The Effects of Productivity Gains and Trade Openness in Asian Emerging Economies: A Global Perspective

ABSTRACT

This paper investigates international responses of key macroeconomic variables to simultaneous shocks to productivity in the traded sector and shocks to trade openness in eight Asian emerging and developing countries. We use panel estimation techniques to construct component sub-models in a thirty country global vector autoregressive (GVAR) model. We identify the shocks by using sign restricted impulse responses. We find that increases in traded-sector productivity in Asian emerging and developing countries have a significant positive effect on economic growth and international trade across countries. An increase in trade openness in Asia leads to long-lasting increases in GDP, particularly in China.

Keywords: International linkages, traded-nontraded productivity differential, openness, global vector autoregressive models, sign restrictions.

1 Introduction

Emerging market economies in Asia have been growing very rapidly in recent decades, transitioning to free-market-oriented economies and gradually integrating with global markets. This economic success was initially known as the "Asian Miracle" when Hong Kong, Singapore, South Korea and Taiwan first started to grow at unprecedented rates. Nowadays, the observation that these and other developing Asian economies have continued to grow has led to the classification of the current century as the "Asian Century". Large economies such as China and India have become major economic forces within Asia and beyond, given the rapid growth in these economies, their expanding markets and their roles in international markets via trade, capital flows and investment. The main drivers of economic growth in these emerging countries include the reallocation of factors to higher productivity sectors and rising global trade, both of which reflect trade liberalization and expanding supply chains (Cubeddu et al (2014)). While it has become clear that emerging Asia's economic progress is having a growing impact on the US, Europe, and the rest of the world, there are many aspects of this growing impact that are not yet documented nor understood.

During the last few decades, many Asian emerging and developing economies have opened their domestic markets to foreign competition in exchange for market access in other countries, adopting an export-led economic growth strategy that relies on high rates of growth in manufactured exports. With this strategy, trade is regarded as an engine of growth, contributing to a more efficient allocation of resources within countries and transmitting growth across countries and regions. It is also considered to be a channel for learning new technologies, leading to capital accumulation and fast productivity growth. However, some have argued that the export strategy that Asian countries have followed has harmed the growth performance of developing countries, because it relies on foreign demand and does not encourage productivity growth arising from domestic demand (see Lawrence and Weinstein (2001), Palley (2002)).

This paper assesses the effects of (positive) shocks to traded-sector productivity in developing Asian economies on key macroeconomic indicators for Asia and the rest of the world. We also assess the effects of increasing openness to trade. In both cases we place an emphasis on how productivity, GDP and exchange rates respond to the shocks, and investigate the importance of traded sector productivity gains and openness in explaining the growth performance in each country.

As an econometric strategy, we use the global vector autoregressive (GVAR) model, originally introduced by Pesaran et al. (2004) and further developed by Dees et al. (2007b) to construct a truly international framework for studying productivity and trade effects. Compared to the existing literature, the use of a GVAR model is more appealing for this study because the GVAR approach can account for interaction between a large number of countries and capture many potential international transmission channels. This is a crucial feature, given that international markets ensure that economic performance of one particular country can be affected not only by a change in its domestic economy, but also by changes in other economies. Therefore, ignoring multi-lateral linkages might lead to invalid conclusions. Also, the inclusion of many countries in the model allows us to answer questions that cannot be tackled in a bi-lateral framework.

We construct a multi-country model composed of thirty countries. This group of countries includes eight Asian emerging and developing countries and another twenty-two countries that represent other developed and developing countries around the globe. Our data set is a panel of annual time series with different time spans, starting from 1970 and extending up to 2008, covering real effective exchange rates, inflation, traded to nontraded productivity differentials, real GDP, government consumption share, openness, short term interest rates, and an oil price index. The individual country models contain domestic variables, country-specific foreign variables and the oil price, where the country-specific foreign variables are constructed as country-specific trade weighted averages of the corresponding domestic variables for all other countries or regions. The country models are constructed separately, but in a way that allows for possible common trends across countries. The key assumption for estimation and inference is that foreign variables and the global oil price variable are weakly exogenous, compatible with a limited degree of weak dependence across idiosyncratic shocks. Individual country models are estimated and then combined into a GVAR using a link matrix that contains country-to-country specific trade weights.

Instead of using a blunt proxy of traded-sector productivity such as per capita GDP, we construct the traded-sector productivity variable by using a newly developed traded-nontraded industrial sector classification (Dumrongrittikul, 2012) which explicitly considers sector-based productivity and price series for each industry. We add to the empirical literature on the behavior of sectoral productivity and aggregate output in a multi-country setting by including both developing and developed countries around the world. The literature related to this field has remained sparse due to the data limitations associated with the developing countries and the difficulties of dealing with the "curse of dimensionality". Here, we specifically analyse the effects of trade related policies in developing Asia on the rest of the world.

Our study is different from the mainstream GVAR literature in two important ways. First, most previous studies have employed generalized impulse response functions (GIRFs), proposed by Koop et al. (1996) and developed by Pesaran and Shin (1998) to examine the international effects of shocks. GIRFs can deal with the cross correlation of shocks within each country and across different countries, but they make economic interpretation difficult because they are associated with a set of non-orthogonalized shocks. We avoid this problem by using economically plausible sign restrictions on impulse response functions to identify the shocks of interest. Second, to the best of our knowledge, this is the first work in the GVAR literature that estimates a country-group model using panel techniques, instead of first aggregating data over the group and then using the aggregated data for estimation. Panel estimation increases the efficiency of parameter estimates and alleviates other estimation issues that arise from the limited data availability for developing countries. Further, after obtaining the panel estimates for a group of countries we can "unpack" the country specific foreign variables in each equation via the link matrix to obtain country specific models that differ.

Our main finding is that productivity gains in the traded sector in Asian developing countries enhance economic growth, inducing a persistent increase in real GDP in many Asian countries. The positive effect on GDP also transmits to other countries and causes a short-run increase in real GDP in many foreign countries. International trade rises in many countries following the shocks. Interestingly, the positive shocks to traded-sector productivity lead to a short-run decline in traded-nontraded productivity differentials for Japan, South Korea and Australia which provide the main source of imports for Asian developing countries, particularly China. This suggests that when Asian developing countries become more productive in traded goods, then other countries shift their production and resources away from traded sectors toward nontraded sectors. In line with Dumrongrittikul and Anderson (2016) and with the commonly made observation that real exchange rates in fast-growing Asian economies have not experienced significant appreciation, real exchange rate reactions do not follow the Balassa (1964) - Samuelson (1964) prediction.

The shocks to trade openness strengthen regional trade linkages and deepen global economic integration in the long run. GDP increases persistently across countries, particularly in China and India, adding support to the often claimed benefits of an export-led growth strategy. Our findings suggest international trade-induced technological spillovers, causing productivity in the traded sectors to rise in US and European countries.

The remainder of the paper is organized as follows. We present the literature most relevant to our study in Section 2 and provide details on the data in Section 3. In Section 4, we set out the country/region-specific models and outline the way that we combine the country/region-specific models into the GVAR framework. Section 5 provides the details of our identification schemes and describes how we obtain the corresponding impulse responses. Section 6 reports the empirical results and Section 7 concludes.

2 Review of the Literature

GVARs were originally developed by Pesaran et al (2004) as a tool for assessing international credit risk, but they have found widespread application in many settings that involve economic interaction between countries, as surveyed by Chudik and Pesaran (2014). Several of these applications have focussed on the effects of oil shocks or the effects of US monetary shocks on European countries and beyond (see, for instance Dees et al (2007b), or Pesaran et al (2007)), but the GVAR literature on shocks originating in Asia is much smaller. Some examples of the latter include Cesa-Bianchi et al (2012), Han et al (2011) and Inoue et al (2015). All of these GVARs rely on GIRFs for inference.

In terms of shock identification, recent research based on standard VARs has employed the sign restriction methodology, developed by Faust (1998) and Uhlig (2005). This approach has become increasingly popular over the recent years because conventional identification approaches require many restrictions, most of which seem too stringent. Most of the sign restricted work on productivity shocks aims to investigate the effects of productivity on labor markets. Dedola and Neri (2007) consider the dynamic effects of such shocks on hours worked, inflation and the short-term interest rate in the US. Similarly, Peersman and Straub (2009) focus on hours worked and employment in the Euro Area. There are only a few studies on how overall economic activity reacts to productivity shocks that use a sign restricted impulse response approach. Corsetti et al. (2014) use a sign-identified VAR model of the US economy and a G7 aggregate to identify a shock to tradable goods productivity, accounting for international transmission with the use of all the variables in the form of cross-country differentials. Similarly, Enders et al. (2011) estimate a VAR model of the US relative to an aggregate of industrialised countries and they derive sign restrictions based on a quantitative general equilibrium model using a wide range of plausible model parameterisations.

In short, we add to the currently sparse empirical literature on the effects of traded-sector productivity and openness shocks. The existing literature on identifying traded sector productivity shocks has relied on two-country models ("Home" and "Foreign") and has focused on industrialized countries. Here we study the world-wide responses to simultaneous shocks to productivity in traded sectors relative to nontraded sectors in eight Asian emerging and developing economies (China, India, Indonesia, Thailand, Philippines, Malaysia, Pakistan, and Sri Lanka). We also study the international repercussions of simultaneous increases in openness in these eight Asian countries. We have paid careful attention to the construction of the traded-nontraded productivity variable by using the method introduced by Dumrongrittikul (2012) for classifying industries, and careful attention to the identification of traded sector productivity and openness shocks.

3 Data

We employ the traded-nontraded good classification in Dumrongrittikul (2012) and the data used in Dumrongrittikul and Anderson (2016). We base our analysis on thirty countries and use annual time series with different time dimensions from 1970 to 2008. Following Pesaran et al. (2004), we treat five countries (France, Germany, Italy, Netherlands and Spain) that are in the euro area as a single economy. In particular, domestic variables of this region are constructed as a weighted average of corresponding country-specific series using the weights based on a ratio of country's PPP-adjusted GDP to the total PPP-adjusted GDP of these five countries. See Table B1 for the list of countries that are used in this application.

We consider the following variables in the model: the logarithm of the real effective exchange rate ($q_{i,t}$); the inflation rate ($\pi_{i,t} = p_{i,t} - p_{i,t-1}$ where $p_{i,t}$ is the logarithm of the consumer price index); the logarithm of the ratio of traded to nontraded productivity measures ($x_{i,t}$); the logarithm of real GDP ($y_{i,t}$); the logarithm of the ratio of government consumption to GDP ($gov_{i,t}$); the logarithm of the openness of the economy ($open_{i,t}$), measured as the ratio of the sum of exports and imports to GDP; the nominal interest rate ($si_{i,t} = \ln(1 + NI_{i,t}/100)$ where $NI_{i,t}$ is the short-term interest rate per annum measured as a percentage); and the log oil price index (oil_t). The data set and details about data sources are available online at https://github.com/farshid-vahid/gvar-productivity.

4 Global VAR Modelling

We consider $N + 1$ countries or regions, indexed by $i = 0, 1, 2, ..., N$, in the global model, with the US being treated as the reference country and labelled country 0. Throughout this analysis, we use a superscript * for foreign variables and no superscript for domestic variables (except the oil price, oil_t). Let $g_{i,t}$ be a $k_i \times 1$ vector of domestic variables, and $g^*_{i,t}$ be a $k^*_i \times 1$ vector that contains country-specific foreign variables and the oil price. Following Pesaran et al. (2004), the country-specific foreign variables are constructed as a weighted average of other countries' corresponding domestic variables:

$$g^*_{i,j,t} = \sum_{l=0}^{N} w_{i,l}\, g_{l,j,t}, \quad i = 0, 1, 2, ..., N,$$

where $g_{i,j,t}$ ($g^*_{i,j,t}$) is the element of $g_{i,t}$ ($g^*_{i,t}$) corresponding to variable j. Following the mainstream GVAR literature, we use a weighting scheme based on bilateral trade exposure (average trade shares over the period 2002 - 2008).[1] In particular, $w_{i,l}$ is the ratio of the total trade between country i and country l to the total trade of country i with all of its trade partners, such that $w_{i,i} = 0$ and $\sum_{l=0}^{N} w_{i,l} = 1$. In this application $N = 25$.

[1] The matrix of trade weights used for constructing the country-specific foreign variables is available online at https://github.com/farshid-vahid/gvar-productivity.

Our model uses the real effective exchange rate $q_{i,t}$, defined following Dees et al. (2007a) as

$$\begin{aligned} q_{i,t} &= \sum_{l=0}^{N} w_{i,l}(e_{i,t} - e_{l,t}) + p^*_{i,t} - p_{i,t} \\ &= \overleftrightarrow{e}_{i,t} - \overleftrightarrow{e}^*_{i,t}, \end{aligned}$$

where $\overleftrightarrow{e}_{i,t} = e_{i,t} - p_{i,t}$, $\overleftrightarrow{e}^*_{i,t} = e^*_{i,t} - p^*_{i,t}$, $e_{i,t}$ is the nominal exchange rate in terms of domestic currency relative to the US dollar and $p_{i,t}$ is the consumer price index (CPI).

Given the nature of macroeconomic variables, we treat all domestic variables as endogenous. For $i = 1, 2, ..., N$, the set of endogenous variables is

$$g_{i,t} = (q_{i,t}, \pi_{i,t}, x_{i,t}, y_{i,t}, gov_{i,t}, open_{i,t}, si_{i,t})',$$

and the set of weakly exogenous variables is

$$g^*_{i,t} = (\pi^*_{i,t}, x^*_{i,t,}, y^*_{i,t}, gov^*_{i,t}, si^*_{i,t}, oil_t)'.$$

For $i = 0$ (the US model), the set of endogenous variables is

$$g_{0,t} = (\pi_{0,t}, x_{0,t}, y_{0,t}, gov_{0,t}, open_{0,t}, si_{0,t}, oil_t)',$$

and the set of weakly exogenous variables is

$$g^*_{0,t} = (\overleftrightarrow{e}^*_{0,t}, \pi^*_{0,t}, x^*_{0,t}, y^*_{0,t}, gov^*_{0,t})'.$$

For all country-specific models except the US model, we include the real effective exchange rate ($q_{i,t}$), the inflation rate ($\pi_{i,t}$), the traded-nontraded productivity differential ($x_{i,t}$), real output ($y_{i,t}$), the government consumption share ($gov_{i,t}$), the openness of the economy ($open_{i,t}$) and the nominal interest rate ($si_{i,t}$) as endogenous variables. All non-US models contain the foreign inflation rate ($\pi^*_{i,t}$), the foreign traded-nontraded productivity differential ($x^*_{i,t}$), the foreign real output ($y^*_{i,t}$), the foreign government consumption share ($gov^*_{i,t}$), the foreign nominal interest rate ($si^*_{i,t}$) and oil prices (oil_t) as weakly exogenous variables. Foreign government consumption is included as a proxy for foreign debt accumulation. In the case of the US model, we do not impose the same specification as that for other countries. Specifically, the US foreign interest rate variable ($si^*_{0,t}$) is not included in the US model because of the dominance of the US financial market in the global economy. The oil price variable (oil_t) is included as endogenous in order to allow other variables to influence oil prices. The variable $\overleftrightarrow{e}^*_{0,t}$ is treated as exogenous in the US model since US is the base economy.

4.1 Individual Country/Region-Specific Models

Unlike the existing GVAR literature, we estimate individual models on a country-group basis, instead of a country-by-country basis. This is because some of our country series are very short and panel data methods can improve the efficiency of our estimated coefficients. In particular, we divide our country set into four panels according to region and the level of economic development, where the four panels include European, non-European developed, Asian developing and non-Asian developing country groups (with the exception of the US). See Table B1 for details of the countries in each group. Then we apply the within-group estimation technique to estimate each country group model separately.[2] This technique relies on the restrictions that the long-run and short-run coefficients in the model for each country from the same country group are the same, but it allows country-specific intercepts to be different across different countries. This assumption seems appropriate in light of the fact that each group consists of country members with similar features. Once we have estimated the model for each country group, we treat each country equation in that group as if it had been estimated separately. We estimate the US country-specific model separately because the US model has a different specification from that of other countries. After presenting our main results, we comment on the sensitivity of the results to country grouping.

