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A Global Vector Autoregressive Analysis of
Asian Monetary Integration

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Abstract

This study employs the global vector autoregressive (GVAR) model to empirically investigate the viability of regional monetary arrangements in Asia. Although numerous studies have been conducted on the feasibility of Asian monetary integration/union, whether regional co-movements of real outputs and other macroeconomic variables are driven by external shocks or self-sustaining development in Asia has not yet been rigorously demonstrated. The novelty of this study is to employ the GVAR model, which allows global inter-linkages between domestic and foreign variables, to investigate the generalized impulse responses of Asian economies' real outputs and other macroeconomic variables to global and regional shocks. In marked contrast to previous studies, we found that a regional shock, i.e., China's output and inflation shock, exerted more influence on Asian economies than a global (U.S.) shock. Another regional shock, i.e., a Japanese shock, had a far smaller influence on Asian economies. The relative importance of regional shocks originating from China needs to be considered when establishing a regional monetary arrangement in Asia.

Keywords: Global vector autoregressive (GVAR) model; global shock; regional shock; monetary integration; optimum currency area; Asia

JEL Classification: C32; C53; F15; F33

1. Introduction

The feasibility of forming a regional economic and monetary union in Asia has gained considerable attention over the last several decades against a backdrop of growing intra-regional trade and investment.[1] The 1997–1998 Asian financial crisis heightened calls to establish regional monetary and financial cooperation among regional economies. After the 2008 collapse of Lehman Brothers, Asian currencies substantially and asymmetrically fluctuated. While the Japanese yen appreciated sharply against almost all currencies, the Korean won began to drastically depreciate. Such large and asymmetric exchange rate responses changed export price competitiveness between Asian economies, which may inhibit region-wide steady economic growth.[2] Thus, regional exchange rate stability has been an important policy agenda for the further growth and development of regional economies.

A large number of studies have also analyzed regional exchange rate stability and possible monetary cooperation and arrangements in Asia. These studies typically rely on the theory of optimum currency area (OCA) to investigate whether it makes economic sense for Asian economies to adopt a regional monetary arrangement. The OCA theory suggests several preconditions to forming a currency area, and existing studies have mostly investigated business cycle synchronization and symmetry in fundamental shocks as one of major OCA preconditions.[3] Most studies, such as Bayoumi *et al*. (2000), Zhang *et al*. (2004), Bacha (2008), Allegret *et al.* (2012), and Lee and Koh (2012), employ a vector autoregressive (VAR) model to analyze the degree of symmetry in shocks among Asian economies. However, this approach cannot explain whether growing similarity in real output fluctuations are driven by external shocks or self-sustaining development in Asia.

Chow and Kim (2003) examined the relative importance of global, regional, and country-specific shocks for Asian economies using variance decomposition tests based on a structural VAR analysis. If business cycle co-movements are mainly affected by

[1] Ferrarini (2013) analyzes recent trade network development in Asia. Kwon and Ryou (2015) investigate value-added trade and vertical specialization focusing on Asia.
[2] See, for instance, Sato *et al*. (2013) and Ito and Shimizu (2015) for an analysis of export price competitiveness of Asian economies.
[3] The OCA theory typically suggests the following preconditions: economic openness and trade integration; business cycle synchronization and symmetry of fundamental economic shocks; financial integration; and factor market integration including free labor mobility.

regional shocks, a common monetary policy can be an effective tool for regional economies. In contrast, if country-specific shocks are prevalent in the region, regional economies need to adopt independent monetary policies. If regional output co-movements are driven largely by global shocks, global arrangements need to be considered when establishing regional monetary coordination.

Hsu (2010) extended the Chow and Kim (2003) approach by constructing weighted average macroeconomic variables as a proxy for regional variables. Sato *et al*. (2011) and Dungey and Vehbi (2015) employed the structural VAR method to compare the degree of regional influence between global and regional shocks according to an impulse response function analysis. Assuming Chinese and Japanese shocks as regional shocks, these studies found that a global (U.S.) shock has a greater regional influence on Asian economies than does regional shocks. However, these standard VAR models can only deal with a relatively small number of variables and interactions between a limited number of variables. To capture the complicated international linkages between variables, the model needs to include either higher-order time lags or a large number of domestic variables, but it then cannot avoid a serious dimensionality problem. Furthermore, it is important to note that the above VAR models maintain a closed-economy assumption, which fails to capture international linkages of endogenous variables across countries.

Recent business cycle studies, such as Lee and Azali (2012) and Hirata *et al*. (2013), employ the dynamic factor model and have found that regional factors play a more important role in Asia than global factors in explaining fluctuations in macroeconomic variables. While the estimated unobserved factors are assumed to summarize the empirical content of a large number of macroeconomic variables, Dees *et al*. (DdPS, 2007) noted that the dynamic factor model's results are subject to the identification problem of unobserved factors, especially when making economic interpretations.[4] To assess the source of macroeconomic fluctuations more rigorously, it is necessary to rely on a far more detailed global model and framework.

To overcome the methodological limitation of the standard VAR and dynamic factor models, Pesaran *et al*. (2004), thereafter modified by DdPS (2007), and Dees *et*

[4] DdPS (2007) emphasized that "even when all such 'common' factors are taken into account, there will be important residual interdependencies due to policy and trade spillover effects that remain to be explained" (page 3).

al. (DPSS, 2014) developed a global VAR (GVAR) model. The associated GVAR model is literally a global model that allows global inter-linkages between domestic and foreign variables. The GVAR modeling approach has a number of attractive features:

1. This approach allows interdependence at various levels, including national and international levels, because the lags of all variables enter individual equations and the reduced-form errors can be cross-sectional dependent.
2. It allows for both long-run and short-run relationships consistent with the theory and data.
3. It solves the dimensionality problem in which both the cross-section dimension *N* and time-series dimension *T* can be relatively large as a result of estimating the country-specific error-correction models (ECMs) separately.

These features are important because they provide a global modeling framework for quantitatively analyzing the relative importance of different shocks and transmission channels. Thus, using the GVAR model offers a strong advantage in examining the feasibility of forming a regional monetary arrangement in Asia.

Various studies have applied the GVAR model to the question of forming a monetary union. DdPS (2007) applied the GVAR model to the analysis of international linkages in the Euro area. Pesaran *et al.* (2007) empirically investigated the consequences of a scenario in which the U.K. adopted the Euro in 1990. Fielding *et al.* (2012) identified the channels through which macroeconomic innovations in one country affect other countries in the West African Economic and Monetary Union (UEMOA).

The objective of this study is to investigate the feasibility of a regional monetary arrangement in Asia by using a GVAR model to evaluate whether a global or regional shock exerts greater influence on Asian economies. We compare the impulse responses of macroeconomic variables, such as real output, inflation rates, and interest rates in Asia, to both global and regional shocks. Recently, Feldkircher and Korhonen (2014) employed the GVAR model to assess the degree of China’s economic influence on various regions and countries and surprisingly found little Chinese influence on Japan and the entire Asian region. In marked contrast, we demonstrate that fluctuations in macroeconomic variables are more affected by a regional (Chinese) shock than by a global (U.S.) shock.

Specifically, by applying the GVAR model rigorously to the OCA question to allow global inter-linkages between domestic and foreign variables, we revealed that Asian economies tend to show significantly positive real output responses to Chinese output shock, while responses to a Japanese output shock are far less statistically significant. Such asymmetric responses are likely due to Japan's unilateral dependence on Asian economies, in that Japan does not import much from Asian economies, while Japanese exports to Asia have increased. Asian real outputs showed a significant but relatively short-lived response to the U.S. shock, which indicates China's growing influence on Asian economies compared with the U.S. influence. While strong financial linkages are still observed between the U.S. and Asian economies, China's influence in Asia surpasses that of the U.S. in terms of real output and inflation shocks, which needs to be considered when determining whether to establish a regional monetary arrangement in Asia

The remainder of this paper is organized as follows. Section 2 reviews the methodology of the GVAR analysis. Section 3 describes the data and empirical approach. The empirical results are presented and discussed in Section 4. Finally, Section 5 concludes this study.

2. Methodology

The GVAR approach can be briefly summarized as a two-step approach.[5] First, individual country-specific augmented models are estimated as being conditional on the rest of the world. In this step, all domestic macroeconomic variables are related not only to corresponding foreign variables constructed to match the international trade pattern of the country under consideration but also to dominant variables that can influence the remaining variables in the model directly and indirectly, but not vice versa. The country-specific foreign variables and the dominant variable are treated as weakly exogenous (or long-run forcing) for most economies when the number of countries N is sufficiently large and the idiosyncratic shocks are weakly correlated. Second, the individual country models are combined in a consistent and cohesive manner to form a global model. The combined model is then used to generate forecasts or impulse

[5] The following exposition of the empirical methodology is based on DdPS (2007) and Chudik and Pesaran (2015).

response functions for all world economy variables simultaneously. Smith and Galesi (2014) provided a toolbox for constructing GVARs.

