the dominance of US in capital market and second to China in the real sector explained the strategic importance of US in the global economy.

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#### Notes

1. Most of the developing Asian economies liberalized their exchange rates and interest rate decades back; Japan deregulate its interest rate in 1979, Malaysia had its own in 1978, Singapore 1975, Hong Kong 1973, while Indonesia, Philippines in early 1980s, Taiwan, Thailand and South Korea abolished their interest rate ceiling in the mid-1980s. During the 1980s still, capital accounts were liberalized, restrictions on foreign asset holding by residents were relaxed; private sectors were allowed to have external finance.
2. ASEAN5+3 are five ASEAN countries of Indonesia, Malaysia, Philippines, Singapore and Thailand referred to ASEAN5, plus China, Japan and South Korea.
3. The lagged length are selected using selection criteria: AIC or SBC.
4. In GVAR model the number of eigenvalues required to fall on the unit circle will be equal to the difference between the number of cointegration relations and the total number on the endogenous variables in the model.

5. Due to the space constraint, result for Unit root, cointegration and the stability test will be provided by the author on request.
6. VAR is the ordinary unrestricted vector autoregressive model including only the domestic variables and global variables (oil prices), whereas the VARX is the augmented VAR including domestic variables, foreign variables and the global variable (oil prices). The VARX residuals are estimated inside the GVAR model while the VAR residuals are computed outside the model; in this case E-view.
7. VECMX is the augmented vector error correction model including foreign variables, domestic variables and oil prices.
8. Within-variable shock means effect of shock to a variable on the same variable in other country, while cross-variable means effect of shock to one variable on a different variable in another country.
9. The intuition behind using of one standard error shocks as against one percent shock is the fact that the former compare shocks probabilistically. Unlike in percentage, the use of standard errors on different category of shocks will be comparable in terms of likelihood.
10. By within-variable, we follow the contemporaneous correlation setup, we restricted on the impact of one variable of one country on the same variable of another country.

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## Appendix A

### GVAR derivation

From Equation (1) in section 2,  $x_{it}^*$  is a matrix of foreign variables including in our case: real output ( $y_{it}$ ), equity prices ( $eq_{it}$ ), exchange rate ( $ex_{it}$ ), interest rate ( $r_{it}$ ) and inflation rate ( $\pi_{it}$ ). It is obtained in the form:

$$x_{it}^* = \sum_{k=0}^N w_{ik}^* x_{kt} \quad (A1)$$

where  $x_{it}^*$  could be  $y_{it}^*$ ,  $eq_{it}^*$ ,  $ex_{it}^*$ ,  $r_{it}^*$ , or  $\pi_{it}^*$

For the avoidance of the effects of over-parameterization, the domestic and foreign variables are stacked in each country-specific model and solve in a system. Thus, reduces the number of unknown parameters of the VAR equations. The stacked variables are defined in a vector:

$$H_{it} = \begin{pmatrix} X_{it} \\ x_{it}^* \end{pmatrix} \quad (A2)$$

Equation (1) can therefore be rewritten as:

$$A_i H_{it} = \theta_{i0} + \phi_{i1t} + B_i H_{i,t-1} + \varepsilon_{it} \quad (A3)$$

where  $A_i = (I_{k_i}, -\Omega_{i0})$  and  $B_i = (\eta_i, \Omega_{i1})$ . Combining all the country-specific variables together (both the endogenous and exogenous) in a  $k_i \times 1$  global vector yield:

$$H_{it} = w_i x_t \quad i = 0, 1, 2, \dots, N \quad (A4)$$

where  $x_t = (x'_{0t}, x'_{1t}, x'_{2t}, \dots, x'_{Nt})$  represent all the stacked country specific variables and  $w_i$  is a  $(k_i + k_i^*) \times k$  link matrix of country-specific weights. Substituting Equation (A4) in to Equation (A3) will therefore yield:

$$A_i w_i x_t = \theta_{i0} + \phi_{i1t} + B_i w_i x_{t-1} + \varepsilon_{it} \quad (A5)$$

where  $A_i w_i$  and  $B_i w_i$  are both  $k_i + k$ -dimensional matrices. Stacking Equation (A5) will therefore yield:

$$Gx_t = \theta_0 + \phi_{1t} + Rx_{t-1} + \varepsilon_t, \quad (A6)$$

$$\text{where } \theta_0 = \begin{pmatrix} \theta_{00} \\ \theta_{10} \\ \vdots \\ \theta_{N0} \end{pmatrix}, \phi_{1t} = \begin{pmatrix} \phi_{01} \\ \phi_{11} \\ \vdots \\ \phi_{N1} \end{pmatrix}, \varepsilon_t = \begin{pmatrix} \varepsilon_{0t} \\ \varepsilon_{1t} \\ \vdots \\ \varepsilon_{Nt} \end{pmatrix}, G = \begin{pmatrix} A_0 W_0 \\ A_1 W_1 \\ \vdots \\ A_N W_N \end{pmatrix} \text{ and } R = \begin{pmatrix} B_0 W_0 \\ B_1 W_1 \\ \vdots \\ B_N W_N \end{pmatrix}$$

Since  $G$  is a  $k_i + k$ -dimensional matrix, it is a non-singular matrix of full rank that depends on trade weights and parameter estimates. Finally, an individual parameter estimate of a GVAR model will be obtained by deriving for  $x_t$  in the system, thus:

$$x_t = G^{-1}\theta_0 + G^{-1}\phi_{1t} + G^{-1}Rx_{t-1} + G^{-1}\varepsilon_t, \quad (A7)$$

As such Equation (8) can be used for variety of purposes by solving it recursively. For example to obtain a future value of  $x_t$  the Equation is solved recursively forward.