When constructing individual country models, we assume that all economies, with the exception of the US, are small relative to the world economy so that the foreign and global variables in each individual country model satisfy the assumption of weak exogeneity. This is the main requirement for estimation, when using the GVAR modelling approach. The validity of such an assumption depends on the relative sizes of the countries/regions in the global model and on whether the idiosyncratic shocks of the individual country models are cross-sectionally weakly correlated. Later, we discuss formal tests of weak exogeneity for foreign and global variables and provide the test results, which support the weak exogeneity assumption.

We use augmented vector autoregressive (VARX*) models with a second-order dynamic specification for domestic variables and a first-order dynamic specification for foreign variables in all individual country models. This choice was dictated by the small number of available time series observations and it corresponds to the GVAR literature, most of which allows a maximum lag of two in the model. The VARX*(2,1) specification for each country i can be written as

$$g_{i,t} = h_{i,0} + \Phi_{i,1} g_{i,t-1} + \Phi_{i,2} g_{i,t-2} + \Psi_{i,0} g^*_{i,t} + \Psi_{i,1} g^*_{i,t-1} + u_{i,t} \tag{1}$$

[2] Alvarez and Arellano (2003) and Judson and Owen (1999) show that within-group estimation seems to have better performance than other methods for sizes of T and N close to our data set.

for $i = 0, 1, 2, ..., N$, and $t = 1, 2, ..., T$, where $g_{i,t}$ is a $k_i \times 1$ vector of $I(1)$ endogenous variables, $g^*_{i,t}$ is a $k^*_i \times 1$ vector of $I(1)$ weakly exogenous variables, $h_{i,0}$ is a $k_i \times 1$ vector of constant terms, $\Phi_{i,1}$ and $\Phi_{i,2}$ are $k_i \times k_i$ matrices of coefficients associated with lagged endogenous variables, $\Psi_{i,0}$ and $\Psi_{i,1}$ are $k_i \times k^*_i$ matrices of coefficients associated with weakly exogenous variables, and $u_{i,t}$ is a $k_i \times 1$ vector of idiosyncratic country-specific shocks. We assume that $u_{i,t}$ is serially uncorrelated with mean zero and a nonsingular variance-covariance matrix $\Sigma_{u,i}$, i.e. $u_{i,t} \sim iid(0, \Sigma_{u,i})$. However, we allow these shocks to be contemporaneously correlated across countries or regions to a limited degree.

The corresponding conditional vector error correction model (VECMX*) is given by

$$\Delta g_{i,t} = h_{i,0} - \Pi_i z_{i,t-1} - \Phi_{i,2} \Delta g_{i,t-1} + \Psi_{i,0} \Delta g^*_{i,t} + u_{i,t}, \tag{2}$$

where

$$\Pi_i = (I - \Phi_{i,1} - \Phi_{i,2}, -\Psi_{i,0} - \Psi_{i,1}) \text{ and } z_{i,t-1} = \left(g'_{i,t-1}, g^{*'}_{i,t-1}\right)'.$$

The cointegrating relationship among variables is summarized in a $k_i \times (k_i + k^*_i)$ matrix Π_i. Suppose that the rank of Π_i is $r_i \leq k_i$, implying that there exist r_i long-run relationships among the domestic and country-specific foreign variables. The matrix $\Pi_i = \alpha_i \beta'_i$, where α_i is a $k_i \times r_i$ loading matrix of full column rank and β_i is a $(k_i + k^*_i) \times r_i$ matrix of cointegrating vectors of rank r_i. In this paper, we use panel dynamic OLS (DOLS) to estimate cointegrating vectors $\widehat{\beta}_i$, where the panel includes all countries in the same country group as country i. Conditional on $\widehat{\beta}_i$, we estimate the remaining parameters of the VECMX* by using OLS.

Equation (1) can be rewritten in terms of $z_{i,t}$ as

$$L_{i,0} z_{i,t} = h_{i,0} + L_{i,1} z_{i,t-1} + L_{i,2} z_{i,t-2} + u_{i,t}, \tag{3}$$

where

$$L_{i,0} = (I_{k_i}, -\Psi_{i,0}), \ L_{i,1} = (\Phi_{i,1}, \Psi_{i,1}) \text{ and } L_{i,2} = (\Phi_{i,2}, \Psi_{i,2})$$

so that estimates of (3) can be deduced from estimates of (2). Note that $\Psi_{i,2} = 0_{k_i \times k^*_i}$, and $L_{i,0}, L_{i,1}$ and $L_{i,2}$ are $k_i \times (k_i + k^*_i)$ matrices with the condition that $L_{i,0}$ has full row rank for $i = 0, 1, ..., N$. Also note that any cross equation restrictions that are imposed on the panel version of (1) during estimation will imply corresponding structure on the $L_{i,0}, L_{i,1}$ and $L_{i,2}$ for all i in the same country group.

4.2 Constructing the GVAR Model

Special techniques are needed to combine the individual country models into the GVAR model owing to the differences between the US model and the models for the remaining countries. Let $k = \sum_{i=0}^{N} k_i$ be the total number of endogenous variables in the global model and define a $(k+1) \times 1$ vector of the global variables, $\overset{\circ}{g}_t$ as

$$\overset{\circ}{g}_t = (\overleftarrow{g}'_{0,t}, \widetilde{g}'_{1,t}, ..., \widetilde{g}'_{N,t})',$$

with

$$\overleftarrow{g}_{0,t} = (\overleftrightarrow{e}_{0,t}, \pi_{0,t}, x_{0,t}, y_{0,t}, gov_{0,t}, open_{0,t}, si_{0,t}, oil_t)',$$

and

$$\widetilde{g}_{i,t} = (\overleftrightarrow{e}_{i,t}, \pi_{i,t}, x_{i,t,}, y_{i,t}, gov_{i,t}, open_{i,t}, si_{i,t})', \;\; i = 1, 2, ..., N.$$

As set out above, the total number of elements in $\overset{\circ}{g}_t$ is one more than the total number of endogenous variables in the global model because $\overset{\circ}{g}_t$ includes $\overleftrightarrow{e}_{0,t}$ which is not an endogenous variable in the US model. Note that $e_{0,t} = 0$ and hence $\overleftrightarrow{e}_{0,t} = e_{0,t} - p_{0,t} = -p_{0,t}$, which will be the first element of the vector $\overset{\circ}{g}_t$. It is easy to see that the vector $z_{i,t}$ can be written in terms of $\overset{\circ}{g}_t$ as

$$z_{i,t} = W_i \overset{\circ}{g}_t, \tag{4}$$

where W_i for $i = 0, 1, 2, ..., N$ are $(k_i + k_i^*) \times (k+1)$ matrices of fixed known constants called the "link" matrices, defined in terms of the country-specific weights. The link matrices play an important role in linking up all country-specific models to construct the GVAR model.

Substituting $z_{i,t}$ from (4) into (3), we can write equation (3) as

$$L_{i,0} W_i \overset{\circ}{g}_t = h_{i,0} + L_{i,1} W_i \overset{\circ}{g}_{t-1} + L_{i,2} W_i \overset{\circ}{g}_{t-2} + u_{i,t}, \;\;\; i = 0, 1, 2, ..., N, \tag{5}$$

where $L_{i,j} W_i$ are $k_i \times (k+1)$ matrices for $j = 0, 1, 2$. Stacking these equations yields

$$\overset{\circ}{H}_0 \overset{\circ}{g}_t = h_0 + \overset{\circ}{H}_1 \overset{\circ}{g}_{t-1} + \overset{\circ}{H}_2 \overset{\circ}{g}_{t-2} + u_t, \tag{6}$$

where

$$\overset{\circ}{H}_j = \begin{pmatrix} L_{0,j} W_0 \\ L_{1,j} W_1 \\ \vdots \\ L_{N,j} W_N \end{pmatrix} \text{ for } j = 0, 1, 2, \;\; h_0 = \begin{pmatrix} h_{0,0} \\ h_{1,0} \\ \vdots \\ h_{N,0} \end{pmatrix}, \text{ and } u_t = \begin{pmatrix} u_{0,t} \\ u_{1,t} \\ \vdots \\ u_{N,t} \end{pmatrix} \sim iid(0, \Sigma_u).$$

$\overset{\circ}{H}_j$ is a $k \times (k+1)$ matrix, h_0 is a $k \times 1$ vector of country-specific intercepts and u_t is a $k \times 1$ vector of reduced-form residuals. To solve for the endogenous variables of the global model, we define the $k \times 1$ vector g_t of global endogenous variables as

$$g_t = \left(\widetilde{g}'_{0,t}, \widetilde{g}'_{1,t}, ..., \widetilde{g}'_{N,t}\right)',$$

where

$$\widetilde{g}_{0,t} = (p_{0,t}, x_{0,t}, y_{0,t}, gov_{0,t}, open_{0,t}, si_{0,t}, oil_t)',$$

and

$$\widetilde{g}_{i,t} = (\overleftrightarrow{e}_{i,t}, \pi_{i,t}, x_{i,t,}, y_{i,t}, gov_{i,t}, open_{i,t}, si_{i,t})', \ i = 1, 2, ..., N.$$

The vector g_t differs from $\overset{\circ}{g}_t$ because it does not include $\overleftrightarrow{e}_{0,t}$. Note that the first element of $\overset{\circ}{g}_t$ is $\overleftrightarrow{e}_{0,t}$ is equal to $-p_{0,t}$, so solving the GVAR model involves solving for the US price level $p_{0,t}$ rather than inflation $\pi_{0,t}$ in the vector g_t of global endogenous variables. We can write $\overset{\circ}{g}_t$ in terms of g_t as

$$\overset{\circ}{g}_t = S_0 g_t - S_1 g_{t-1}, \tag{7}$$

where $(k+1) \times k$ matrices of S_j for $j = 0, 1$ are given by

$$S_0 = \begin{pmatrix} -1 & 0_{1\times(k-1)} \\ 1 & 0_{1\times(k-1)} \\ 0_{(k-1)\times 1} & I_{(k-1)} \end{pmatrix} \text{ and } S_1 = \begin{pmatrix} 0 & 0_{1\times(k-1)} \\ 1 & 0_{1\times(k-1)} \\ 0_{(k-1)\times 1} & 0_{(k-1)\times(k-1)} \end{pmatrix}.$$

Substituting $\overset{\circ}{g}_t$ from equation (7) into (6), we have

$$H_0 g_t = h_0 + H_1 g_{t-1} + H_2 g_{t-2} + H_3 g_{t-3} + u_t, \tag{8}$$

where

$$H_0 = \overset{\circ}{H}_0 S_0, \ H_1 = \overset{\circ}{H}_1 S_0 + \overset{\circ}{H}_0 S_1, \ H_2 = \overset{\circ}{H}_2 S_0 - \overset{\circ}{H}_1 S_1, \ H_3 = -\overset{\circ}{H}_2 S_1.$$

Then the GVAR model can be written as

$$g_t = a_0 + F_1 g_{t-1} + F_2 g_{t-2} + F_3 g_{t-3} + \varepsilon_t, \tag{9}$$

where $F_j = H_0^{-1} H_j$ for $j = 1, 2, 3$, $a_0 = H_0^{-1} h_0$, and $\varepsilon_t = H_0^{-1} u_t$.

5 Shock Identification Using Sign Restrictions

We implement sign restrictions in the context of our global framework to identify simultaneous productivity improvement shocks and simultaneous trade openness shocks in eight Asian emerging economies. With this approach, we can identify a particular economic shock by imposing a small set of a priori restrictions that are widely agreed upon by many economists. There are three main advantages of using this approach in the context of our global model. First, the sign restriction approach allows us to concentrate on identifying just a subset of structural innovations of interest. This is useful because the identification of all the shocks required for conventional identification schemes may be impossible in a multi-country model that includes a large number of endogenous variables. Second, one can easily increase the number of sign restrictions to help identify the structural shocks in question, when working with the global context. This leads to stronger results than those in the mainstream sign-restriction literature, most of which is based on VARs in a closed-economy setting. Third, we can obtain results that are invariant to the ordering of the variables and the countries in the GVAR.

Consider the reduced-form VAR model (9), where $\varepsilon_t = H_0^{-1}u_t$, u_t is a $k \times 1$ vector of reduced-form errors, and its fundamental moving average representation is

$$g_t = d_t + \sum_{j=0}^{\infty} B_j \varepsilon_{t-j} = d_t + \sum_{j=0}^{\infty} B_j H_0^{-1} u_{t-j}, \tag{10}$$

where d_t is the deterministic component of g_t. Our interest is to obtain impulse responses to economically meaningful structural shocks. For country i, we adopt the usual assumption that there are k_i mutually independent structural shocks with unit variances. Hence, if we denote these shocks by $v_{i,t}$, we have $v_{i,t} = A_i^{-1}u_{i,t}$ with $A_i A_i' = \Sigma_{u,i}$ for $i = 0, \ldots, N$. The GVAR framework includes country-specific foreign variables in each individual country model to capture the cross-country correlations, and they are viewed as proxies for the common global factors. We assume that this sufficiently accounts for cross correlation in variables among different countries and any remaining correlation in shocks across countries is weak and incidental. We provide supporting empirical evidence on this issue in Section 6.3. As a result, the mapping between structural and reduced form shocks can be written as

$$A = \begin{bmatrix} A_0 & 0 & \cdots & 0 & 0 \\ 0 & \ddots & & & 0 \\ \vdots & & A_i & & \vdots \\ 0 & & & \ddots & 0 \\ 0 & 0 & \cdots & 0 & A_N \end{bmatrix},$$

and the $k \times k$ matrix $r(h)$ of impulse responses of all endogenous variables in the GVAR to k underlying shocks v_t at horizon h would be

$$r(h) = B_h H_0^{-1} A, \tag{11}$$

where the b^{th} row and a^{th} column element of the matrix $r(h)$ represents the impulse response of the b^{th} endogenous variable to a shock to the a^{th} endogenous variable in the GVAR. However, the requirement that $A_i A_i' = \Sigma_{u,i}$ for $i = 0, \ldots, N$ is not sufficient for the identification of A. Instead of identifying a unique A, we identify a set of possible A matrices that lead to impulse responses that satisfy a set of plausible sign restrictions.

We identify a set of impulse responses that satisfy pre-specified sign restrictions by using the procedure suggested by Rubio-Ramirez et al. (2010) and implemented by Eickmeier and Ng (2011) in the GVAR context. The basis of this procedure is the fact that any matrix A_i such that $\Sigma_{u,i} = A_i A_i'$ can be written as $\overrightarrow{A}_i M_i$ where $\overrightarrow{A}_i$ is the lower triangular Cholesky factor of $\Sigma_{u,i}$ and M_i is an orthonormal matrix. We therefore start with computing $\overrightarrow{A}_i$, the lower triangular Cholesky factor of the covariance matrix of residuals for each country model i for $i = 0, 1, 2, ..., N$. We then focus on shocks originating from a country of interest, say country j. Let $r_j(h)$ be the impulse response of all endogenous variables in the GVAR at horizon h to all the shocks originating in country j. We examine a wide range of possible choices for A_j by repeatedly drawing $k_j \times k_j$ orthonormal rotation matrices M_j and checking the corresponding impulse responses for each draw. If the candidate impulse responses satisfy a set of a priori identifying restrictions on the impulse response functions, we retain M_j. Otherwise, we discard M_j. We repeat this procedure until we retain 200 valid M_js. These 200 M_js produce 200 values for the impulse response function at each horizon. We report the median and 16^{th} and 84^{th} percentiles of these values for each horizon.

In our study, we are interested in the effect of simultaneous shocks to the eight Asian emerging economies. We repeat the above process for all the eight countries shocked. As we define a composite shock as a linear combination of country variable-specific shocks across the eight countries, we then compute the responses of the composite shock as weighted averages of the responses to a country variable-specific shock in these countries, using PPP-adjusted GDP weights that reflect the relative importance of each country within the world economy.

5.1 Shock Identification Assumptions

Our identification strategy simply requires restrictions on the short-run impulse responses of a small set of variables whose responses to a given shock are unambiguous according to theoretical predictions and conventional views. The responses of variables that can be subject to debate are left unconstrained.