2.1 Country-Specific Models

Assume that there are $N+1$ countries in the global economy, indexed by $i = 0,1,2,\cdots,N$, where 0 serves as a reference country. For each country i, $k_i \times 1$ vector of domestic variables $Y_{i,t}$ are related to the $k_i^* \times 1$ vector of foreign variables $Y_{i,t}^*$, the $m_\omega \times 1$ vector of dominant unit ω_t, and the deterministic variable time trends $t = 1,2,\cdots,T$. This augmented VAR model is denoted as VARX* and expressed as

$$Y_{i,t} = \alpha_{i,0} + \alpha_{i,1}t + \sum_{\ell=1}^{p_i} \phi_{i,\ell} Y_{i,t-\ell} + \sum_{\ell=0}^{q_i} \Lambda_{i,\ell} Y_{i,t-\ell}^* + \sum_{\ell=0}^{s_i} D_{i,\ell}\omega_{t-\ell} + \epsilon_{i,t} \quad (1)$$

where $\epsilon_{i,t}$ is a $k_i \times 1$ vector of idiosyncratic country-specific shocks; $\phi_{i,\ell}$ are $k_i \times k_i$ matrices of lagged coefficients; $\Lambda_{i,\ell}$ are $k_i \times k_i^*$ matrices of coefficients associated with the foreign-specific variables; and $\mathrm{D}_{i,\ell}$ are $k_i \times m_\omega$ matrices of coefficients associated with the common variables. The lag orders p_i, q_i, and s_i of the domestic, foreign, and dominant variables, respectively, are selected using the Akaike information criterion (AIC).

The set of country-specific foreign variables $Y_{i,t}^*$ is built using fixed trade weights $w_{i,j}$, as $Y_{i,t}^* = \sum_{j=0}^{N} w_{i,j} Y_{j,t}$. Specifically, $w_{i,j}$ are calculated as the total trade between country i and country j divided by the total trade of country i with all of its trading partners, where $w_{i,i} = 0$ and $\sum_{j=0}^{N} w_{i,j} = 1$ for all i. The trade weights are important for accommodating the effects of external shocks that could pass through all countries' output via trade channels. The set of country-specific foreign variables represents the dynamics of global economic variables, which are assumed to affect and shape Asian countries' macroeconomic variables.

Assume that the idiosyncratic shocks $\epsilon_{i,t}$ are serially uncorrelated with mean 0 and nonsingular covariance matrix $\Sigma_{ii}(\sigma_{ii,ℓs})$, where $\sigma_{ii,ℓs} = cov(\epsilon_{iℓt,}\epsilon_{ist})$. The idiosyncratic shocks are denoted as $\epsilon_{i,t} \approx iid(0,\Sigma_{ii})$.

2.2 Dominant Variables

In modeling the dominant variable ω_t, a possible cointegration among the elements of ω_t is first checked using the Johansen procedure. Consider the following $VAR(p_\omega)$ specification for the dominant model:

$$\omega_t = \mu_0 + \mu_1 t + \sum_{\ell=1}^{p_\omega} \phi_{\omega\ell}\, \omega_{t-\ell} + \eta_{\omega t} \tag{2}$$

which can be equivalently written in the ECM as

$$\Delta\omega_t = c - \alpha_\omega \beta_\omega' [\omega_{t-1} - \kappa(t-1)] + \sum_{j=1}^{p_\omega - 1} \Gamma_{\omega j} \Delta\omega_{t-j} + \eta_{\omega t} \tag{3}$$

where $\alpha_\omega \beta_\omega' = \sum_{\ell=1}^{p_\omega} \phi_{\omega\ell}$, α_ω and β_ω are $m_\omega \times r_\omega$ vectors, r_ω denotes the number of cointegrating relationships, $\Gamma_{\omega j} = -(\phi_{\omega,\ell+1} + \phi_{\omega,\ell+2} + \cdots + \phi_{\omega,\ell+p_\omega})$, and the lag length p_ω is selected by the AIC information criterion. For cases in which ω_t contains $I(1)$ variables, Eq (3) clearly allows cointegration among the dominant variables.

To allow for feedback effects from the variables included in the GVAR model back to the dominant variables via cross-section averages, Eq (2) can be augmented with lagged changes of the variables in the rest of the GVAR model, $\tilde{Y}_{\omega t} = \widetilde{W}_\omega Y_t$, where Y_t is the $k \times 1$ vector of the variables included in the models of the non-dominant variables ($k = \sum_{i=0}^{N} k_i$), and $\widetilde{W}_\omega$ is an $m_{\tilde{x}} \times k$ matrix of weights defining $m_{\tilde{x}}$ global cross-section averages:

$$\omega_t = \mu_0 + \mu_1 t + \sum_{\ell=1}^{p_\omega} \phi_{\omega\ell}\, \omega_{t-\ell} + \sum_{\ell=1}^{q_\omega} \Lambda_{\omega\ell}\, \tilde{Y}_{\omega,t-\ell} + \eta_{\omega t} \tag{4}$$

Assuming there is no cointegration among the common variables ω_t and the cross-section averages $\tilde{Y}_{\omega t-\ell}$, Eq (4) can be written as

$$\Delta\omega_t = c - \alpha_\omega \beta_\omega' [\omega_{t-1} - \kappa(t-1)] + \sum_{j=1}^{p_\omega - 1} \Gamma_{\omega j} \Delta\omega_{t-j} + \sum_{j=1}^{q_\omega - 1} \theta_{\omega j} \Delta\tilde{Y}_{\omega,t-\ell} + \eta_{\omega t} \tag{5}$$

where $\theta_{\omega j}$ is consistently estimated by least squares. Note that contemporaneous values of $\Delta\tilde{Y}_{\omega t}$ do not feature in Eq (5).

2.3 Building the Global Vector Autoregressive Model (GVAR)

The conditional country-specific model Eq (1) and the marginal model Eq (5) can be combined and solved as a complete global VAR model.

To construct the GVAR model from the country-specific models, first define the $(k_i + k_i^*) \times 1$ vector $Z_{i,t} = (Y_{i,t}, Y_{i,t}^*)^T$. Assuming for simple exposition that $p_i = q_i$, Eq (1) can be rewritten as

$$G_{i,0} Z_{i,t} = \alpha_{i,0} + \alpha_{i,1} t + \sum_{\ell=1}^{p_i} G_{i,\ell} Z_{i,t-\ell} + \sum_{\ell=1}^{s_i} D_{i,\ell} \omega_{i,t-\ell} + \epsilon_{i,t} \tag{6}$$

where $G_{i,0} = (I_{k_i}, -\Lambda_{i,0})$ and $G_{i,\ell} = (\phi_{i,\ell}, \Lambda_{i,\ell})$ for $\ell = 1, \cdots, p_i$. Both $G_{i,0}$ and $G_{i,\ell}$ are $k_i \times (k_i + k_i^*)$ matrices, and $G_{i,0}$ has a full row rank, namely $\mathrm{rank}\left(G_{i,0}\right) = k_i$.

Second, collect all the country-specific variables together in the $k \times 1$ global vector $Y_t = \left(Y_{0,t}^{'}, Y_{1,t}^{'}, \cdots, Y_{N,t}^{'}\right)^{'}$, where $k = \sum_{i=0}^{N} k_i$ is the total number of the endogenous variables in the global model. Then, the country-specific variables can all be written in terms of Y_t, as

$$Z_{i,t} = W_i Y_t, \qquad i = 0,1,2, \cdots, N \tag{7}$$

where W_i is a $(k_i + k_i^*) \times k$ matrix of fixed constants defined in terms of the country-specific weights $w_{i,j}$. The matrix W_i links all country-specific and foreign variables in the system. Because no subscript i is attached to Y_t, variables for all countries in the system are stacked in Y_t.