### GVAR Error-correction form

The error correction model (ECM) of the first difference GVAR model of Equation (1) above can be drive as follows:

From Equation (1) since  $x_{it} = \Delta x_{it} - x_{it-1}$  we have

$$\Delta x_{it} = \theta_{i0} + \phi_{i1t} + (I_{k_i} - \eta_i) x_{i,t-1} + (\Omega_{i0} + \Omega_{i1}) x_{i,t-1}^* + \Omega_{i0} \Delta x_{it}^* + \varepsilon_{it}, \quad i = 0, 1, \dots, N, \quad (A8)$$

The above equation is a general error correction form. However, we are interested in the ECM model which brings both domestic and foreign variables in a stacked form. To obtain this we use the stacked representation  $H_{it} = (x'_{it}, x'^*_{it})$  in Equation (A4) and the respective coefficients ( $A_i$  and  $B_i$ ) earlier defined. Thus, the GVAR error correction model (VECMX) will be in the form:

$$\Delta x_{it} = \theta_{i0} + \phi_{i1t} - (A_i - B_i) H_{i,t-1} + \Omega_{i0} \Delta x_{it}^* + \varepsilon_{it}, \quad (A9)$$

Therefore,  $A_i - B_i$  is the error correction term for country or region  $i$  and of the matrix form  $k_i \times (k_i + k_i^*)$  represented as:

$$\Pi_i = A_i - B_i \quad (A10)$$

where  $\Pi_i$  is the cointegration matrix whose rank order, determines the number of long run relations among the country-specific domestic and foreign variables  $x_{it}$  and  $x_{it}^*$ .

## Appendix B

**Table B1. F-statistics for weak exogeneity test of country-specific foreign variables and oil prices**

Country	F-test	Critical values	Real GDP	Inflation	Equity prices	Interest rate	Oil prices
China	$F(2,117)$	3.07	0.16	0.33	0.18	2.15	1.40
Indonesia	$F(3,116)$	2.68	0.47	1.06	1.23	1.50	0.79
Japan	$F(2,115)$	3.08	1.77	2.29	1.10	0.03	0.63
Korea	$F(3,114)$	2.68	0.32	0.24	2.35	0.55	1.49
Malaysia	$F(1,117)$	3.92	2.10	0.04	1.02	1.98	3.21
Philippines	$F(2,116)$	3.07	0.08	1.55	0.95	1.92	2.75
Singapore	$F(2,116)$	3.07	2.97	0.39	1.91	1.41	2.18
Thailand	$F(2,116)$	3.07	0.65	0.69	0.20	0.02	0.01
USA	$F(2,119)$	3.07	0.76	2.35	-	-	-



**Table B2. Average pairwise cross-section correlations; variables and residuals**

	Real output				Inflation			
	Levels	First Differ.	VAR Resi.	VARX Resid.	Levels	First Differ.	VAR Resi.	VARX Resid.
China	0.973	0.075	0.071	−0.066	0.076	0.081	0.091	−0.018
Indonesia	0.963	0.104	0.066	−0.012	0.015	0.044	0.063	0.025
Japan	0.904	0.196	0.108	−0.036	0.461	0.104	0.111	0.036
Korea	0.961	0.126	0.056	0.006	0.397	0.068	0.097	0.017
Malaysia	0.968	0.217	0.153	−0.008	0.309	0.122	0.138	0.017
Philippines	0.946	0.072	0.030	0.011	0.242	0.040	0.061	0.019
Singapore	0.971	0.205	0.110	−0.020	0.313	0.052	0.069	0.009
Thailand	0.950	0.185	0.112	0.011	0.338	0.076	0.134	−0.003
USA	0.969	0.255	0.117	−0.053	0.466	0.209	0.230	0.041
	Short-term interest				Equity prices			
	Levels	First Differ.	VAR Resi.	VARX Resid.	Levels	First Differ.	VAR Resi.	VARX Resid.
China	0.525	0.074	0.012	0.017	0.412	0.454	–	−0.073
Indonesia	0.169	0.072	0.064	0.047	0.707	0.346	–	−0.027
Japan	0.651	0.074	0.045	0.023	0.580	0.362	0.337	0.007
Korea	0.616	0.084	0.052	0.061	0.717	0.354	0.305	−0.011
Malaysia	0.470	0.086	0.048	0.055	0.727	0.519	0.348	0.002
Philippines	0.601	0.098	0.073	0.027	0.621	0.365	0.279	0.007
Singapore	0.589	0.085	0.061	0.016	0.813	0.559	0.394	−0.009
Thailand	0.612	0.119	0.099	0.042	0.612	0.119	0.349	0.042
USA	0.606	0.111	0.085	0.017	0.606	0.111	0.473	0.017
	Exchange rate							
	Levels	First Differ.	VAR Resi.	VARX Resid.	Levels	First Differ.	VAR Resi.	VARX Resid.
China	0.300	0.086	0.220	0.046				
Indonesia	0.153	0.214	0.188	0.112				
Japan	0.727	0.230	0.182	0.177				
Korea	0.794	0.265	0.232	0.154				
Malaysia	0.694	0.283	0.262	0.188				
Philippines	0.792	0.166	0.179	0.137				
Singapore	0.810	0.408	0.286	0.274				
Thailand	0.787	0.302	0.276	0.219				
USA	–	–	–	–				

Notes: The VAR residuals are obtained from the estimates of the endogenous variables including oil price (excluding the weakly exogenous foreign variables) for the country specific models using the lag specified for the VARX equations. The average pairwise correlations of the VAR residuals are computed outside the GVAR model.



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