The restrictions used for identifying a shock to productivity improvement in the traded sector are derived from the production function. The shock can be viewed as a supply shock. Thus, we consider productivity shocks in traded sectors as shocks that not only raise the traded good vs nontraded good productivity differential on impact but which also raise real output on impact. Note that although an increase in the traded good vs nontraded good productivity differential could possibly be induced by a decline in productivity in nontraded goods, one would expect real output decline in that case, and our restriction that output must increase precludes this scenario.

Our restrictions set the scene for examining the Balassa-Samuelson hypothesis (BSH), that predicts that productivity gains in the traded sector will lead to higher economic growth and an appreciation of the real exchange. Our restrictions allow both the traded good productivity and output to rise, but leave the real exchange unrestricted so that we can examine its response. There are several debates regarding real exchange rate behavior in fast growing countries in Asia, and it is this that motivates us to examine the effects of simultaneous productivity shocks in China, India, Indonesia, Thailand, Philippines, Malaysia, Pakistan, and Sri Lanka, which are now emerging and developing economies in Asia. To model this composite shock, our short-run restrictions are imposed simultaneously on the impulse responses of productivity and real output for these eight countries.

We also examine the effects of opening up a country's markets in developing and emerging Asia to the international market. We define an openness shock as a shock that causes an unexpected rise in the size of international trade relative to GDP and an increase in real GDP on impact. This set of restrictions on short-run impulse responses is imposed simultaneously for the eight Asian countries. The total trade to GDP is commonly used as a measure of trade openness. The restrictions on openness and GDP are consistent with the so-called export-led growth hypothesis, that stipulates that exports stimulate growth.

In our analysis, we identify traded-sector productivity and trade openness shocks simultaneously, requiring that both be present in the data and be orthogonal to each other. In particular, we impose the orthogonality condition to help identify the shock by filtering out the contemporaneous responses of each variable to other shocks. In this respect, our identification strategy limits the risk that our results combine the effects of several shocks.

6 Empirical Investigation

6.1 Preliminary Analysis

Each domestic and foreign variable for each of the 30 countries is tested for the presence of a unit root by using both time series and panel unit root tests.[3] As a result, we treat all domestic and foreign variables - the real effective exchange rate ($q_{i,t}$), the inflation rate ($\pi_{i,t}$), the traded-nontraded productivity differential ($x_{i,t}$), real output ($y_{i,t}$), the government consumption share ($gov_{i,t}$), the openness of the economy ($open_{i,t}$), the nominal interest rate ($si_{i,t}$) and oil prices (oil_t) - as I(1) except for measures of domestic inflation in Asian developing countries and in the US that are considered as I(0).

We conduct tests for specific long-run relationships suggested by economic theory including PPP, the Fisher equation, output convergence, UIP and a real exchange rate relationship derived from the BSH and the Edwards (1989) model separately by using Pedroni (1999) panel cointegration tests for each country group. We then consider two possible choices of long-run relationships that are (1) coefficients suggested by economic theory; and (2) cointegrating vectors estimated by panel DOLS, developed by Mark and Sul (2003). Following Garratt et al. (2006), we base the final choice of long-run relationships in the four country group models and in the US model in our GVAR on a satisfactory performance of the GVAR model in terms of its stability. Based on these criteria, the final set of long-run relationships for each country group and the US model is summarized and presented in Table 1.

Persistence profiles (defined in Pesaran and Shin (1996)) that measure the speed of convergence to long-run equilibrium after any system shock, are all well-behaved and eventually return to zero, supporting our choice of the long-run relationships in Table 1. These profiles are not reported to save space, but they are available upon request.

The BSH and Edwards relationships reported in Table 1 suggest that an increase in the degree of openness in most country groups is associated with a real depreciation, and higher government consumption is associated with a real appreciation after controlling for other factors. Note that we add the last column named inflation because the data suggests that inflation in Asian developing countries and in the US is stationary and therefore can be viewed as being cointegrated with itself. We estimate individual models for each country group employing the set of over-identifying long-run restrictions provided in Table 1, and then we separate them out into individual country-specific models prior to undertaking impulse response analysis.

[3] We do not report the detailed results of unit root and cointegration tests here, but these results are available upon request.

Table 1: Over-identifying long-run relations for each individual model

Country groups	Fisher	UIP	BSH and Edwards model	Inflation
European countries	-	$si_{i,t} - 0.641 si^*_{i,t}$ (0.073)	$q_{i,t} + 0.439(x^*_{i,t} - x_{i,t}) - 0.145(y^*_{i,t} - y_{i,t})$ (0.086) (0.049) $+0.137 open_{i,t} - 0.683(gov^*_{i,t} - gov_{i,t})$ (0.120) (0.196)	-
Non-European developed countries	-	$si_{i,t} - 0.940 si^*_{i,t}$ (0.228)	$q_{i,t} + 0.247(x^*_{i,t} - x_{i,t}) + 0.110(y^*_{i,t} - y_{i,t})$ (0.065) (0.043) $-0.685 open_{i,t} + 0.213(gov^*_{i,t} - gov_{i,t})$ (0.065) (0.153)	-
Asian developing countries	-	$si_{i,t} - si^*_{i,t}$	$q_{i,t} + 0.539(y^*_{i,t} - y_{i,t}) - 0.071 open_{i,t}$ (0.074) (0.056) $-0.276(gov^*_{i,t} - gov_{i,t})$ (0.097)	$\pi_{i,t}$
Non-Asian developing countries	$si_{i,t} - \pi_{i,t}$	-	$q_{i,t} - 0.119(x^*_{i,t} - x_{i,t}) - 0.302(y^*_{i,t} - y_{i,t})$ (0.119) (0.212) $-0.048 open_{i,t} - 0.425(gov^*_{i,t} - gov_{i,t})$ (0.159) (0.136)	-
US	-	-	-	$\pi_{0,t}$

Notes: An increase (a fall) in the value of the real exchange rate $q_{i,t}$ represents real depreciation (appreciation).

6.2 Contemporaneous Effects of Foreign Variables on their Domestic Counterparts

Table B2 in Appendix B reports the estimates of impact elasticities of foreign variables on corresponding domestic variables, derived from the coefficient estimates associated with first differenced contemporaneous foreign variables, $\Psi_{i,0}$ in model (2). These elasticities measure the percentage change in a domestic variable caused by a one percent change in its corresponding foreign counterpart, and they show general co-movement among variables across different countries.

Our results show that all the elasticities relating to inflation and nominal interest rates are statistically significant, indicating strong linkages between financial variables across different regions. Looking at short-term interest rates, all contemporaneous elasticities have a positive sign. This implies contemporaneous co-movement between financial markets and cross-country monetary policy reactions, i.e. a change in the monetary policy employed by foreign countries may influence monetary policy in a domestic country within the same period. In particular, a 1 percent increase in foreign nominal interest rates can lead to a rise of 0.9 percent in nominal interest rates in non-Asian developing countries.

The estimates of foreign inflation effects suggest that there is co-movement in inflation across countries. Impact elasticities are greater in developing countries than those in developed countries, revealing a stronger effect of foreign inflation on domestic inflation in developing countries. For the European group and the US, we find low elasticities for inflation, suggesting that prices in the European group and in the US are not greatly affected by changes in foreign inflation in the short run. This finding is in line with the general idea that the transmission channel of inflation from large to small economies is unidirectional.

The estimates of foreign government consumption shares are positive and significant in European and Asian countries, suggesting some degree of co-movement in fiscal policy in these countries. Most elasticities of productivity differentials and real GDP are small and insignificant. This is consistent with our expectation that real variables will react quite slowly to a change in foreign variables.

6.3 Weak Exogeneity of Foreign Variables and Cross-country Correlation

We test the validity of weak exogeneity assumption for the foreign variables and the oil price. Following Johansen (1992) and Granger and Lin (1995), this assumption means that there is no long-run force from $g_{i,t}$ to $g^*_{i,t}$, regardless of lagged short-run effects between these variables. We can indirectly check this assumption by testing the joint significance of the estimated error correction terms in the auxiliary models for the country-specific foreign variables, $g^*_{i,t}$ (See Dees et al. (2007b) for details). Note that we test weak exogeneity on a country-group basis. Table B3 in Appendix B provides the test results. They show that most of the foreign variables and the oil price can be considered as weakly exogenous in the individual models. The weak exogeneity hypothesis is rejected only for inflation in the non-Asian developing country group, but this single result is unconvincing given the other results. In addition to our formal tests we also inspected the average pair-wise cross-section correlations for the endogenous variables and then the corresponding cross-section correlations in individual country VECMX* residuals. We found substantial cross-section correlations between the endogenous variables, but the cross-section correlations of the associated residuals were much lower, especially in the case of output where the correlations fell from 92 percent to 2 percent on average. While the observed patterns for real exchange rates provide an exception (as was also the case in Dees et al (2007b)), these findings are consistent with a conclusion that the inclusion of foreign variables in the models helps to capture the cross-section correlations and common effects across countries, leaving the models with just a modest degree of correlation across the idiosyncratic shocks.

6.4 Impulse Response Analysis

We compute the impulse responses of each country in the GVAR using sign restrictions to identify a one standard deviation composite shock to the productivity differential between traded and nontraded sectors and a composite shock to openness in eight developing economies (China, India, Indonesia, Thailand, Philippines, Malaysia, Pakistan, and Sri Lanka) in Asia. Given space considerations, we show the responses for the main countries of interest and the aggregate responses for other countries, computed by weighting the impulse responses of individual countries using the averages of PPP-adjusted GDP over the period 2002 - 2008. Figures A1 - A16 display the median responses, together with two lines that show the 16^{th} and 84^{th} percentile impulse responses of the posterior distribution of impulse responses which satisfy the sign restrictions for each horizon.[4] In our analysis below, the word "significance" is used whenever both the 16^{th} and 84^{th} percentile responses are either above or below zero at a particular horizon.

We also note that our use of the median responses can be challenged, as Fry and Pagan (2011) point out that the median of the impulse responses will typically be generated by different models and there is nothing to ensure that the identified shocks are orthogonal. To examine this issue, we use Fry and Pagan's (2011) approach to find a single model which generates impulse responses that are as close to the median responses as possible, and compute impulse responses on the basis of this single model. The responses based on this approach, displayed by the dashed line in Figures A1 - A16, almost always fall between the 16^{th} and 84^{th} percentiles of the generated responses.

6.4.1 Domestic Responses to Simultaneous Productivity Improvement Shocks

Figure A1 displays the impulse responses of domestic variables to a one standard deviation composite shock to sectoral productivity differentials in developing Asia. This shock causes productivity in the traded sector relative to the nontraded sector to initially rise in China (by 0.70 percent), in India (by 0.25 percent), in Indonesia (by 0.22 percent) and in other developing Asian countries by lower amounts. The shock is constrained to have an initial positive effect on real GDP in the eight developing countries in Asia. However the effects on real GDP in these countries remain positive for longer periods and in particular the positive effect on real GDP in India, Thailand, Malaysia, Philippines and other South Asian countries is long-lasting.

In addition, our findings suggest positive and significant effects of the productivity shocks on trade related activities in Southeast Asian countries. This is what we expect as we normally think that technological progress leads to an efficient allocation of traded sector production at a global level. The countries that the shocks directly affect will have a competitive advantage as exporters and foreign-invested firms will also likely shift production to them. Exports from these countries will rise, as will imports of materials and components used in their production. Note that the positive responses of the ratio of international trade to GDP in China and India are not significant, probably because of the large capacity for domestic absorption in these economies.

[4] Note that by construction, these error bands actually reflect model uncertainty, rather than sampling uncertainty.

The Balassa-Samuelson hypothesis predicts that higher productivity gain in the domestic traded sector relative to the nontraded sector compared to that of other countries will lead to a real appreciation. However, we find that the real exchange rate responses in these eight countries do not follow this hypothesis. Indeed, a sudden rise in productivity improvement in traded sectors has an insignificant short and long-run effect on real exchange rates, in line with work in Dumrongrittikul and Anderson (2016). This finding is relevant for deliberations regarding the exchange rate behavior of Asian emerging economies, as policy makers in these economies have observed that their currencies do not tend to appreciate after strong traded-sector productivity growth.

The shocks cause inflation in these countries to increase initially and this response is especially strong in China. This is probably because a rise in real GDP stimulates domestic aggregate demand, inducing domestic prices to increase. As the shocks have a larger positive effect on real GDP in China relative to the other countries, inflation in China also reacts more strongly in the short run. However, inflation in all emerging Asian economies declines slightly in the long run.

The responses of short-term interest rates and government consumption shares in the eight countries are generally not significant and the associated diagrams are therefore not shown in Figure A1.

6.4.2 International Responses to Simultaneous Productivity Improvement Shocks

Figures A2 - A8 show how traded sector productivity improvement shocks in Asian developing countries propagate internationally. Interestingly, Figure A3 shows that the traded-sector productivity shocks drive up productivity in the traded sector in the US and European countries which are large net importing countries with China in the short run.[5] The shocks also lead to an increase in real output in these countries (see Figure A4). In contrast, the shocks cause an increase in productivity in the nontraded sector relative to that in the traded sector in almost all other countries including Japan, South Korea, Brazil and Australia, which are net exporters for China. This suggests that traded-sector productivity increases in Asia may make the firms that produce traded goods in these net export countries less internationally competitive as exporters. Many of these firms are in the manufacturing sector. They may move production facilities to China and other Asian developing countries, and shift their own production and resources away from traded sectors toward nontraded sectors, inducing relative productivity improvement in their nontraded sectors. This corresponds to the rise of *Factory Asia*. As a result, the traded good production in the countries that compete with exports from Asian developing countries can fall in the short run. See Figure A3. Figure A5 shows a temporary rise of international trade shares in most non emerging Asian economies in response to

[5] This is based on trade information in 2011 sourced by National Bureau of Statistics of the People's Republic of China.

the productivity improvement shocks, which is consistent with an increase in their imports via global supply chains.

Figure A2 shows that the shocks to Asian traded-sector productivity have no significant effects on real exchange rates in foreign countries. Figure A6 illustrates that there are international inflationary spillovers from the Asian countries shocked to other economies including US, Japan, South Korea, Australia and other non-Asian developed countries. The productivity shocks in developing Asia have little effect on government consumption shares and short-term interest rates in foreign countries, suggesting little policy response to the shocks. An exception is found in non-Asian developing countries which experience a sudden drop of short-term interest rates in response to traded good productivity shocks in developing countries in Asia (see Figure A7).

6.4.3 Domestic Responses to Simultaneous Openness Shocks

In addition to productivity growth, economists who study developing countries believe that rapid growth in emerging Asian economies over several decades has been driven by trade policy that emphasises outward-oriented development strategies. These trade strategies, referred to as export-led growth strategies aim to speed up economic growth and improve domestic living standards quickly by exporting goods for which they have a comparative advantage. Emerging Asian countries have also undergone voluntary trade openness under multi-country cooperative agreements in order to expand international trade. Most of these countries changed the nature of international trade policy toward free trade agreements (FTAs) and multilateralism from about the 1990s onwards, and nowadays they are at the forefront of global FTA activity (Kawai and Wignaraja, 2009, 2013). Therefore, in this paper we also examine the dynamic effects of simultaneous openness shocks to developing Asia on global economies.

Figure A9 shows the impulse responses of domestic variables to a one standard deviation composite shock to trade openness in developing Asia. Our results suggest that the shocks cause international trade shares to immediately rise in China (by 1.32 percent), in India (by 0.54 percent), in Indonesia (by 0.48 percent) and in other developing Asian countries (by 0.27 percent on average) and the effects on trade share remain positive for some time. It is likely that this reflects an increase not only in trade with industrialized countries but also in intraregional trade.

Several studies have shown a positive effect of trade openness on economic growth and overall productivity (Berg and Krueger, 2003). We find a strong and persistent positive impact on real GDP. In particular, the trade shocks in Asian economies spur fast economic growth, especially in China and India, but also in other developing Asian economies. This leads to a long-lasting increase in real GDP of these economies. On the other hand, trade openness does not seem to have a strong and significant effects on traded-nontraded productivity differentials in China, India and Indonesia. This is probably because trade shocks can benefit productivity growth in both sectors in a similar way.