Third, substituting Eq (7) into Eq (6) yields:

$$G_{i,0} W_i Y_t = \alpha_{i,0} + \alpha_{i,1} t + \sum_{\ell=1}^{p_i} G_{i,\ell} W_i Y_{t-\ell} + \sum_{\ell=1}^{s_i} D_{i,\ell} \omega_{i,t-\ell} + \epsilon_{i,t},$$

where both $G_{i,0} W_i$ and $G_{i,\ell} W_i$ are $k_i \times k$ dimension matrices. Stacking these equations yields a "global" solution:

$$G_0 Y_t = \alpha_0 + \alpha_1 t + \sum_{\ell=1}^{p} G_\ell Y_{t-\ell} + \sum_{\ell=0}^{s} D_\ell \omega_{t-\ell} + \epsilon_t \tag{8}$$

where both the contemporaneous and lagged values of ω_t now appear on the right-hand side of Eq (8) with $p = \max(p_i)$, $s = \max(s_i)$, and

$$G_0 = \begin{pmatrix} G_{00} W_0 \\ G_{10} W_1 \\ \vdots \\ G_{N0} W_N \end{pmatrix},\ G_\ell = \begin{pmatrix} G_{0\ell} W_0 \\ G_{1\ell} W_1 \\ \vdots \\ G_{N\ell} W_N \end{pmatrix},\ \alpha_0 = \begin{pmatrix} \alpha_{00} \\ \alpha_{10} \\ \vdots \\ \alpha_{N0} \end{pmatrix},\ \alpha_1 = \begin{pmatrix} \alpha_{01} \\ \alpha_{11} \\ \vdots \\ \alpha_{N1} \end{pmatrix},\ \epsilon_t = \begin{pmatrix} \epsilon_{0t} \\ \epsilon_{1t} \\ \vdots \\ \epsilon_{Nt} \end{pmatrix}.$$

Defining the $(m_\omega + k) \times 1$ vector $X_t = (\omega_t', Y_t')'$, then Eq (4) and Eq (8) for $p = p_\omega = q_\omega = s$ can be written as

$$H_0 X_t = h_0 + h_1 t + \sum_{\ell=1}^{p} H_\ell X_{t-\ell} + \zeta_t \tag{9}$$

where

$$H_0 = \begin{bmatrix} I_{m_\omega} & 0_{m_\omega \times k} \\ -D_\ell & G_0 \end{bmatrix},\ h_0 = \begin{bmatrix} \mu_0 \\ \alpha_0 \end{bmatrix},\ h_1 = \begin{bmatrix} \mu_1 \\ \alpha_1 \end{bmatrix},\ H_\ell = \begin{bmatrix} \phi_{\omega\ell} & \Lambda_{\omega\ell} \widetilde{W}_\omega \\ D_\ell & G_\ell \end{bmatrix},\ \zeta_t = \begin{bmatrix} \eta_{\omega t} \\ \epsilon_t \end{bmatrix}.$$

Finally, because H_0 is a $k \times k$ dimensional matrix and will be a full rank, it is a nonsingular matrix. Therefore, the GVAR model in all the variables can be expressed as

$$X_t = {H_0}^{-1} h_0 + {H_0}^{-1} h_1 t + H_0^{-1} \sum_{\ell=1}^{p} H_\ell X_{t-\ell} + {H_0}^{-1} \zeta_t \tag{10}$$

where

$$H_0^{-1} = \begin{bmatrix} I_{m_\omega} & 0_{m_\omega \times k} \\ G_0^{-1} D_\ell & G_0^{-1} \end{bmatrix}$$

which is a block lower triangular matrix showing the causal nature of the dominant variables ω_t. Eq (10) can be solved recursively forward to obtain the future values of X_t.

3. Empirical Application

3.1 Countries and Regions

To have a sufficiently long time series for reliable statistical inference, this study uses quarterly data over the period from 1990Q1 to 2013Q4 for 20 countries from different regions of the world (see Table 3.1). The eight countries in the Euro area are grouped together and treated as a single economy. The following ten Asian economies are included: China, Hong Kong, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Taiwan, and Thailand.

[Insert Table 3.1 around here.]

The regional variables are constructed from country-specific variables using the following weighted averages:

$$Y_{it} = \sum_{i=1}^{N} w_{i,l}^{0}\, Y_{i,l,t},$$

where $Y_{i,l,t}$ indicates a variable of country l in region i, and $w_{i,l}^{0}$ is the aggregation weight.

3.2 Variables

The choice of variables in this study follows Pesaran *et al*. (2004) and DdPS (2007): real output measured by real gross domestic product (*RGDP*); inflation rate (*INF*) measured by $[(CPI_t - CPI_{t-4})/CPI_{t-4}] * 100$, where *CPI* is the consumer price index; money market interest rate measured by interest rate (*IR*); and real effective exchange rate (*REER*). The *RGDP* is used as a proxy for real output, *INF* is used as the proxy for the general price level, and the *IR* is used as the proxy for money markets. The *REER* is included to capture the multi-country nature of the analysis. The price of oil is included to account for possible common factors. All these variables are expressed in natural logarithms except *IR*, which is expressed as a percentage. Seasonality is adjusted using the Census X12 method for all variables except *REER* and *IR*.

The country-specific foreign variables are built using the fixed trade weights $w_{i,j}$ based on the share of trade (exports plus imports). The regional variables are built using the aggregation weights based on the purchasing power parity's adjusted *GDP* series (*PPP-GDP*) weights. Both weights are constructed with annual data computed over the sample period of 1990–2013. The data source for each variable is reported in Table 3.2.

[Insert Table 3.2 around here.]

For country $i = 0,1,2,\cdots,N$, the country-specific domestic $Y_{i,t}$ and foreign variables, $Y_{i,t}^*$ are

$$Y_{i,t} = (RGDP_{i,t}, INF_{i,t}, IR_{i,t}, REER_{i,t})' \text{ and } Y_{i,t}^* = (RGDP_{i,t}^*, INF_{i,t}^*, IR_{i,t}^*)'.$$

The country-specific foreign variables are defined as

$$RGDP_{i,t}^* = \sum_{j=0}^{N} w_{i,j}\, RGDP_{i,t},\ INF_{i,t}^* = \sum_{j=0}^{N} w_{i,j}\, INF_{i,t} \text{ and } IR_{i,t}^* = \sum_{j=0}^{N} w_{i,j}\, IR_{i,t},$$

where $w_{i,i} = 0$ and $\sum_{j=0}^{N} w_{i,j} = 1$. The matrix of the trade weights is presented in Table 3.3.

[Insert Table 3.3 around here.]

This study treats the oil price as the globally dominant variable. The global dominance of the oil price implies that idiosyncratic shocks to the oil price would have a non-negligible effect on potentially any country in the world while the effect of a small economy on the oil price is negligible. Therefore, oil price effectively becomes a dynamic common factor for other economies. In this study, *RGDP* and *INF* are the two feedback variables selected to enter the augmented ECM.

3.3 Estimation of the Country Models

The GVAR model assumes foreign and dominant variables are weakly exogenous and the parameters are stable over time. Under weak exogeneity, the parameters of the country-specific models can be estimated consistently using the reduced-rank estimation procedure. However, the Johansen (1988, 1995) reduced-rank estimation procedure treats all the variables in the model as endogenous *I*(1). Thus, this study estimates the individual VARX* models using the modified technique developed by Harbo *et al.* (1998) and Pesaran *et al.* (2000). Following the estimation procedure, we first conduct the cointegration test and then estimate the individual country models subject to the reduced rank restrictions. We then derive the corresponding ECM and, finally, use the ECM to conduct weak exogeneity tests.

3.3.1 Integration Properties of the Series

To select appropriate transformations of the domestic and foreign variables for inclusion in the country-specific cointegrating VAR models, the integration properties of the individual series under consideration are examined. Because the traditional Dickey-Fuller (DF) test has poor power performance in small samples, this study employs the Weighted Symmetric Augmented Dickey-Fuller (WS-ADF) test introduced by Park and Fuller (1995). The WS-ADF unit root test uses the time reversibility of stationary autoregressive processes to increase their power performance (Leybourne *et al.*, 2005; Pantula *et al.*, 1994). The lag length employed by the WS-ADF unit root test is selected using the Akaike Information Criterion (AIC). Because quarterly data is employed, this study sets the maximum lag length to four.

The WS-ADF test results for the level and first differences of all country-specific domestic, foreign, and global variables in the GVAR model are reported in Table 3.4, which shows that most of the variables are integrated with order 1 or *I*(1). To avoid over-differencing and efficiency loss in the remaining countries, all the variables are treated approximately as *I*(1).

[Insert Table 3.4 around here.]

3.3.2 Rank of Cointegration Space

For each country model, the corresponding cointegrating VAR model is estimated and the rank of the cointegrating space is identified. Initially, the order of the individual country VARX$^*(p_i, q_i)$ models are selected, where p_i is the domestic variables' lag order and q_i is that of the foreign variables in the VARX* models. The variables' lag order is selected according to the AIC. Due to data limitations, the domestic variables have a maximum lag order of two, while that for foreign variables is set to one.

Then, the cointegration rank is derived by employing the trace test and the asymptotic 5% critical values taken from MacKinnon *et al.* (1999). The deterministics of the VARX* models were unrestricted intercept and restricted trend. Table 3.5 provides the orders of the VARX* models and the number of cointegrating relationships. The cointegrating relationships can be interpreted as long-run relationships among the domestic variables and between the domestic and foreign variables.

[Insert Table 3.5 around here.]

3.3.3 Weak Exogeneity Test

The weak exogeneity of variables is tested using weak exogeneity tests from Johansen (1992) and Harbo *et al.* (1998). The *F*-statistics for testing the weak exogeneity of all country-specific foreign and global variables are summarized in Table 3.6. No weak exogeneity assumptions can be rejected for most variables, where only 5 of 52 exogeneity tests were statistically significant. Thus, the analysis was re-estimated by assuming those five variables as endogenous, which showed that it did not affect the number of cointegrating relationships in the model. Therefore, the variables are treated as exogenous throughout the GVAR model.

[Insert Table 3.6 around here.]

4. Empirical Results

In this section, we study the dynamic properties of the GVAR model to assess the time profile of the effects following various shocks. The purpose of this empirical analysis is to evaluate the extent to which the Asian integration process has been driven by external or regional shocks based on the impulse response function analysis. In this study, the U.S. is considered a possible source of the global shock, while Japan and China are considered possible regional shock sources for Asian economies. We consider the following one standard error positive shocks: (1) real output shock, (2) inflation shock, (3) interest rate shock, and (4) oil price shock. This study employs the generalized impulse response function (GIRF), which is invariant to the variables' order and to the countries in the model, which is especially important in a large macroeconomic system. We display the results of GIRF analysis over 20 quarters (i.e., 5 years), with the bootstrap estimates of the GIRF and their associated 90% confidence bounds.

4.1 Real Output Shocks

We first analyze the impulse responses of real outputs to a one standard error positive real output shock originating from China (Figure 4.1), Japan (Figure 4.2), and the U.S. (Figure 4.3), which are equivalent to a positive rise in the real output of China, Japan, and the U.S., respectively.

First, in Figure 4.1, all Asian economies exhibit positive and significant real output responses to the Chinese real output shock except the Philippines, where the impulse response is significantly positive only for the first few periods. This result indicates that most Asian economies tend to be positively affected by a shock from China, likely reflecting China's role as a regional production hub and the growing regional trade between China and neighboring economies. It is interesting to note that not only the U.S. but also the Euro area shows a significantly positive response of real outputs to Chinese real output shock. This result is consistent with the findings of Sato and Shrestha (2014) and Amador *et al*. (2015), which demonstrate China's strong participation in global value chains and the growing dependence of the U.S. and European countries on China for their intermediate input imports.

Second, all Asian economies show positive and significant real output responses to a Japanese real output shock only for an initial period. Subsequently, these countries' impulse responses rapidly become small and insignificant. The impulse responses of the U.S. and Euro area are not statistically significant at all. Thus, Japan's real output shock has a surprisingly small effect on Asian economies, likely because Japan is not a major export market for Asian economies compared to China. Sato and Shrestha (2014) empirically investigated trade and production linkages based on a globally linked input–output table and demonstrated that Japan' import-dependence on Asian economies for intermediate inputs is far smaller than the degree of Asian import-dependence on Japan, whereas Asian economies have a substantially high import dependence on Japanese intermediate goods.

Third, as found in the previous studies, a U.S. real output shock has significantly positive influences on Asian economies. In Figure 4.3, all Asian economies can be seen to respond positively to the U.S. real output shock for at least the first two years. A comparison between Figures 4.1 (Chinese real output shock) and 4.3 (U.S. real output shock) shows that the degrees of impulse response by real outputs are mostly similar in all Asian economies except the Philippines. However, the period of statistically significant response to Chinese real output shock is clearly longer than the corresponding responses to the U.S. real output shock. In terms of a real output shock, China's regional influence becomes comparable to, or even stronger than, the U.S. influence, which contrasts markedly with the findings of Sato *et al*. (2011), Feldkircher and Korhonen (2014), and Dungey and Vehbi (2015).

4.2 Inflation Shocks

To further assess the degree of China's economic influence on Asian economies in comparison with the U.S. influence, we generated two additional shocks: a one standard error positive inflation shock from China (Figure 4.4) and the U.S. (Figure 4.5) to inflation, respectively.

In Figure 4.4, Hong Kong, Taiwan, Malaysia, and Korea can be seen to exhibit positive and significant responses to Chinese inflation shock over the five-year time horizon. Indonesia, Singapore, and Thailand also show significantly positive responses to Chinese inflation shock for at least the first few quarters, but the responses of Japan and the Philippines are not statistically significant at all. Although not reported in this study, we also attempted to estimate the impulse responses of Asian economies' price inflation to a Japanese inflation shock, which indicates that the response of Asian economies' price inflation is not statistically significant in most cases.

Figure 4.5 shows the impulse responses of Asian economies to a U.S. inflation shock. It is interesting to note that the U.S. shock has a significantly positive effect on Asian inflation only for the first one or two quarters in Hong Kong, Korea, Malaysia, Thailand, and Taiwan. For other Asian economies, the U.S. shock has no significant influences on domestic price inflation. In terms of the inflation shock, China has far stronger influences than the U.S. on Asian regional economies.

4.3 Interest Rate Shocks

In addition to the real and price linkages, it is necessary to assess the degree of financial linkages. Under the GVAR framework, we investigate the degree of interest rate shock transmission. Figure 4.6 shows that nominal interest rates of all Asian economies respond positively and significantly to the U.S. interest rate shock at least for the first several periods. In contrast, although not presented in this study, an interest rate shock from either China or Japan has no significant effect on the nominal interest rates in Asian economies, likely due to the China's capital controls and Japan's near-zero interest rate policy since the end of the 1990s. In terms of financial linkages, Asian economies are subject not to regional shocks but to global shocks originating from the U.S.

4.4 Oil Price Shocks

Lastly, to assess the effects of an oil price shock, another possible source of global shock, on Asian economies, a one standard error positive shock to oil prices is generated, and the effects of an oil price shock on real output (Figure 4.7) and inflation (Figure 4.8) are investigated. A one standard error positive shock results in a 0.1% increase in the price of oil. Most real output of Asian economies first shows a positive response but soon decreases sharply. The above responses are not statistically significant for most Asian economies. On the other hand, although short-lived, an oil price shock has a positive and significant effect on inflation in Asian economies. Compared to its effects on real output, an oil price shock has stronger effects on Asian economies by causing inflationary pressure. Furthermore, the short-lived responses to inflation support the finding of Galesi and Lombardi (2009) that inflationary effects of oil price shocks are felt mostly in advanced countries, with less sizeable effects felt in emerging economies.

[Insert Figures 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, and 4.8 around here.]

5. Concluding Remarks

The main goal of this study is to assess the feasibility of forming a regional monetary arrangement in the Asian region. By employing a GVAR model that covers 20 economies from all over the world, we generated two types of shocks, i.e., global

(U.S.) and regional (Japanese and Chinese) shocks. We investigated whether recent regional economic growth and inflation dynamics are driven by external shocks or self-sustaining development in Asia.

We found that Asian economies tend to show significantly positive and longer responses to a Chinese real output shock than to a U.S. shock. While previous studies found the Chinese economy has increasing importance in the global economy (Cesa-Bianchi *et al*., 2012; Feldkircher and Korhonen, 2014; Dreger and Zhang, 2014), no studies have found that China's influence surpass that of the U.S. in the context of Asian monetary integration/union. By estimating a GVAR model that allows global inter-linkages between domestic and foreign variables, we demonstrate that China's influence on the Asian economies are greater than the U.S. influence in terms of both real output and inflation shocks, although the U.S. still has a greater financial effect on Asian economies in terms of interest rate shocks. Furthermore Asian economies' responses to a Japanese real output shock are far less statistically significant, which is likely due to Japan's unilateral dependence on the Asian economies, in that Japan does not import much from Asian economies.

The rising role of regional (Chinese) shocks in driving business cycles and inflation indicates that Asian economies meet some of the key preconditions in establishing a regional monetary union. However, Asian economies are financially affected by the U.S., in that nominal interest rates of Asian economies are significantly influenced by a U.S. interest rate shock. To facilitate regional monetary arrangements, China needs further financial liberalization and removal of capital controls to strengthen its financial linkages with other Asian economies.

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Table 3.1: Countries and Regions in the Global VAR Model

Regions	Countries	Regions	Countries
Asian countries	China	Euro area	Austria
	Hong Kong		Belgium
	Indonesia		Finland
	Japan		France
	Korea		Germany
	Malaysia		Italy
	Philippines		Netherlands
	Singapore		Spain
	Taiwan	Developed countries	U.K.
	Thailand		U.S.

Table 3.2: Data Sources

Country	RGDP	CPI	IR	REER	Oil Price	Imports	Exports	PPP-GDP
Austria	CEIC	IFS	CEIC	IFS	IFS	DOT	DOT	WB
Belgium	CEIC	IFS	CEIC	IFS	IFS	DOT	DOT	WB
China	CEIC	CEIC	CEIC	IFS	IFS	DOT	DOT	WB
Finland	CEIC	IFS	CEIC	IFS	IFS	DOT	DOT	WB
France	CEIC	IFS	CEIC	IFS	IFS	DOT	DOT	WB
Germany	CEIC	IFS	CEIC	IFS	IFS	DOT	DOT	WB
Hong Kong	CEIC	IFS	CEIC	BIS	IFS	DOT	DOT	WB
Indonesia	CEIC	IFS	CEIC	BIS	IFS	DOT	DOT	WB
Italy	CEIC	IFS	CEIC	IFS	IFS	DOT	DOT	WB
Japan	CEIC	IFS	CEIC	IFS	IFS	DOT	DOT	WB
Korea	CEIC	IFS	CEIC	BIS	IFS	DOT	DOT	WB
Malaysia	CEIC	IFS	CEIC	IFS	IFS	DOT	DOT	WB
Netherlands	CEIC	IFS	CEIC	IFS	IFS	DOT	DOT	WB
Philippines	CEIC	IFS	CEIC	IFS	IFS	DOT	DOT	WB
Singapore	CEIC	IFS	CEIC	IFS	IFS	DOT	DOT	WB
Spain	CEIC	IFS	CEIC	IFS	IFS	DOT	DOT	WB
Taiwan	CEIC	CEIC	CEIC	CEIC	IFS	DOT	DOT	WB
Thailand	CEIC	IFS	CEIC	CEIC	IFS	DOT	DOT	WB
U.K.	CEIC	IFS	CEIC	IFS	IFS	DOT	DOT	WB
U.S.	CEIC	IFS	CEIC	IFS	IFS	DOT	DOT	WB

Note: CEIC is the CEIC Global Database; IFS is the International Monetary Fund, International Financial Statistics (IMF, IFS) CD-ROM edition; BIS is the Bank of International Settlements; DOT is the IMF Direction of Trade; and WB is the World Development Indicator database of the World Bank.