The responses of real exchange rates and interest rates are insignificant. Most countries experience a small and temporary increase in inflation one year after the shock as the domestic economies expand. However, in the long run inflation falls slightly, suggesting that higher competition in labor and product markets resulting from increased openness contributes to lower inflation in the long run.

6.4.4 International Responses to Simultaneous Openness Shocks

Asian emerging economies have become global factories, as evidenced by a significant increase in the region's share of world imports and exports. In particular, these economies' shares of world exports and imports have increased to constitute about 30 percent of world trade in 2013 (Kawai and Wignaraja, 2014). Therefore, it is not surprising that the positive shocks to trade openness in these Asian countries have strong and significant positive effects on the international trade shares in other economies around the world (Figure A13), reflecting an increase in global trade. This suggests that the shocks enhance the formation of production networks and supply chains that incorporate Asian countries. They not only strengthen trade linkages among Asian developing economies but also deepen global economic integration.

Looking at the responses of traded-nontraded productivity differentials suggests international trade-induced technological spillovers. In general, the trade shocks cause productivity in traded sectors to rise faster than nontraded sector productivity in US and European economies. Essentially US productivity in traded sectors relative to nontraded sectors increases by 0.16 percent on impact, higher than the other countries examined. See Figure A11. Interestingly, Figure A12 suggests that increased openness can trigger higher real GDP in other countries, which may then spill back to Asian GDPs.

Figure A10 shows that real exchange rate responses are insignificant across all countries, while the responses of inflation and interest rates (illustrated in Figures A14 and A15) tend to be positive in developed economies. Hence, aggregate demand and income effects seem to dominate aggregate supply effects. On the other hand, opening the Asian developing economies seems to reduce inflation and interest rates in other developing economies, suggesting the dominance of aggregate supply effects in these countries. Openness shocks slightly decrease government consumption shares in other countries in the short run (Figure A16), in contrast to Benarroch and Pandey's (2008) finding that there is no relationship between openness and government consumption. However, it is possible that the decline in government consumption *shares* may be a result of increased GDP.

6.5 Sensitivity Analysis

In this section, we discuss the sensitivity of our results to three types of robustness checks.

First, we impose an alternative set of equally plausible identifying restrictions, i.e. openness is restricted to rise and inflation is restricted to fall in eight Asian developing countries after trade openness shocks, while the restrictions for identifying productivity shocks remain the same. The restriction on the impact response of inflation to the openness shocks is plausible because trade openness can be viewed as a reduction of trade barriers. Weaker trade restrictions imply an instantaneous fall in the price of imports, and then import substitution for domestic goods can lead to a decline in domestic prices, causing inflation to fall. The restriction that inflation must fall serves an additional purpose, in that an increase in just trade shares might be due to another factor such as an increase in income, but a fall in inflation ensures that the positive shock to the trade openness that we consider arises from trade integration rather than from positive income shocks. The responses that are generated under this new set of restrictions are very similar to the previous responses, and they are not shown here but are available on request. The only significant difference between the impulses in Figures A1 to A16 and those considered here are due to the constraint on inflation are the inflation responses, which now show that after the openness shocks the inflation in those countries shocked decline only on impact.

Second, we explicitly identify an income shock together with the productivity and openness shocks to confirm that our two identified shocks are uncontaminated by income shocks. In addition to the identification scheme in Section 5.1, a positive income shock is identified by a rise of output and inflation on impact. Since the number of restrictions imposed simultaneously is larger, it becomes more difficult to find responses satisfying the new set of sign restrictions in the data, leading us to reject a higher number of draws from the reduced-form posterior of our VAR. However, once we have sufficient draws to obtain the responses, then we find no significant difference from these new responses and the originals in diagrams A1 to A16.

Third, we assess the sensitivity of our results to country grouping. As China might have different features from other Asian developing countries, we take China out from the Asian developing group and estimate an individual model for China. Then we combine all the country models into the GVAR and use the same set of restrictions as those used to obtain our main set of results to identify the effects of the two shocks of interest. We represent the responses of the main variables of interest to productivity and trade shocks in Figures A17 - A26. Most of the signs of initial impact and shapes of the responses are similar to those found previously, suggesting that the change in country grouping has had little effect. Output still rises in non Asian countries and openness still rises in most countries when traded-nontraded productivity in Asian emerging economies increases, while traded-nontraded productivity in developed Asian countries and Australia falls. (See Figures A19, A20 and A18). However, the scale of these responses is usually smaller than in Figures A4, A5 and A3. Further, an increase in openness in Asian emerging economies leads to increased output and openness around the globe, although evidence of a decline in prices is no longer present (comparing Figures A24, A25 and A26 with A12, A13 and A14). Not surprisingly, the Chinese variable responses (in Figures A17 and A22) undergo the most visible changes - while all have the same instantaneous signs as in Figures A1 and A9, these responses now fluctuate more than the previous responses. We also find (but do not illustrate) that traded-nontraded productivity shocks in Asia emerging economies have no statistically significant effect on real exchange rates, just as in Figure A2.

7 Conclusion

This paper constructs a multi-country model covering sixteen developed and fourteen developing countries to investigate the international effects of traded sector productivity gains and trade openness in eight Asian emerging and developing countries (China, India, Indonesia, Thailand, Philippines, Malaysia, Pakistan and Sri Lanka) on key macroeconomic variables. We use an econometric strategy based on a global vector autoregression (GVAR), which captures direct channels of international shock transmission by including foreign variables in the models and indirect channels through error spillover effects, while keeping dimensionality manageable. The GVAR enables us to model international linkages between a large number of countries, which is an important feature in the era of globalization.

We identify the structural shocks of interest by using sign restricted impulse response functions rather than generalized impulse response functions. This identification scheme is appropriate for our study because it gives our shocks a clear economic interpretation. Within the GVAR framework, we can impose a large number of economic theory-based sign restrictions on short-run impulse responses, yielding results that are robust to the ordering of variables and countries in the system.

The main results are that a positive shock to traded-sector productivity contributes to real GDP growth in Asian developing countries and has a significant positive effect on GDP in US and European countries in the short run. The responses of sectoral productivity differentials in foreign countries are interesting. That is, the shock benefits traded-sector productivity in US and European countries. On the other hand, it seems to drive up productivity in the nontraded sector relative to the traded sector in Japan, South Korea, Australia and other non-Asian developing countries. This suggests that as more traded products are made in Asian developing countries, there is a compositional shift in the other countries' production and resources away from the traded sectors toward the nontraded sector, allowing their productivity in the nontraded sector to increase. The shock stimulates openness to external markets and raises global trade in the short run. Inconsistent with the Balassa-Samuelson prediction, the responses of real exchange rates of Asian emerging economies are insignificantly different from zero. This is interesting, in light of the political pressures that have been placed on rapidly growing economies such as China to raise the value of their currencies relative to the USD.

Further, simultaneous shocks to trade openness in Asian developing countries enhance global production networks and supply chains, leading to economic integration in the areas of trade over a long period. The resulting expansion of trade has a very persistent and significant positive effect on real GDP in Asian countries. Hence an export-led growth strategy can be regarded as a crucial growth stimulator. Trade also transmits growth across countries and regions, but although the effects on productivity are initially positive they decline over time, and real exchange rate effects are generally insignificant.

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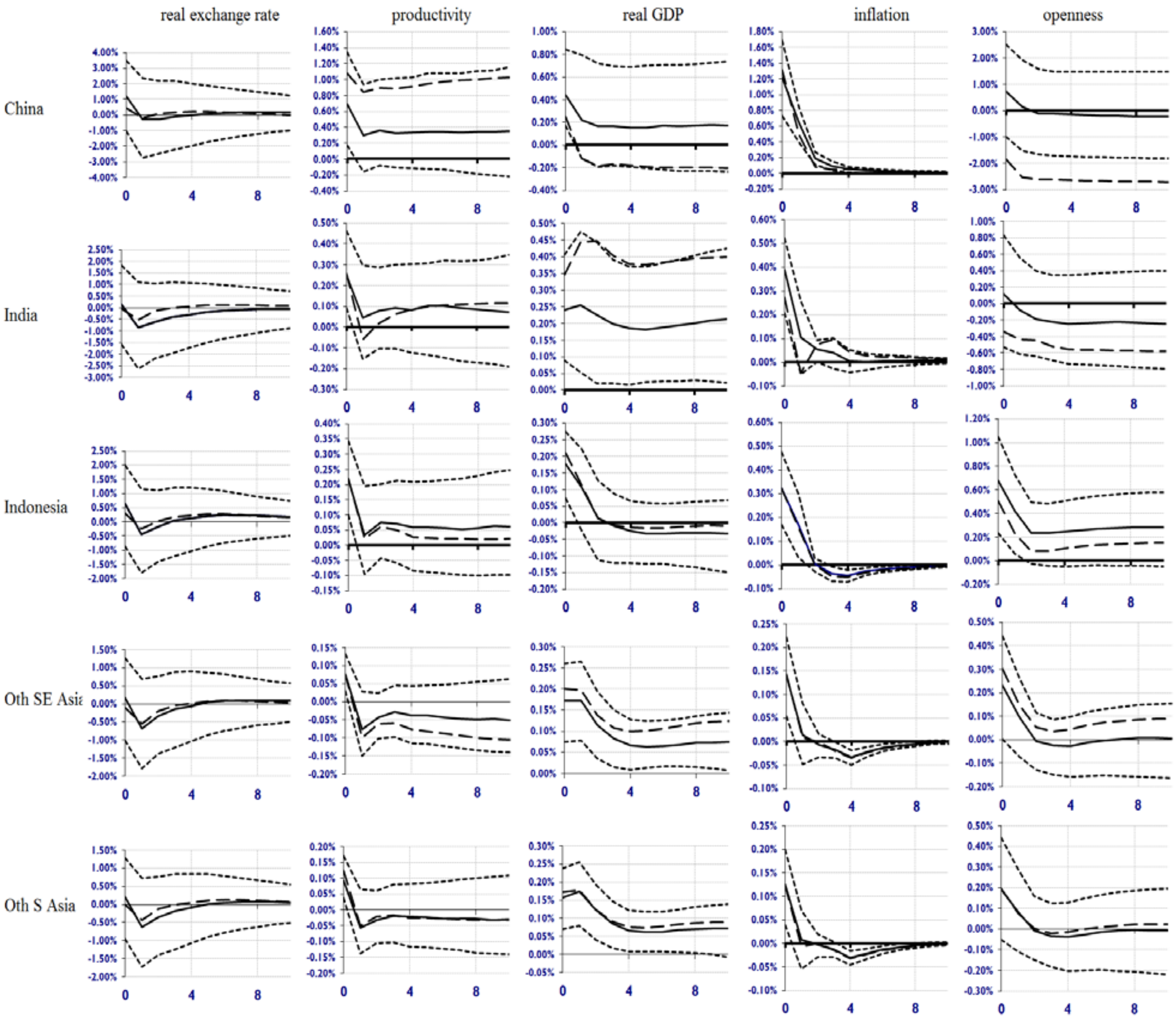
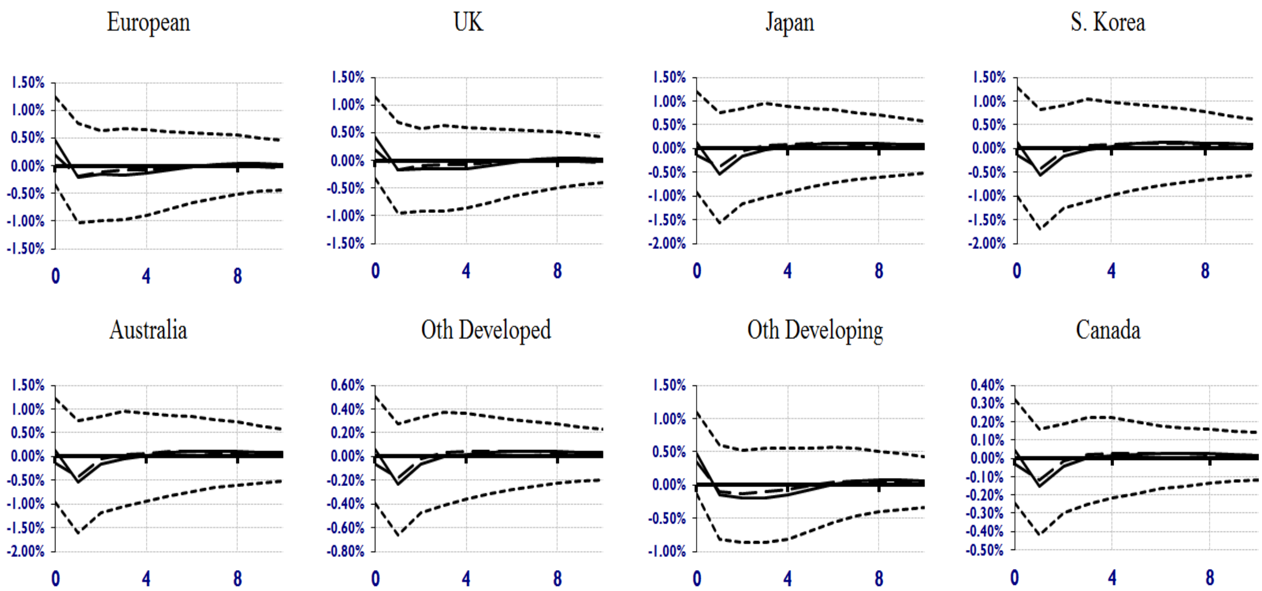
A Figure Appendix

Figure A1: Transmission of a composite shock to traded-sector productivity improvement to selected variables in Asian developing countries



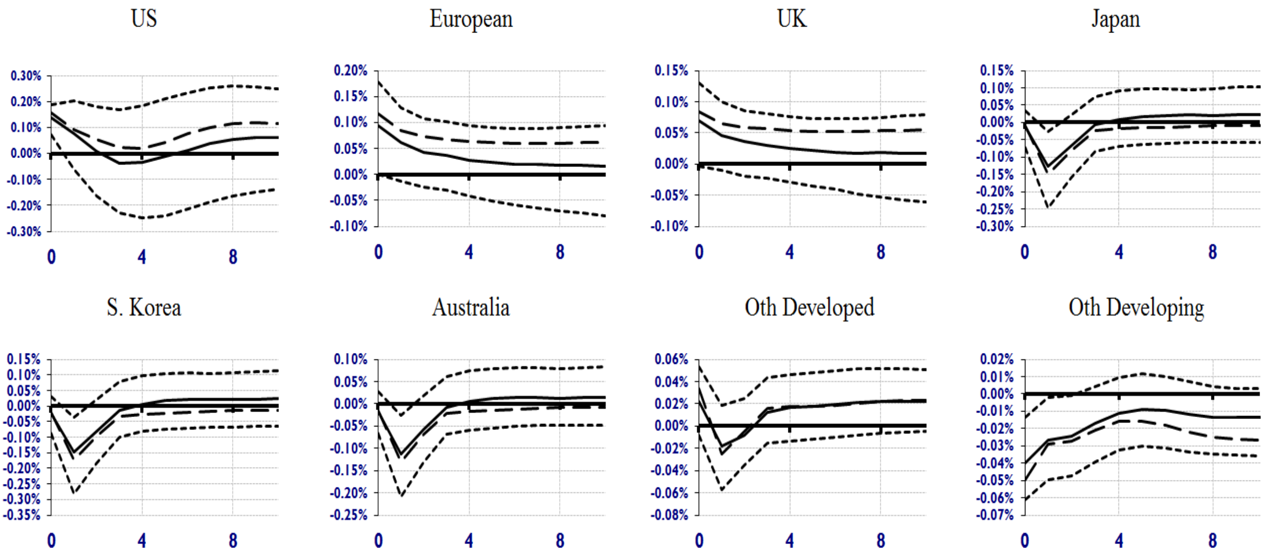
Notes: Solid line represents median impulse responses, and dashed line displays impulse responses implied by a single model as proposed by Fry and Pagan (2011). Dotted lines correspond to $16^{th}/84^{th}$ percentile responses. Note that 1) Other Southeast Asia countries include Thailand, Malaysia, and Philippines, 2) Other South Asia countries include Pakistan and Sri Lanka, 3) An increase (a fall) in the real exchange rate (q_t) represents a real depreciation (appreciation).