Table 3.3: Trade Weights (w_{ij}) Based on Direction of Trade Statistics

Country	China	Euro	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand	U.K.	U.S.
China	0	0.1574	0.4943	0.1225	0.2026	0.2457	0.1095	0.0783	0.1105	0.2377	0.1285	0.0537	0.2182
Euro	0.1645	0	0.0847	0.1156	0.1297	0.1142	0.1053	0.1138	0.1091	0.0963	0.1149	0.6425	0.2671
Hong Kong	0.1424	0.0227	0	0.0202	0.0441	0.0503	0.0454	0.0628	0.0798	0.0877	0.0458	0.0245	0.0256
Indonesia	0.0209	0.0145	0.0068	0	0.0399	0.0362	0.0391	0.0223	0.0345	0.0160	0.0403	0.0049	0.0149
Japan	0.1650	0.0903	0.0895	0.2208	0	0.1847	0.1609	0.1887	0.1090	0.1740	0.2384	0.0420	0.1792
Korea	0.1026	0.0351	0.0350	0.0838	0.0817	0	0.0489	0.0603	0.0561	0.0506	0.0398	0.0138	0.0617
Malaysia	0.0333	0.0187	0.0176	0.0616	0.0389	0.0288	0	0.0428	0.1791	0.0312	0.0721	0.0103	0.0313
Philippines	0.0145	0.0071	0.0111	0.0141	0.0198	0.0161	0.0182	0	0.0248	0.0145	0.0214	0.0036	0.0149
Singapore	0.0301	0.0241	0.0446	0.1399	0.0350	0.0407	0.1733	0.0857	0	0.0611	0.0771	0.0160	0.0349
Taiwan	0.0779	0.0270	0.0546	0.0389	0.0693	0.0445	0.0489	0.0666	0.0610	0	0.0419	0.0115	0.0525
Thailand	0.0240	0.0167	0.0165	0.0449	0.0463	0.0179	0.0584	0.0414	0.0519	0.0217	0	0.0084	0.0229
U.K.	0.0255	0.3136	0.0240	0.0177	0.0279	0.0218	0.0233	0.0182	0.0285	0.0187	0.0265	0	0.0768
U.S.	0.1993	0.2727	0.1214	0.1201	0.2649	0.1990	0.1689	0.2191	0.1558	0.1907	0.1533	0.1689	0

Note: Trade weights are computed as shares of exports and imports, displayed in columns by region (such that a column, but not a row, total 1).

Table 3.4: WS-ADF Unit Root Test for Domestic, Foreign, and Global Variables

	China	Euro	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand	U.K.	U.S.
Domestic													
RGDP	-2.70	-1.37	-2.95	-1.85	-2.57	-0.91	-0.79	-0.19	-2.19	-0.82	-1.77	-1.02	-1.61
∆RGDP	-2.61*	-4.41*	-4.71*	-5.58*	-5.38*	-5.67*	-5.48*	-4.19*	-6.04*	-6.46*	-6.07*	-3.60*	-3.74*
INF	-2.07	-2.75	-1.14	-6.82*	-1.19	-2.67	-3.09	-1.44	-1.74	-2.49	-2.67	-3.00	-2.10
∆INF	-3.80*	-8.61*	-4.48*	-4.57*	-7.15*	-7.89*	-8.81*	-4.55*	-5.20*	-7.28*	-8.61*	-3.55*	-5.00*
REER	-2.03	-2.46	-1.31	-1.88	-2.66	-3.22	-2.27	-1.88	-0.65	-3.10	-2.95	-2.52	-1.72
∆REER	-6.35*	-6.08*	-3.69*	-6.87*	-4.38*	-5.30*	-7.17*	-5.22*	-5.23*	-5.21*	-7.59*	-4.53*	-7.84*
IR	-1.92	-2.46	-3.32*	-4.64*	-1.81	-2.85	-3.55*	-2.96	-3.31*	-2.24	-3.48*	-2.21	-4.40*
∆IR	-5.41*	-5.27*	-4.72*	-6.40*	-3.61*	-8.73*	-4.86*	-5.41*	-5.29*	-3.87*	-6.16*	-5.42*	-4.15*
Foreign													
RGDP*	-1.86	-1.51	-0.99	-1.31	-1.13	-1.35	-1.96	-1.50	-0.96	-1.44	-1.24	-1.29	-1.16
∆RGDP*	-4.99*	-4.41*	-3.85*	-5.37*	-4.93*	-4.67*	-5.44*	-5.26*	-4.74*	-4.69*	-5.12*	-4.98*	-4.68*
INF*	-1.57	-2.13	-2.05	-2.00	-2.12	-2.01	-2.13	-1.99	-2.09	-1.91	-2.12	-2.37	-1.97
∆INF*	-5.11*	-7.04*	-4.04*	-7.53*	-4.82*	-6.89*	-7.96*	-8.12*	-8.16*	-4.63*	-7.87*	-8.19*	-6.32*
IR*	-3.60*	-2.95	-2.30	-3.24	-2.87	-2.71	-3.00	-3.26*	-2.63	-2.66	-2.50	-3.05	-2.59
∆IR*	-5.33*	-4.59*	-4.78*	-5.54*	-5.60*	-5.13*	-5.46*	-4.95*	-5.87*	-5.04*	-5.55*	-4.64*	-5.08*
Dominant													
Oil Price	-2.29												
∆Oil Price	-6.01*												

Note: * indicates significance at a 5% level of significance.

Table 3.5: VARX* Order and Cointegrating Relationship in Country-Specific Models

	Lag order of domestic variables	Lag order of foreign variables	Number of cointegrating relations
China	2	1	1
Euro	2	1	2
Hong Kong	1	1	1
Indonesia	2	1	3
Japan	2	1	2
Korea	2	1	2
Malaysia	2	1	1
Philippines	2	1	3
Singapore	1	1	2
Taiwan	1	1	2
Thailand	1	1	2
U.K.	2	1	2
U.S.	2	1	2

Note: The rank of the cointegrating orders for each country/region is computed using Johansen’s trace statistics at the 95% critical value level.

Table 3.6: Weak Exogeneity Tests of Country-Specific Foreign and Global Variables

Country	F test	Critical values	Country-specific foreign and global variables			
			RGDP	INF	IR	Oil Price
China	F(1,77)	3.97	5.96	0.03	0.62	0.11
Euro	F(2,76)	3.12	0.33	0.58	1.89	0.17
Hong Kong	F(1,73)	3.97	0.80	0.86	0.46	0.19
Indonesia	F(3,81)	2.72	1.49	0.18	1.54	0.92
Japan	F(2,82)	3.11	0.70	0.78	0.20	0.69
Korea	F(2,82)	3.11	1.53	2.73	0.10	4.73
Malaysia	F(1,73)	3.97	0.51	0.02	0.81	1.55
Philippines	F(3,75)	2.73	0.67	1.87	2.52	1.98
Singapore	F(2,76)	3.12	0.80	0.23	0.52	1.28
Taiwan	F(2,82)	3.11	0.10	0.65	0.14	2.64
Thailand	F(2,82)	3.11	3.27	1.24	3.55	0.89
U.K.	F(2,82)	3.11	0.11	0.63	0.02	6.47
U.S.	F(2,72)	3.12	0.22	1.12	0.77	2.58

Note: Critical values are at the 5% level of significance.