Figure A2: Real exchange rate responses to a composite shock to traded-sector productivity improvement



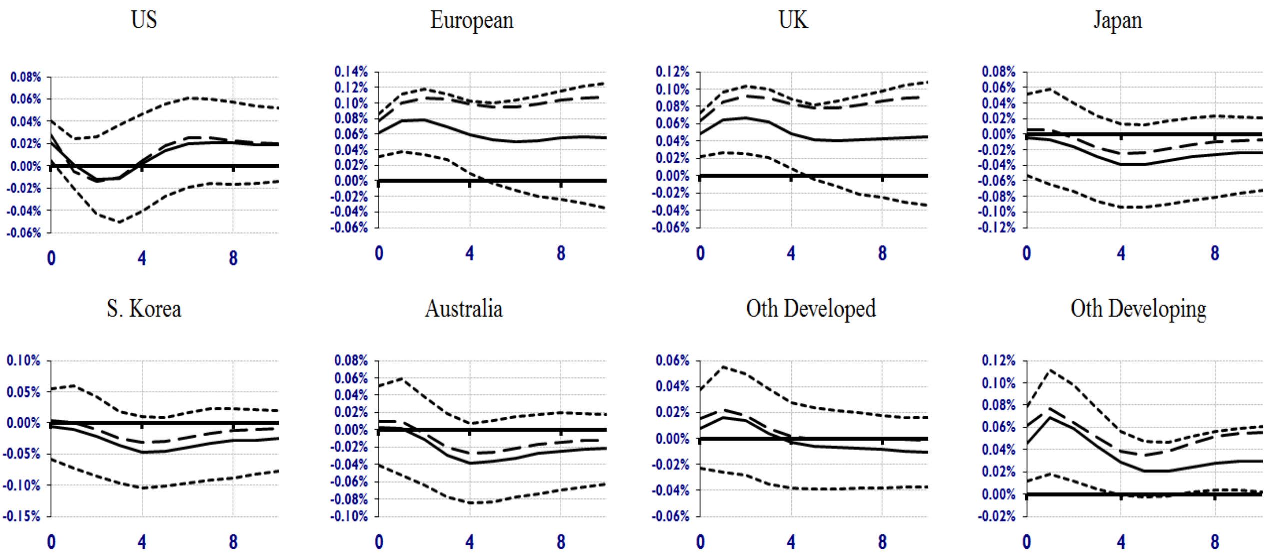
Notes: An increase (a fall) in the real exchange rate (q_t) represents a real depreciation (appreciation). Solid line represents median impulse responses, and dashed line displays impulse responses implied by a single model as proposed by Fry and Pagan (2011). Dotted lines correspond to $16^{th}/84^{th}$ percentile responses. Note that 1) European countries include the Euro Area countries, Norway, Sweden, Switzerland, 2) Other developed countries include Canada, New Zealand, Singapore, 3) Other developing countries include Brazil, Mexico, Chile, Turkey, Argentina, South Africa.

Figure A3: Traded-nontraded productivity differential responses to a composite shock to traded-sector productivity improvement



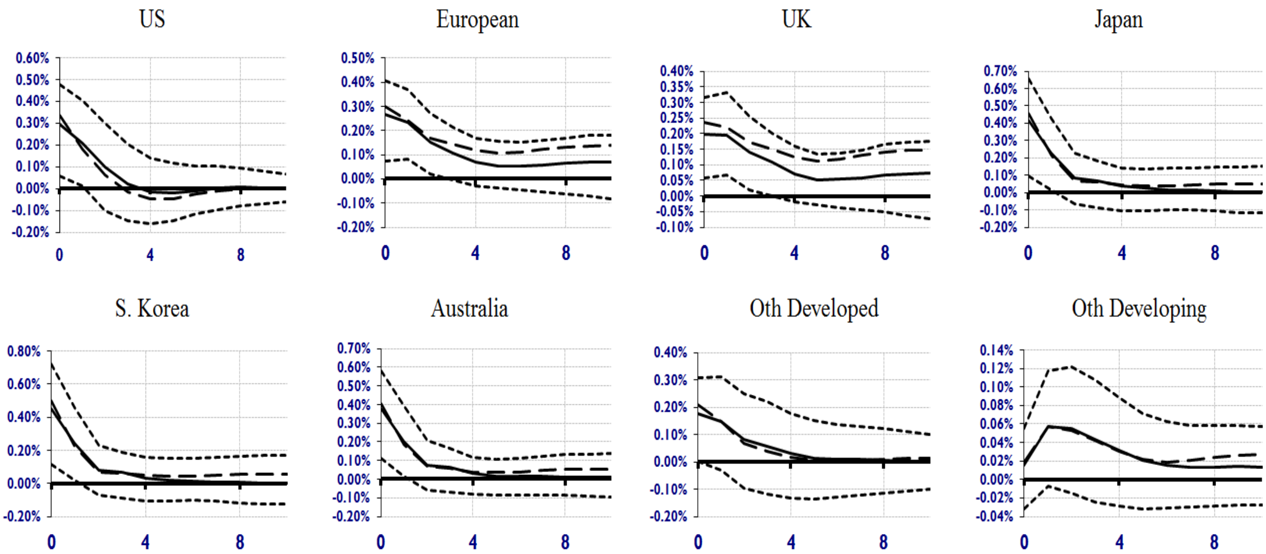
Notes: See Figure A2.

Figure A4: Real GDP responses to a composite shock to traded-sector productivity improvement



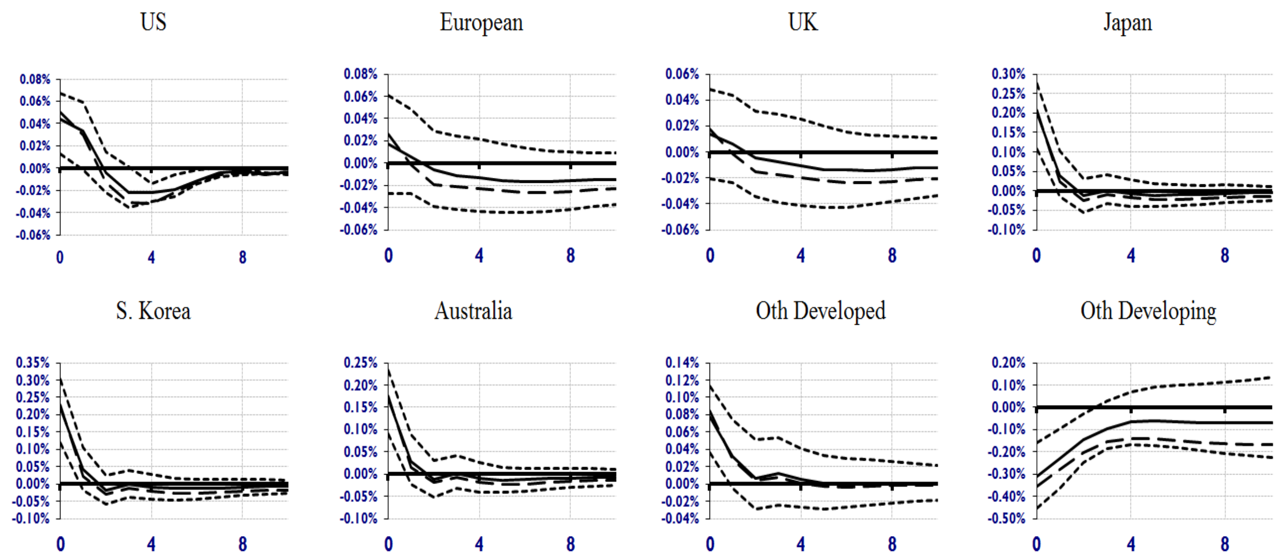
Notes: See Figure A2.

Figure A5: Openness responses to a composite shock to traded-sector productivity improvement



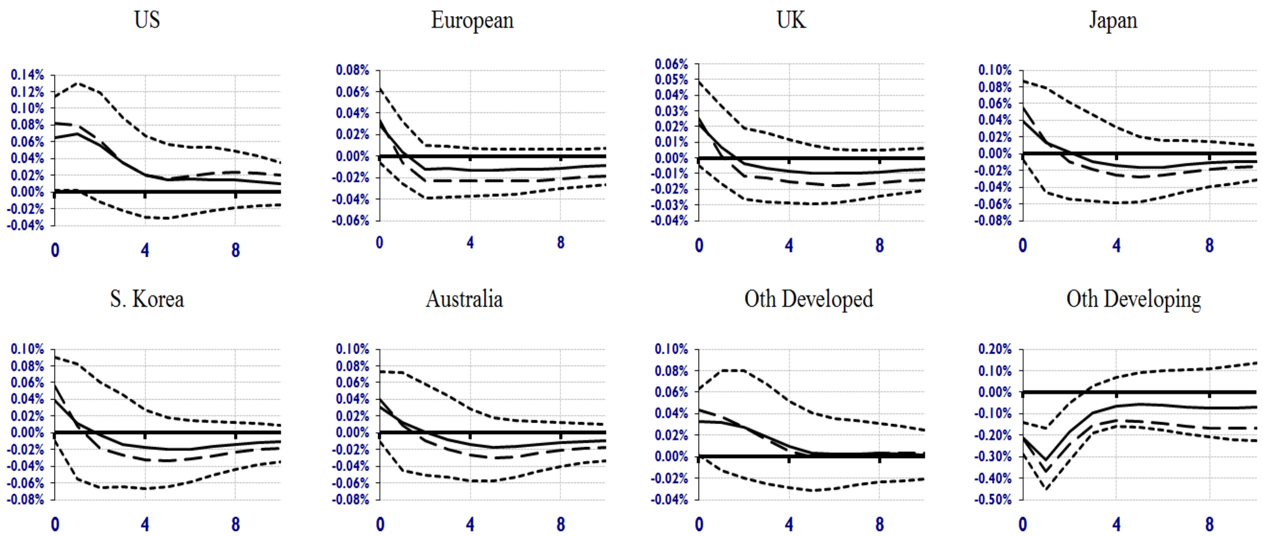
Notes: See Figure A2.

Figure A6: Inflation responses to a composite shock to traded-sector productivity improvement



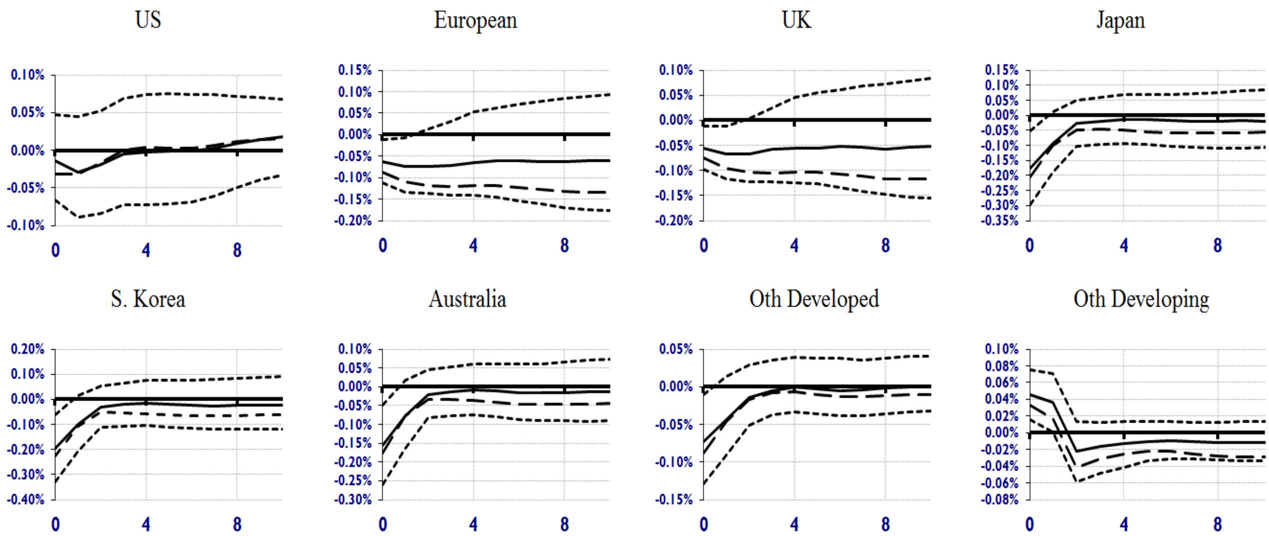
Notes: See Figure A2.

Figure A7: Short-term interest rate responses to a composite shock to traded-sector productivity improvement



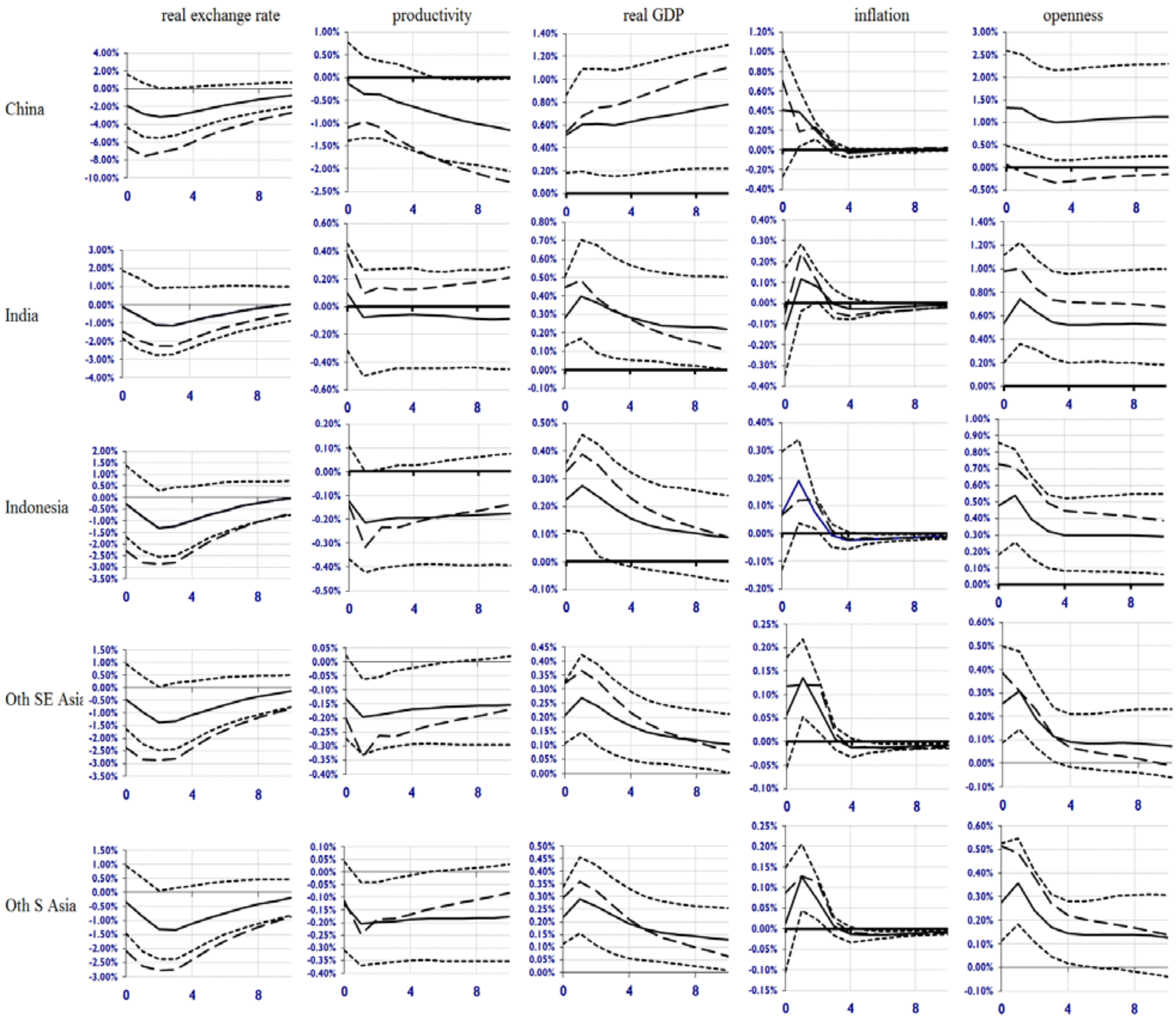
Notes: See Figure A2.

Figure A8: Government consumption responses to a composite shock to traded-sector productivity improvement



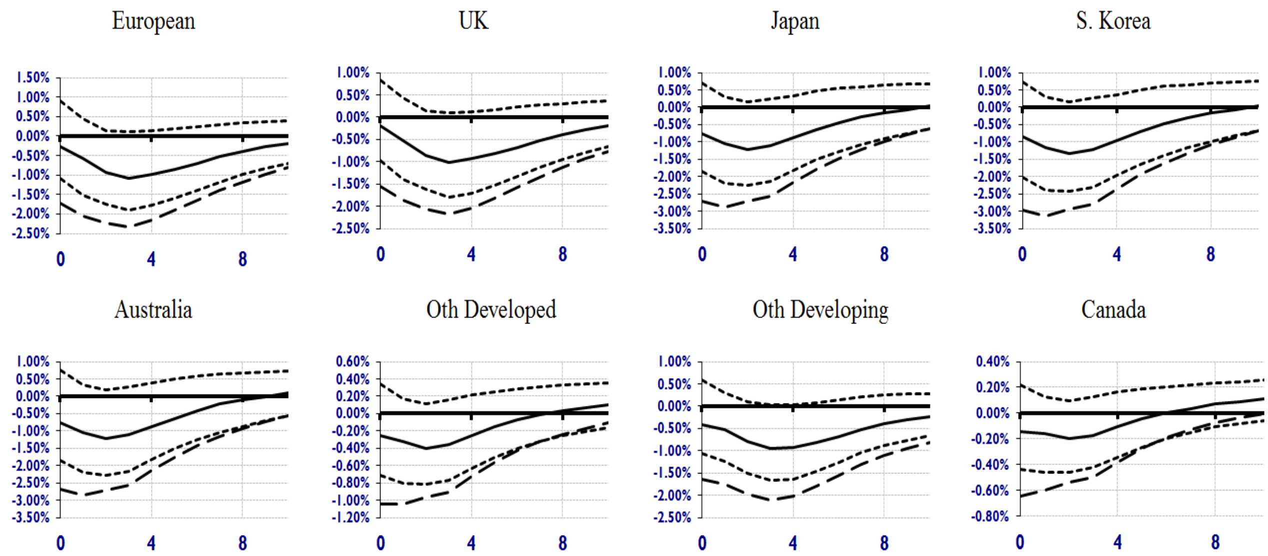
Notes: See Figure A2.

Figure A9: Transmission of a composite shock to openness to selected variables in Asian developing countries



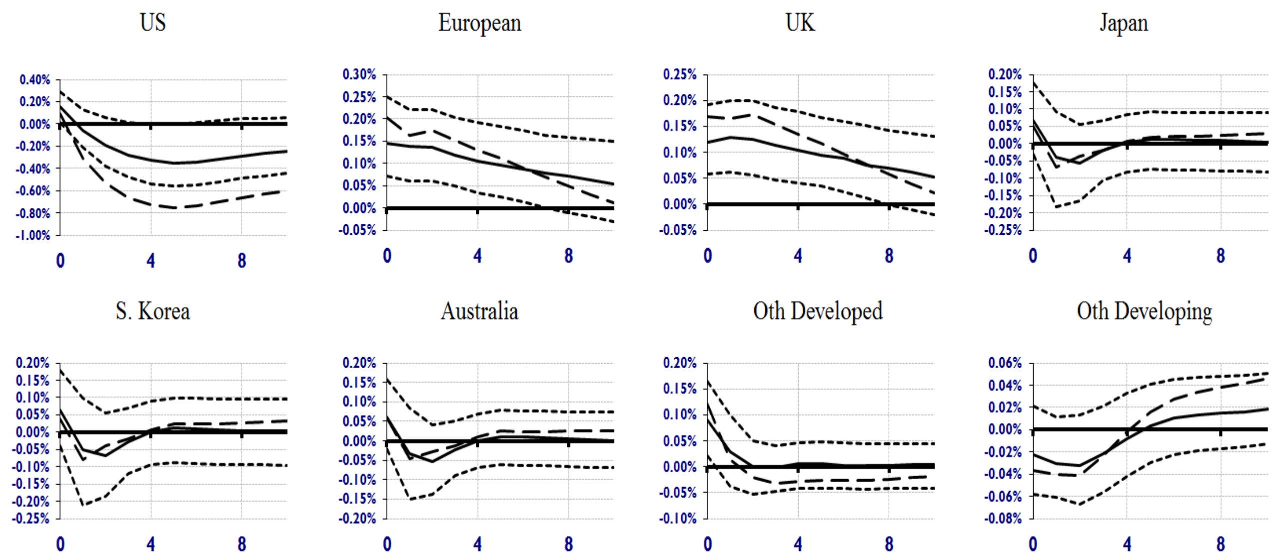
Notes: See Figure A1.

Figure A10: Real exchange rate responses to a composite shock to openness



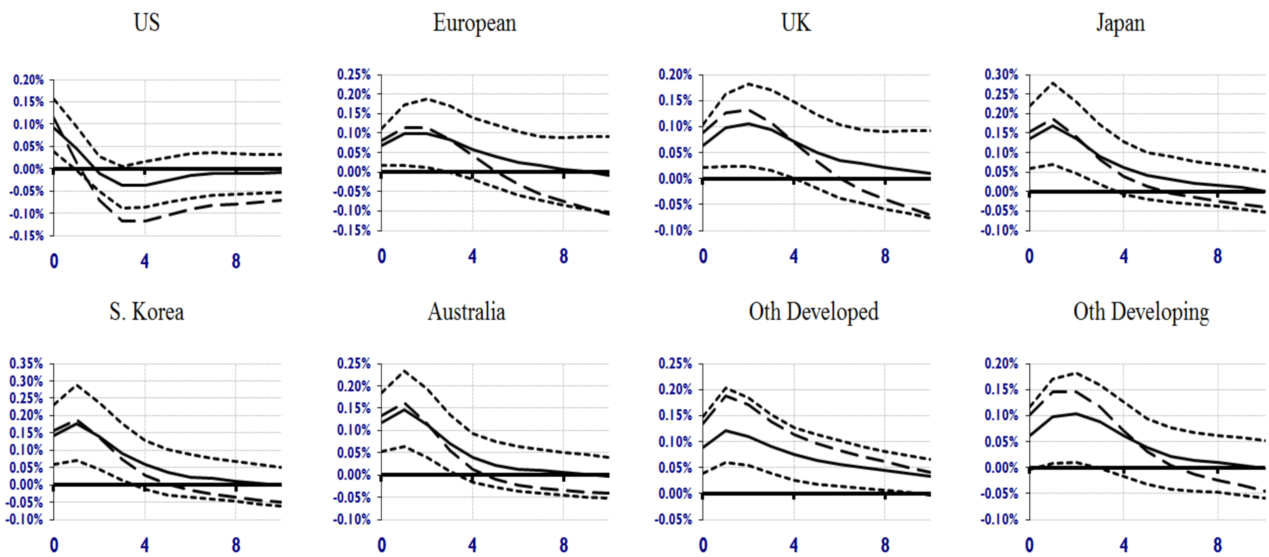
Notes: See Figure A2.

Figure A11: Traded-nontraded productivity differential responses to a composite shock to openness



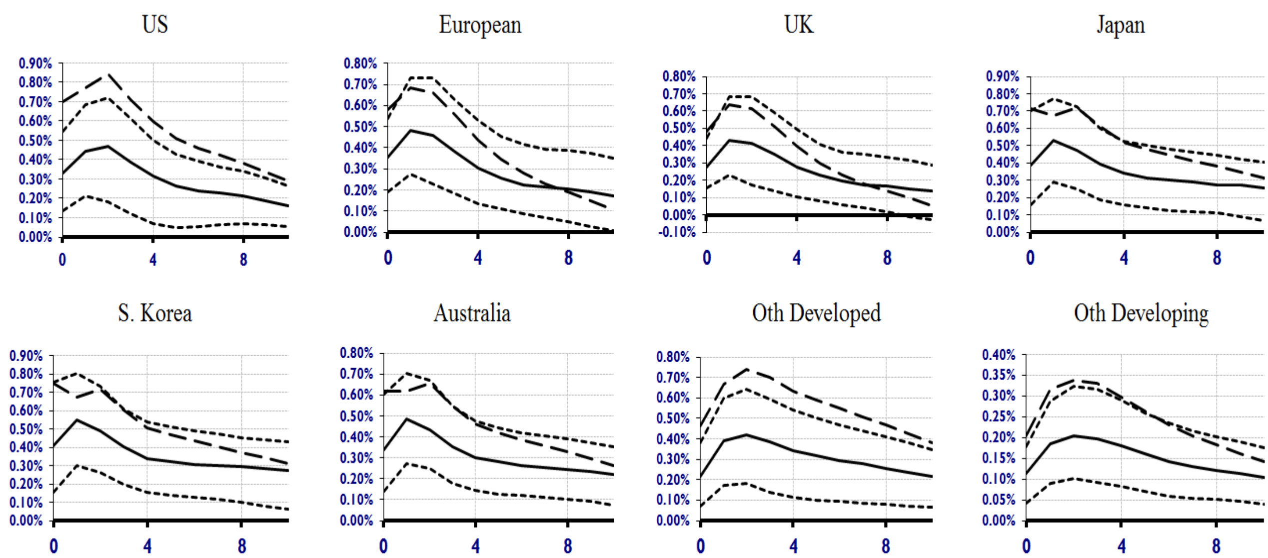
Notes: See Figure A2.

Figure A12: Real GDP responses to a composite shock to openness



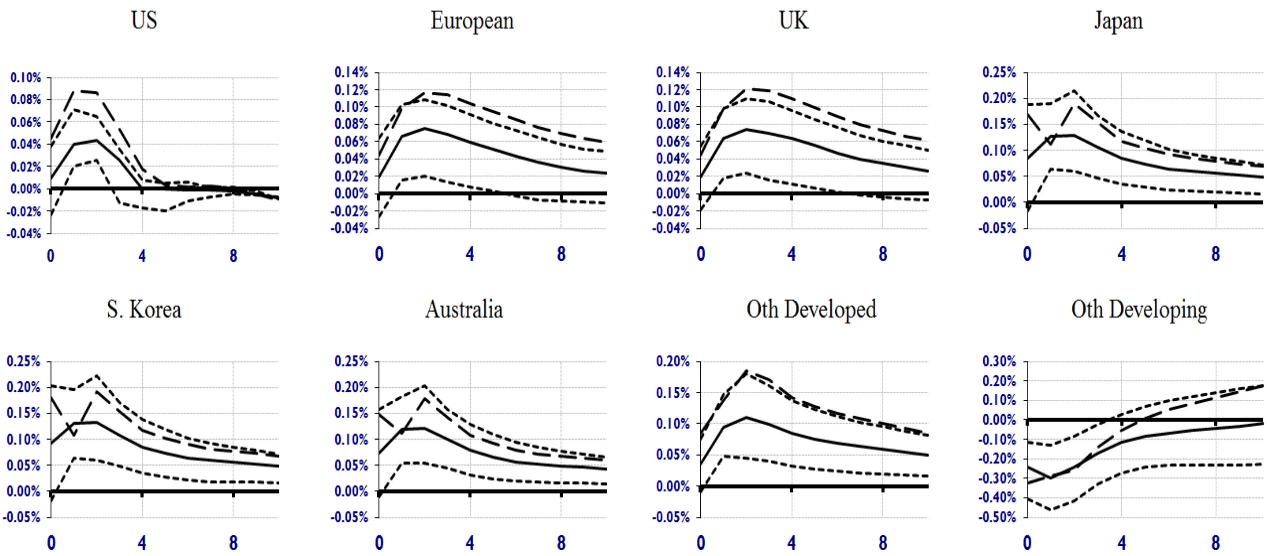
Notes: See Figure A2.

Figure A13: Openness responses to a composite shock to openness



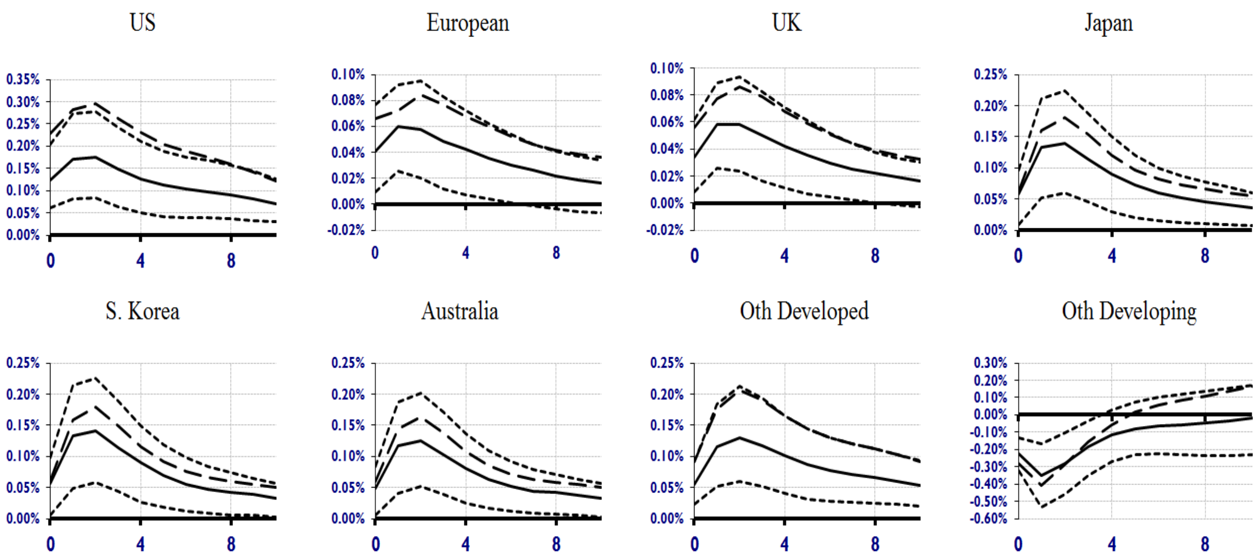
Notes: See Figure A2.

Figure A14: Inflation responses to a composite shock to openness



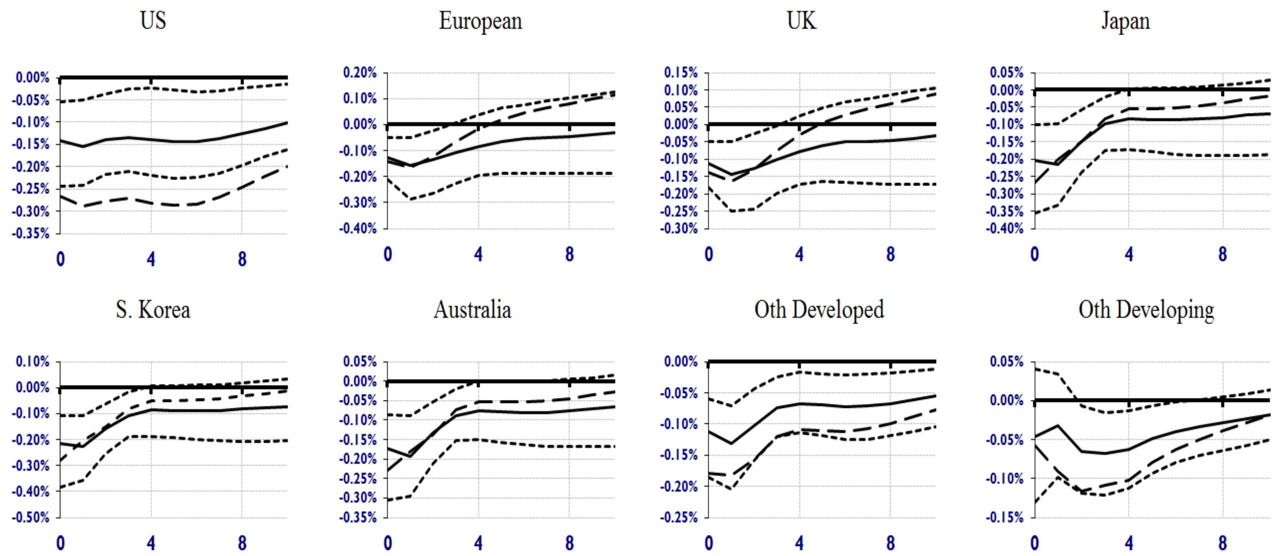
Notes: See Figure A2.