Figure 4.1: GIRFs of Real Output to a Positive Chinese Real Output Shock

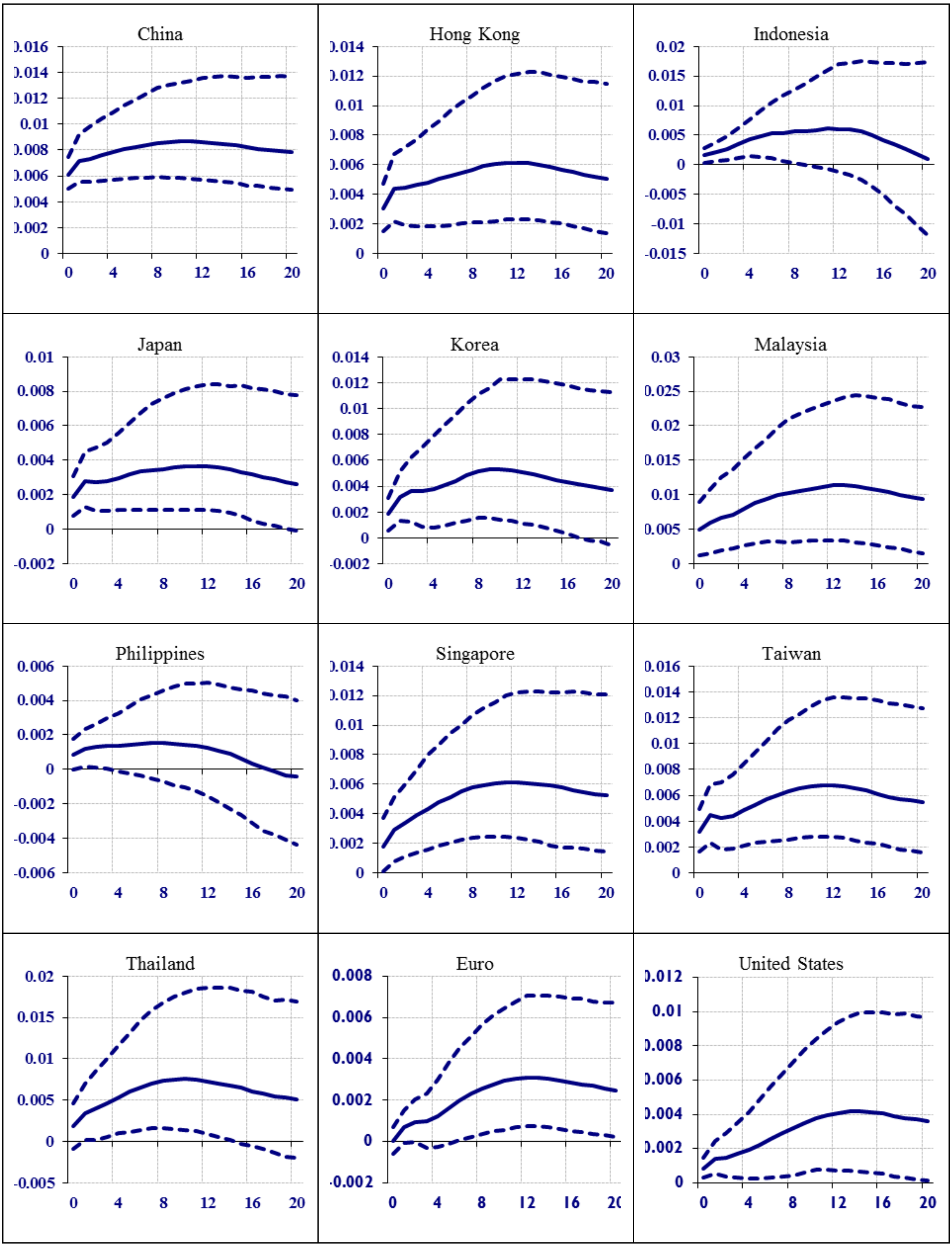

Figure 4.2: GIRFs of Real Output to a Positive Japanese Real Output Shock

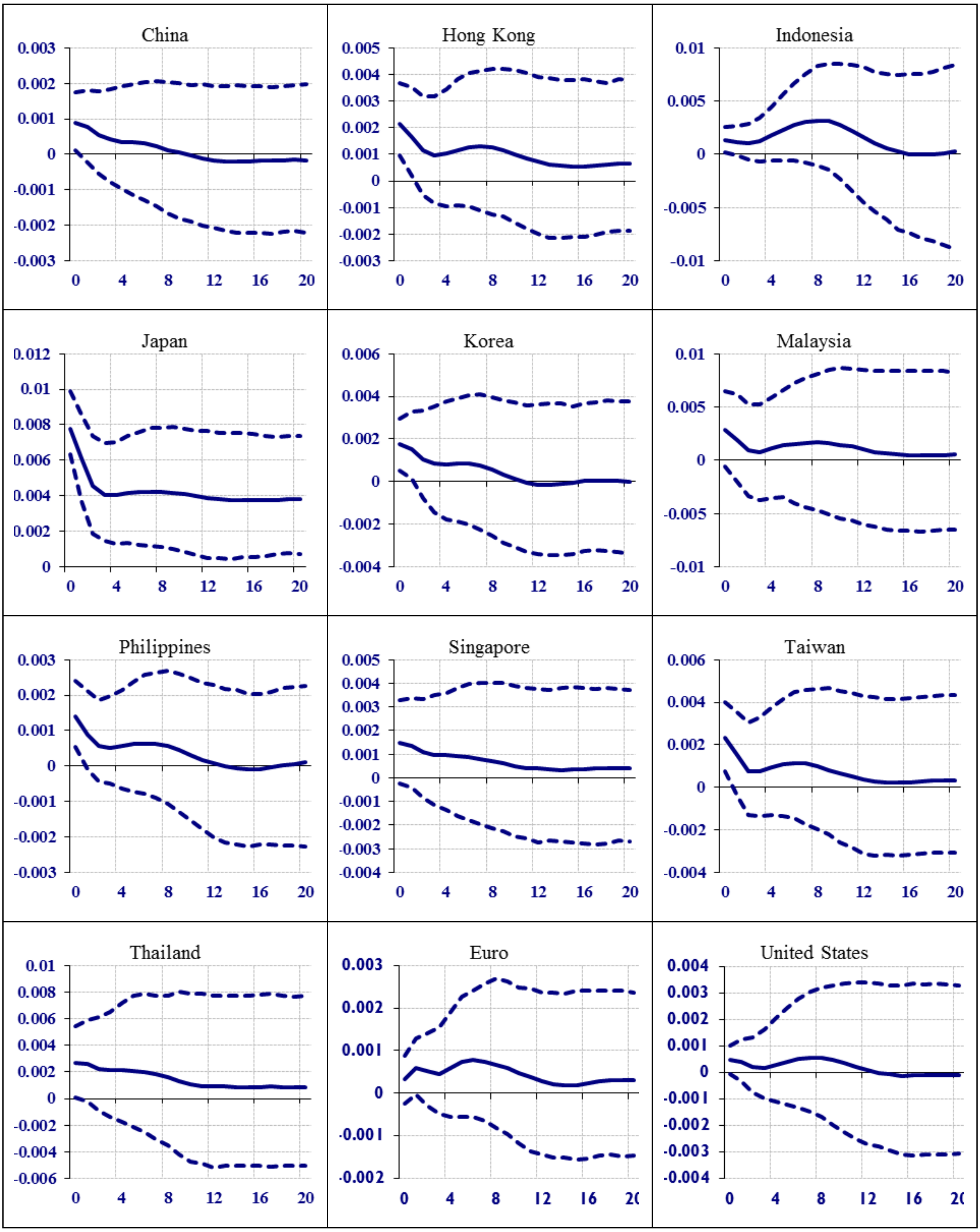

Figure 4.3: GIRFs of Real Output to a Positive U.S. Real Output Shock