Figure A15: Short-term interest rate responses to a composite shock to openness



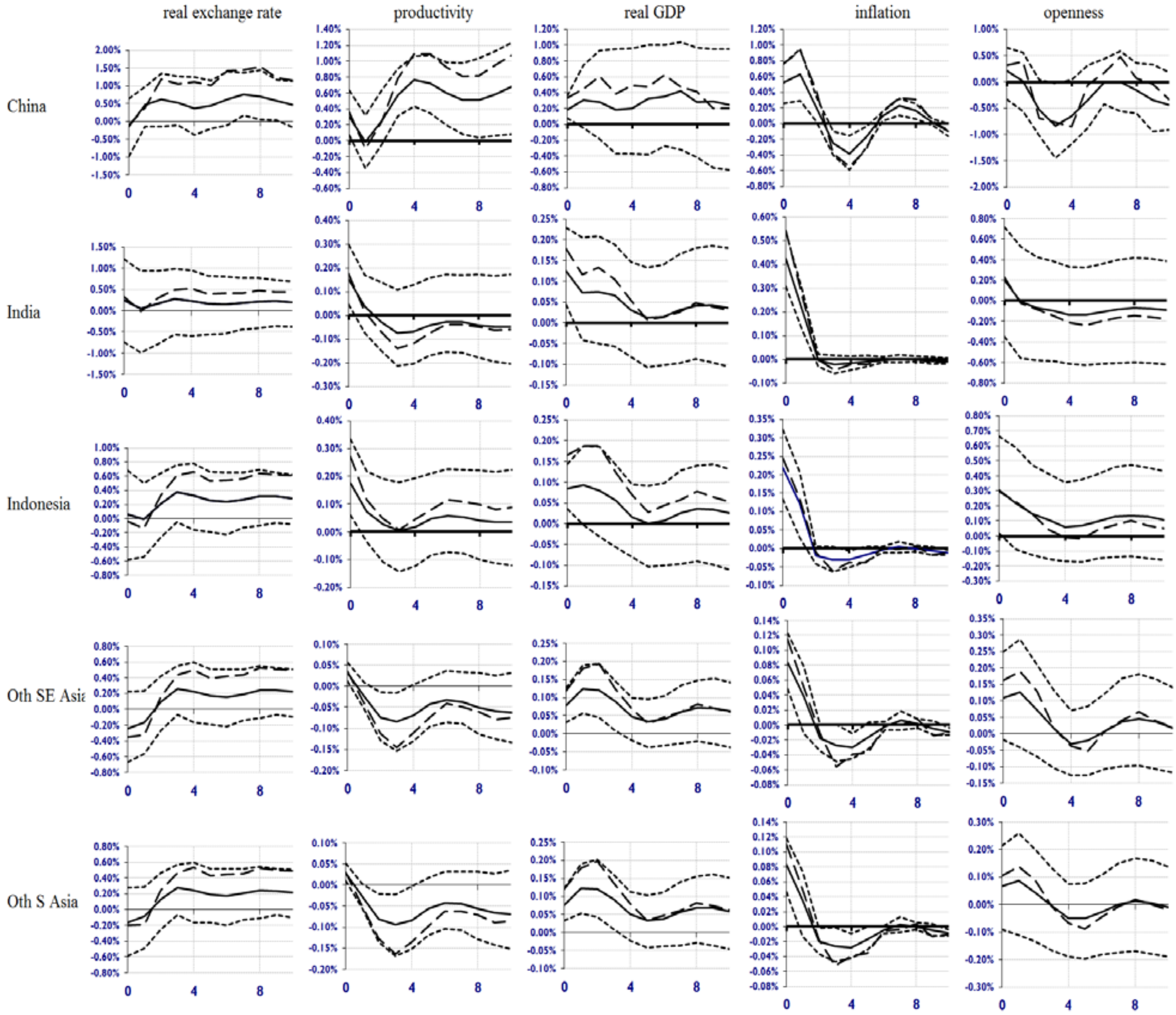
Notes: See Figure A2.

Figure A16: Government consumption responses to a composite shock to openness



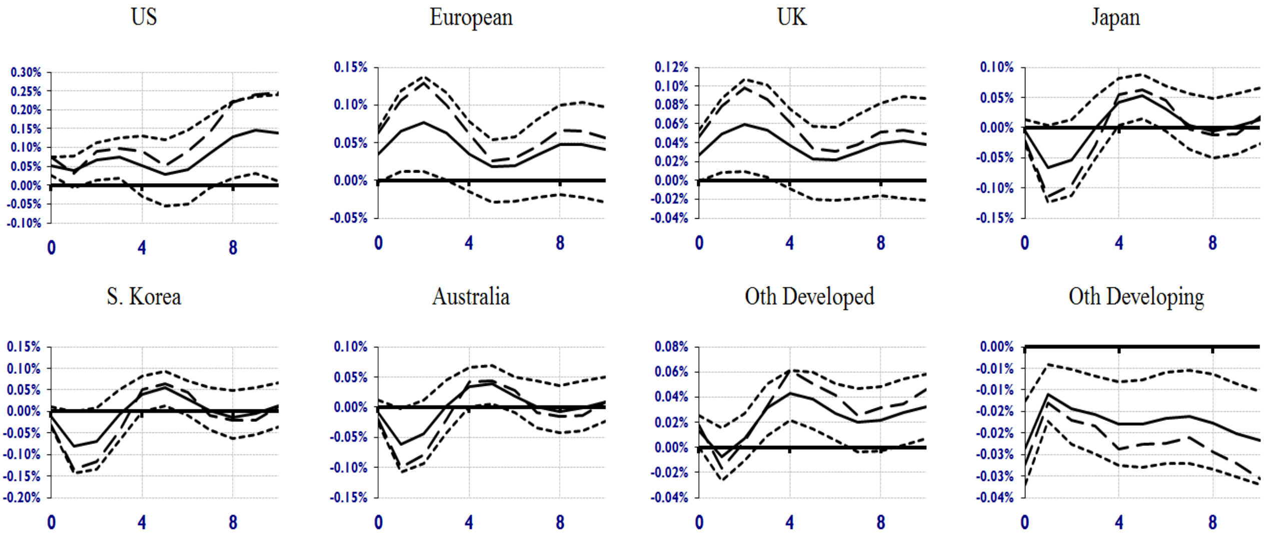
Notes: See Figure A2.

Figure A17: Robustness check: Transmission of a composite shock to traded-sector productivity improvement to selected variables in Asian developing countries



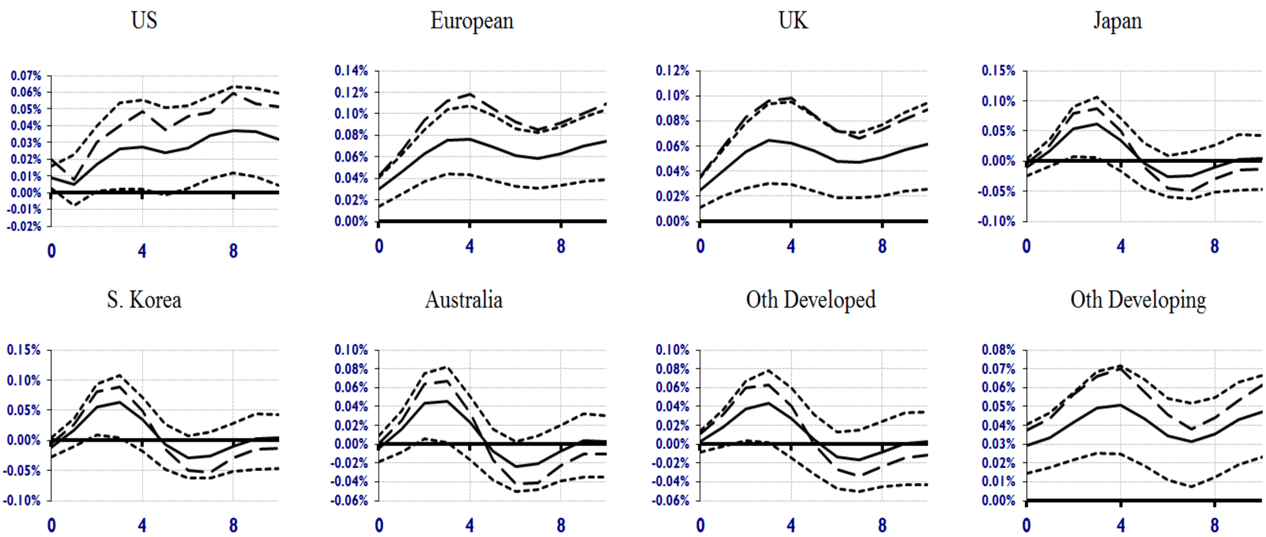
Notes: See Figure A1.

Figure A18: Robustness check: Traded-nontraded productivity differential responses to a composite shock to traded-sector productivity improvement



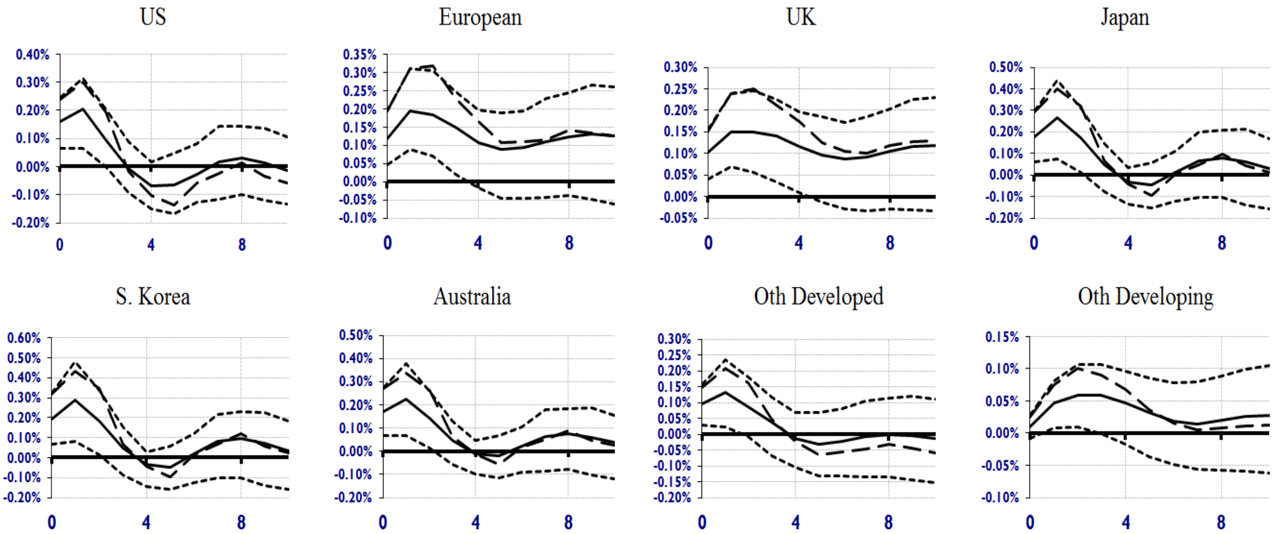
Notes: See Figure A2.

Figure A19: Robustness check: Real GDP responses to a composite shock to traded-sector productivity improvement



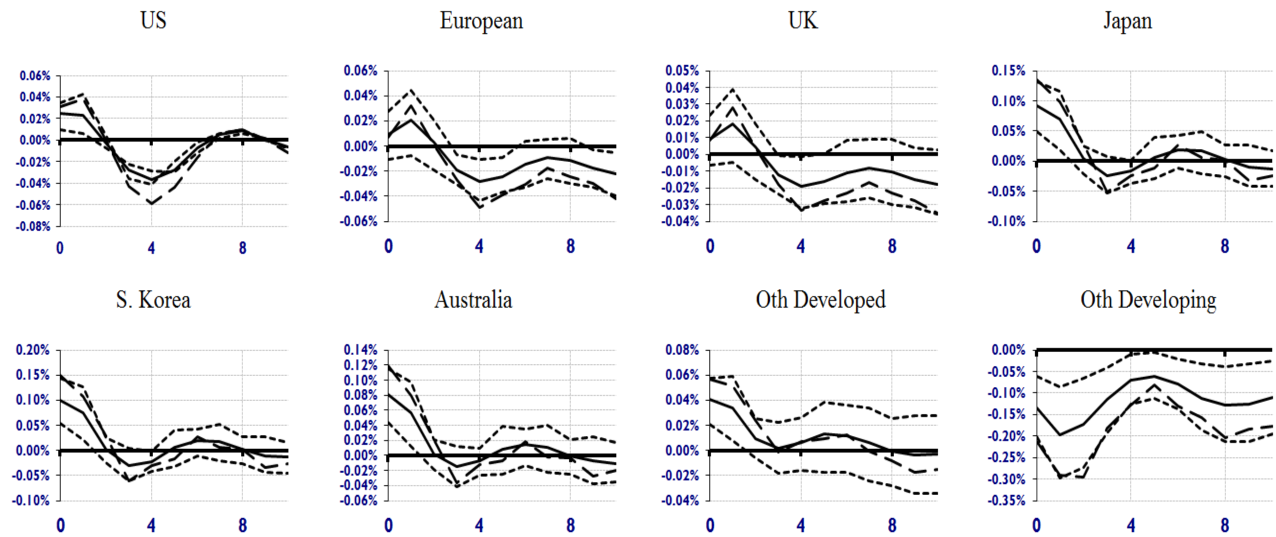
Notes: See Figure A2.