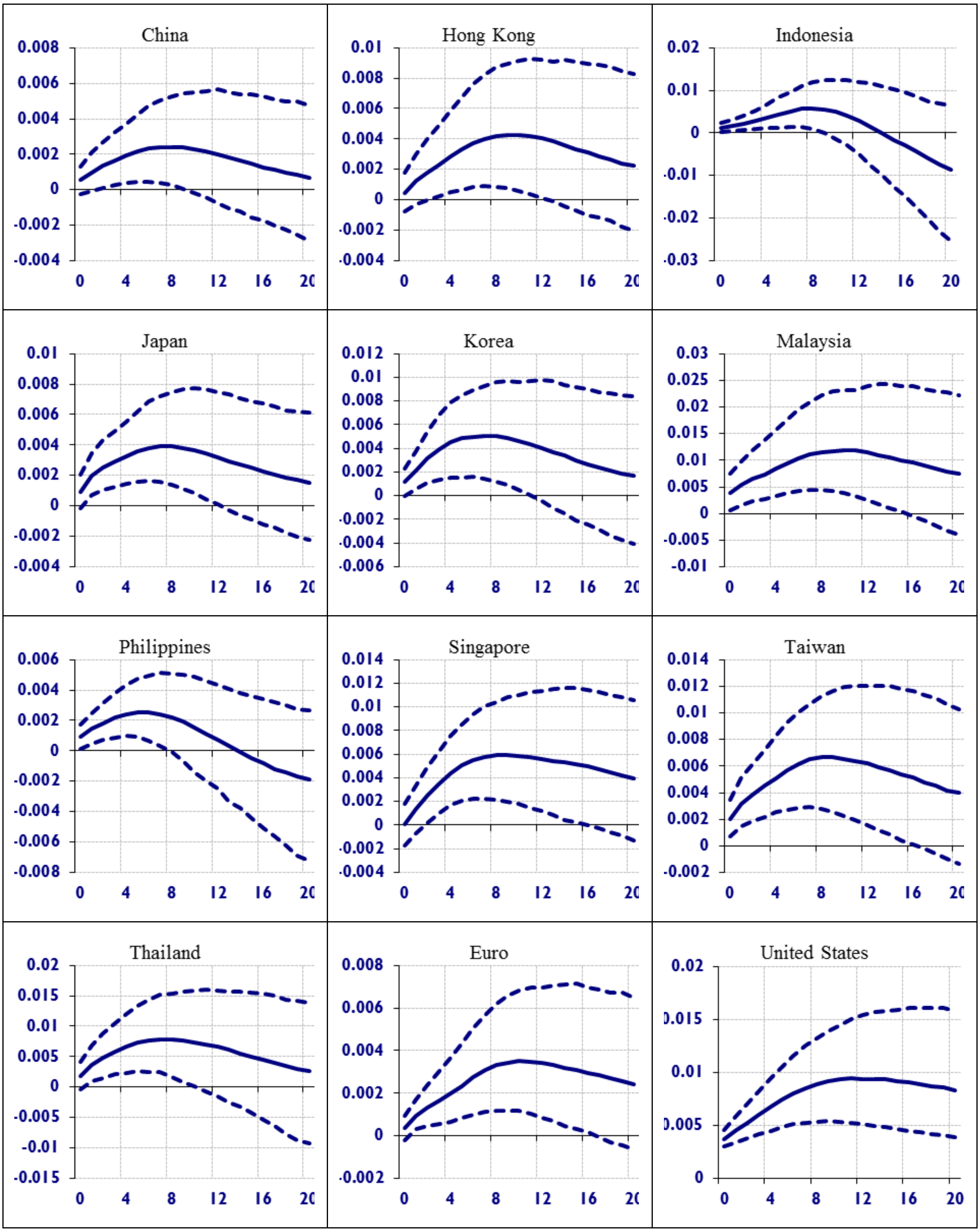

Figure 4.4: GIRFs of Inflation Rates to a Positive Chinese Inflation Shock

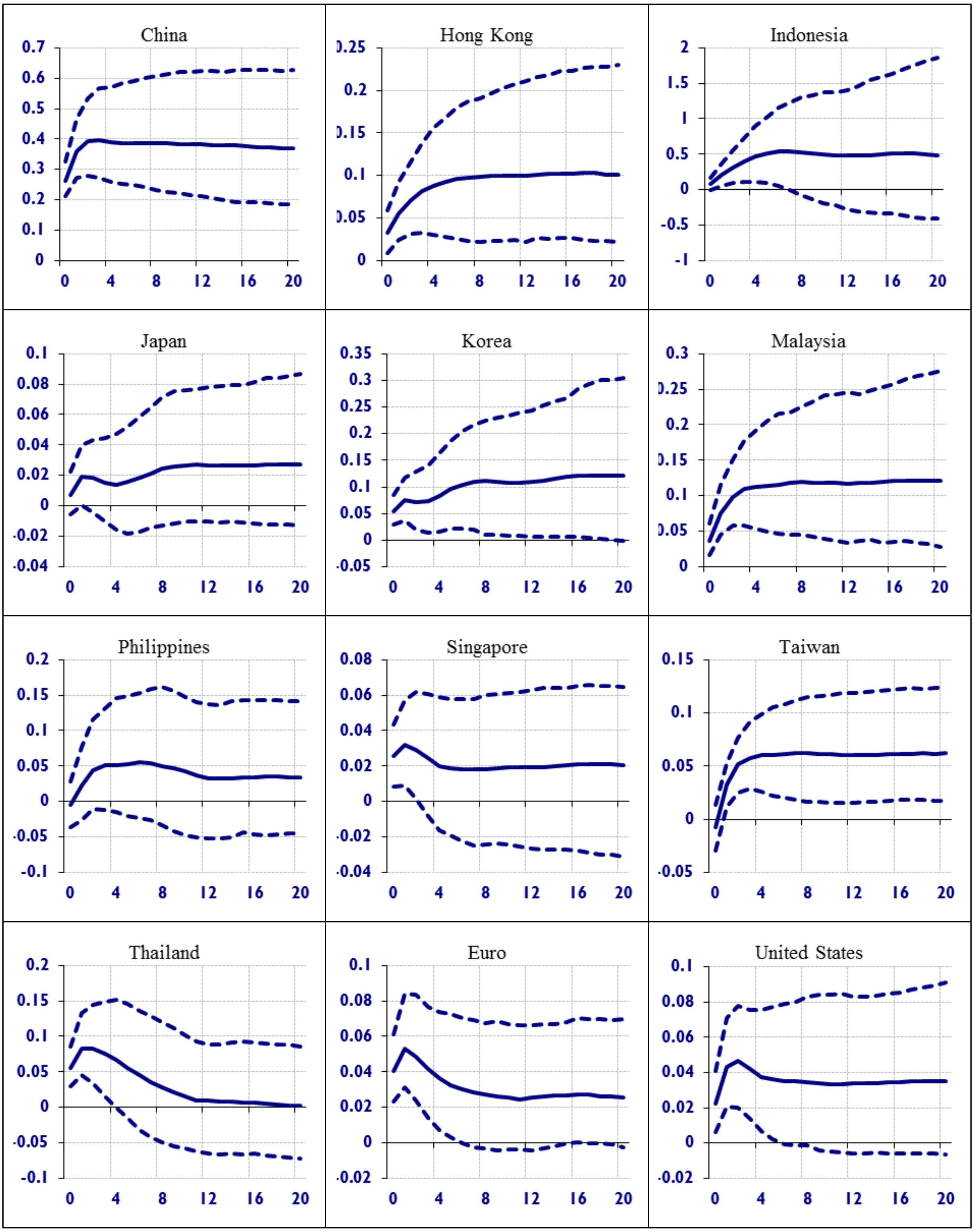

Figure 4.5: GIRFs of Inflation Rates to a Positive U.S. Inflation Shock

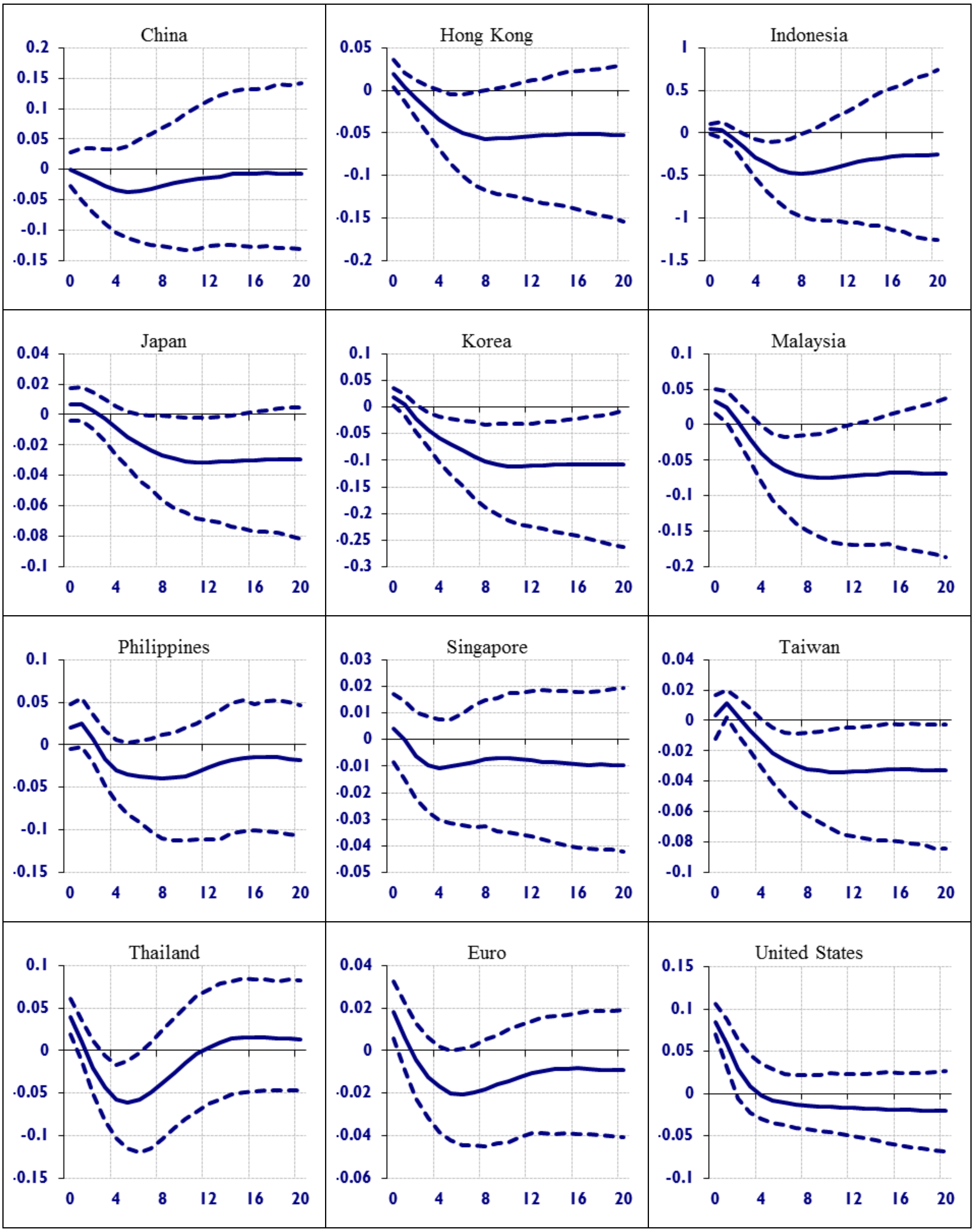

Figure 4.6: GIRFs of Interest Rates to a Positive U.S. Interest Rate Shock

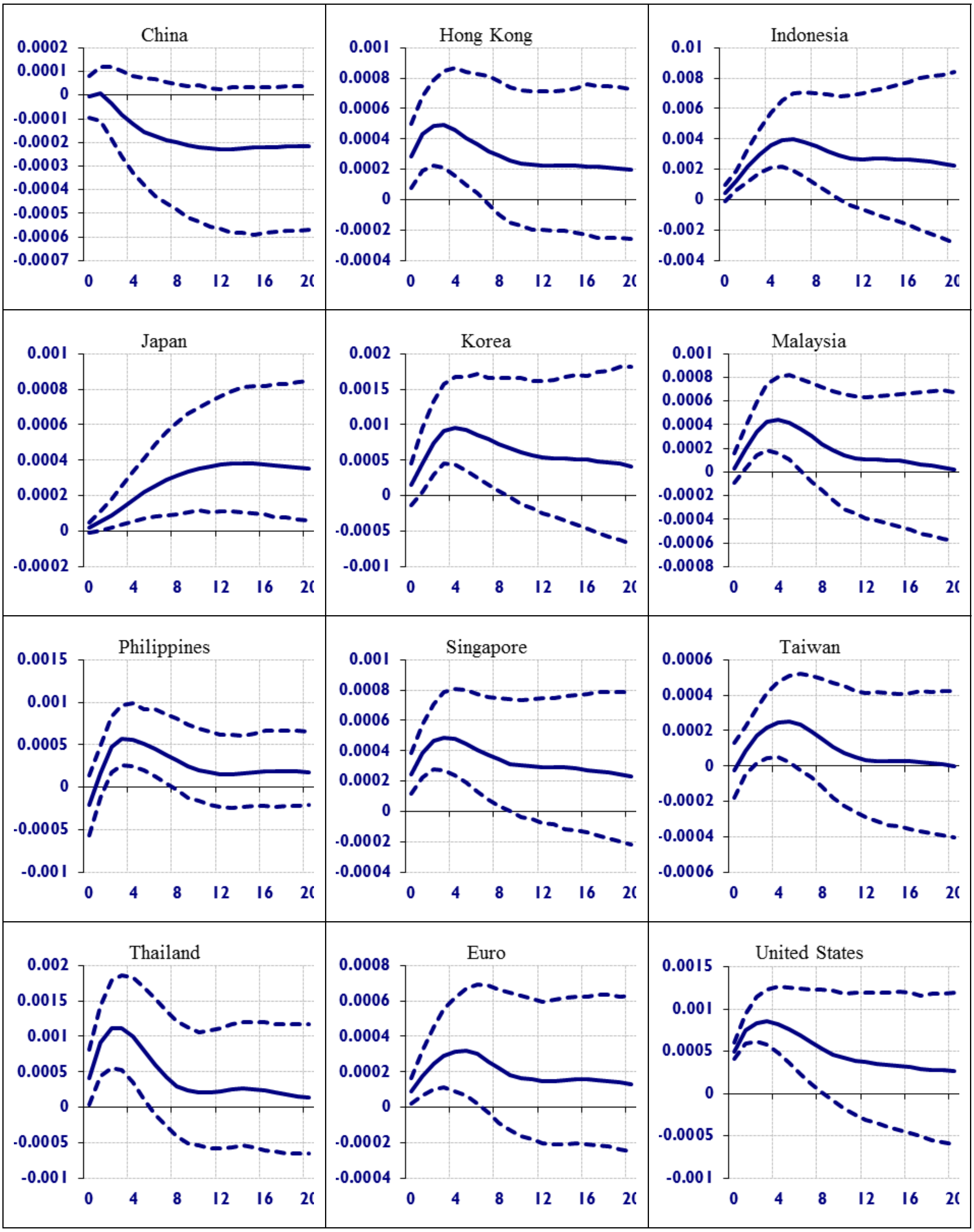

Figure 4.7: GIRFs of Real Output to a Positive Oil Price Shock

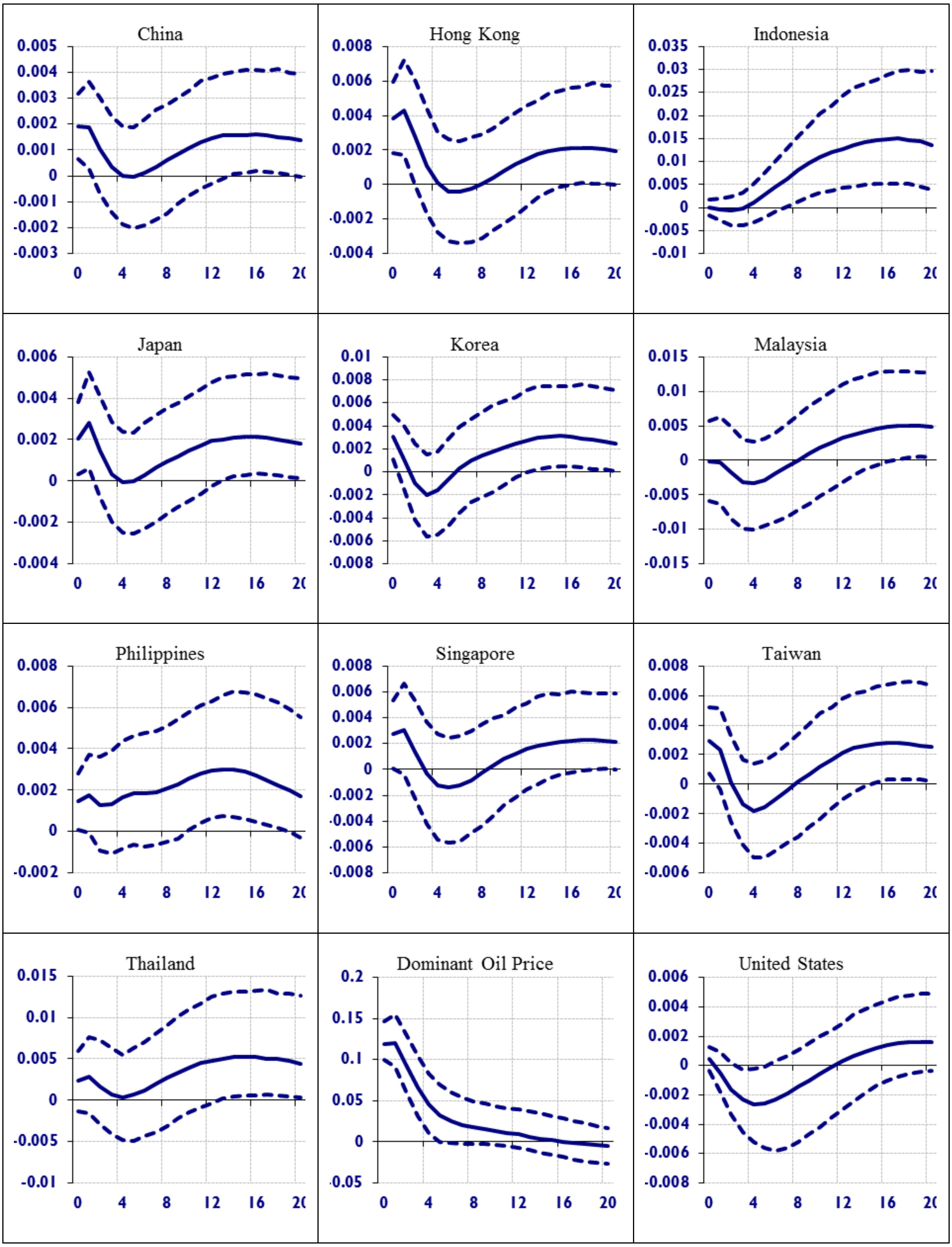

Figure 4.8: GIRFs of Inflation Rates to a Positive Oil Price Shock