Figure A20: Robustness check: Openness responses to a composite shock to traded-sector productivity improvement



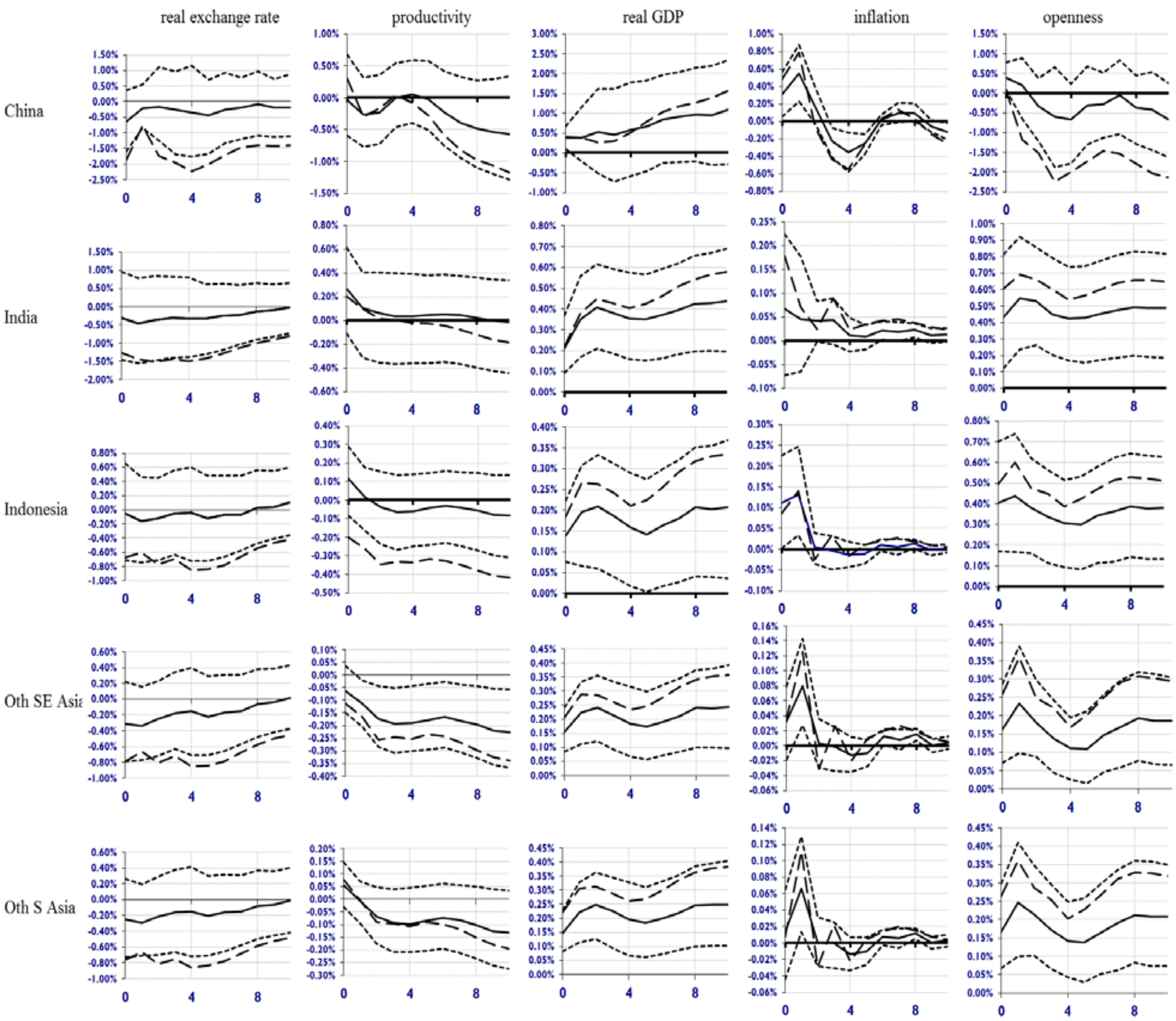
Notes: See Figure A2.

Figure A21: Robustness check: Inflation responses to a composite shock to traded-sector productivity improvement



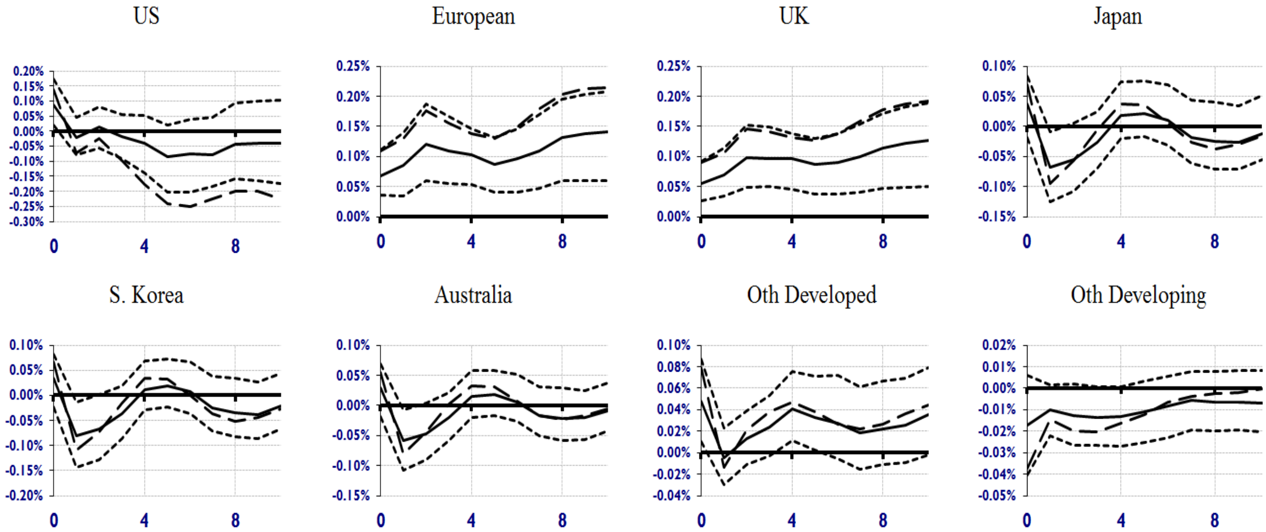
Notes: See Figure A2.

Figure A22: Robustness check: Transmission of a composite shock to openness to selected variables in Asian developing countries



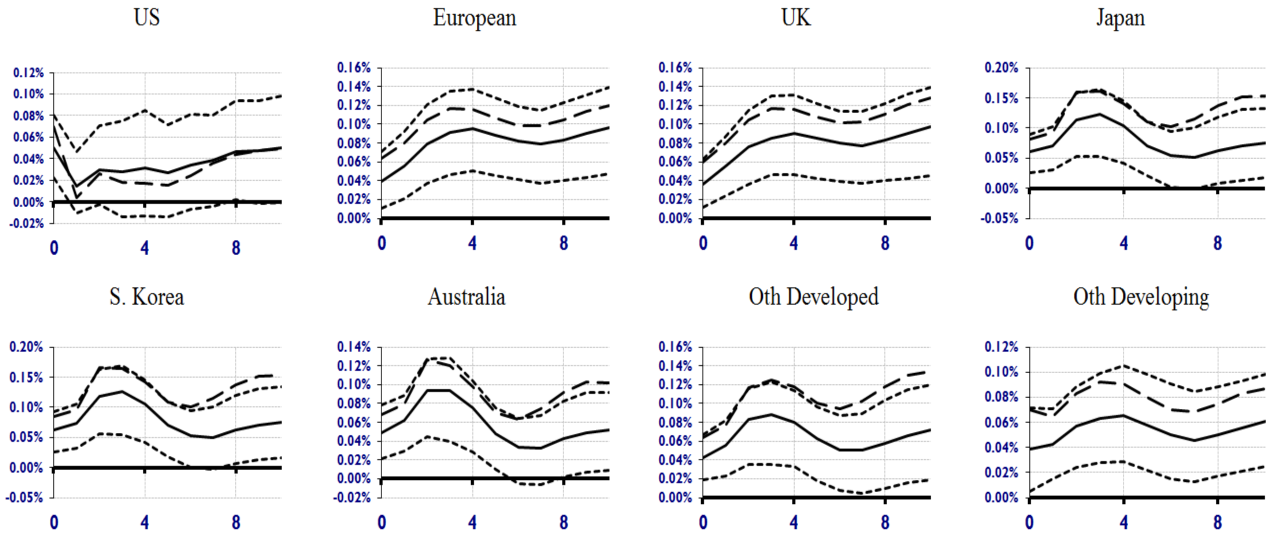
Notes: See Figure A1.

Figure A23: Robustness check: Traded-nontraded productivity differential responses to a composite shock to openness



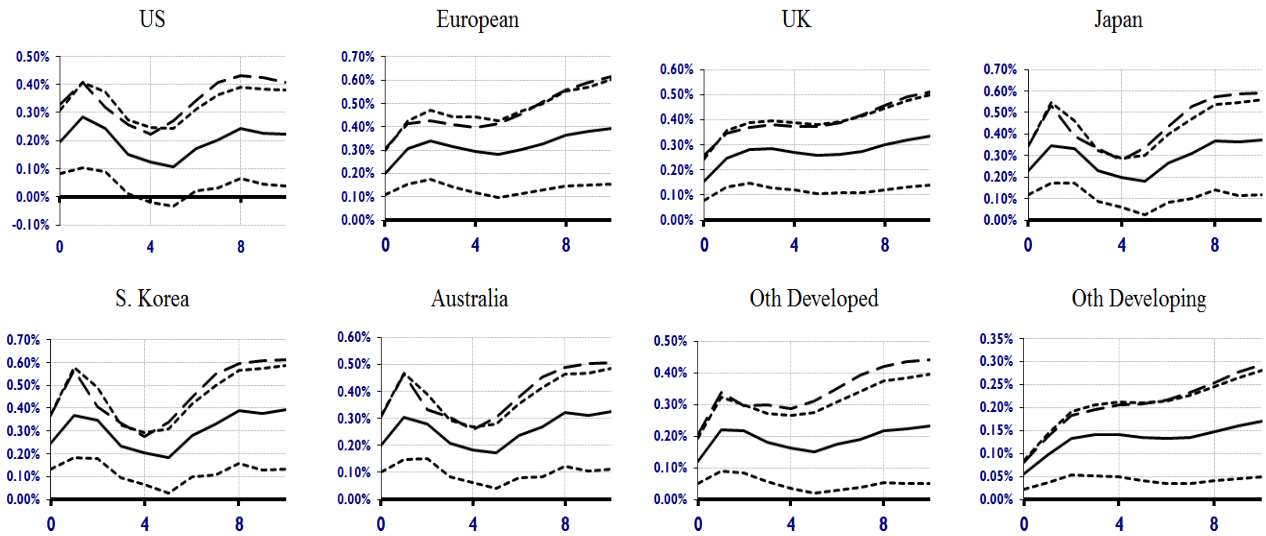
Notes: See Figure A2.

Figure A24: Robustness check: Real GDP responses to a composite shock to openness



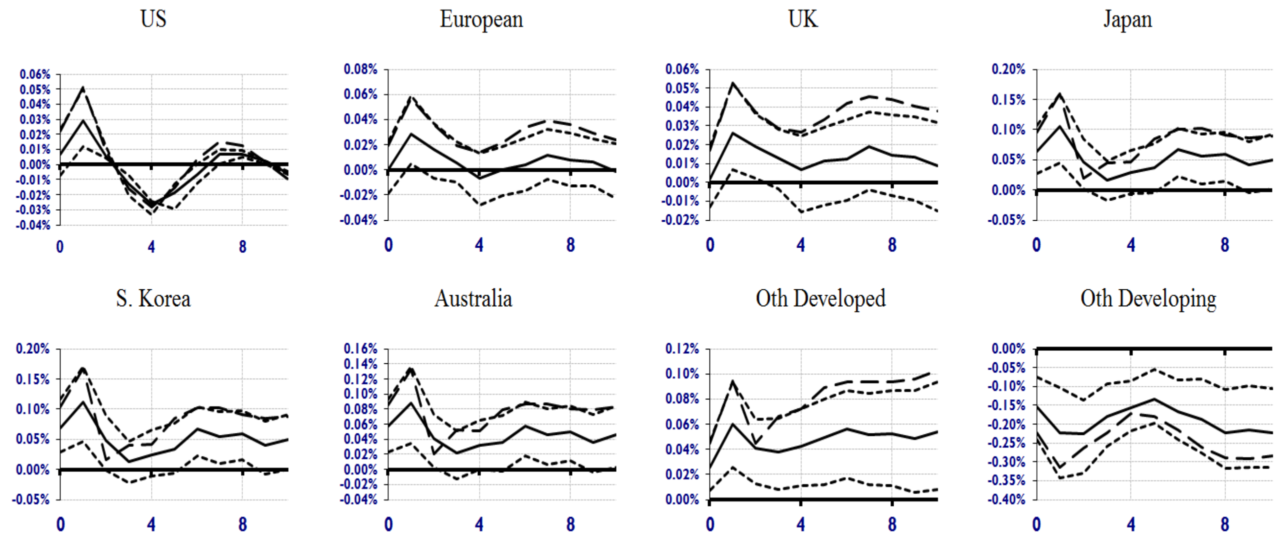
Notes: See Figure A2.

Figure A25: Robustness check: Openness responses to a composite shock to openness



Notes: See Figure A2.

Figure A26: Robustness check: Inflation responses to a composite shock to openness



Notes: See Figure A2.

B Table Appendix

Table B1: List of countries in each group

Country grouping	Members
Developed countries	
European countries (9 countries)	Euro Area (Germany, France, Italy, Spain, Netherlands), U.K., Norway, Sweden, Switzerland
Non-European developed countries (7 countries)	Japan, South Korea, Singapore, Australia, New Zealand, Canada, USA
Developing countries	
Asian developing countries (8 countries)	China, Malaysia, Indonesia, Philippines, Thailand, India, Pakistan, Sri Lanka
Non-Asian developing countries (6 countries)	Brazil, Mexico, Chile, Turkey, Argentina, South Africa

Notes: We classify countries into developed and developing countries according to the International Monetary Fund's World Economic Outlook Report, April 2010.

Table B2: Contemporaneous effects of foreign variables on their domestic counterparts

Country groups	Domestic dependent variables				
	gov	x	y	π	si
European countries	0.507**	−0.002	−0.002	0.227*	0.346**
	(3.156)	(−0.017)	(−0.018)	(1.836)	(6.234)
Non-European developed countries	0.475**	0.113	0.048	0.547**	0.453**
	(2.345)	(0.835)	(0.518)	(5.046)	(3.970)
Asian developing countries	0.499**	−0.015	0.148	0.566**	0.388**
	(2.246)	(−0.086)	(1.426)	(2.012)	(2.161)
Non-Asian developing countries	0.119	−0.191*	0.108	−1.703**	0.908**
	(0.408)	(−1.874)	(0.475)	(−2.786)	(2.243)
US	0.364	0.550	0.241**	0.261**	–
	(1.501)	(1.511)	(2.617)	(3.507)	–

Notes: We specify the VECMX* for each country i as:

$$\Delta g_{i,t} = h_{i,0} - \Pi_i z_{i,t-1} - \Phi_{i,2}\Delta g_{i,t-1} + \Psi_{i,0}\Delta g^*_{i,t} + u_{i,t},$$

where $i = 0, 1, 2, ..., N$, and $t = 1, 2, ..., T$. We report the elements of estimated coefficients $\Psi_{i,0}$ of first differenced contemporaneous foreign variables, which correspond to the elements of their domestic counterparts. For instance, the elasticity of the government consumption share in European countries with respect to the government consumption share in the rest of the world is 0.507. Note that when constructing individual country models, we estimate country models on a country-group basis. Here T-statistics are reported in parentheses. *,** indicate 10% and 5% significance levels, respectively.

Table B3: F statistics for testing the weak exogeneity of country/region-specific foreign and global variables

Country groups	Foreign variables						
	$x^*_{i,t}$	$y^*_{i,t}$	$gov^*_{i,t}$	$si^*_{i,t}$	$inf^*_{i,t}$	oil_t	$\overleftrightarrow{e}^*_{i,t}$
European countries	1.323	0.025	1.907	2.131	0.243	1.735	
	[0.269]	[0.975]	[0.152]	[0.122]	[0.785]	[0.181]	
Non-European developed countries	0.820	0.526	0.732	0.842	2.835	1.860	
	[0.442]	[0.592]	[0.482]	[0.062]	[0.062]	[0.159]	
Asian developing countries	1.254	2.570	0.658	1.773	2.303	1.315	
	[0.292]	[0.056]	[0.579]	[0.154]	[0.078]	[0.270]	
Non-Asian developing countries	0.291	1.669	0.411	2.457	3.623**	2.642	
	[0.748]	[0.192]	[0.664]	[0.090]	[0.030]	[0.075]	
US	1.421	0.271	0.329	–	1.077	–	−0.068
	[0.169]	[0.979]	[0.745]	–	[0.307]	–	[0.946]

Notes: The weak exogeneity test can be performed by estimating

$$\Delta g^*_{s,t} = c_s + \Sigma^R_{r=1}\phi_{s,r}ecm^r_{t-1} + \Sigma^B_b \theta_{s,b}\Delta g_{t-b} + \Sigma^L_l \theta_{s,l}\Delta g^*_{t-l} + \varepsilon_{s,t},$$

where $g^*_{s,t}$ is the s^{th} element of the foreign variable vector g^*_t, c_s is a constant term, $\varepsilon_{s,t}$ is an error term and ecm^r_{t-1} are the estimated error correction terms corresponding to the r cointegrating relationships. We choose the lag orders, B and L in the light of serial correlation tests, allowing for a maximum of four lags for both domestic and foreign variables. We test the null hypothesis that the foreign variable is weakly exogenous by testing the joint significance of the estimated error correction terms in the above regression. ** denotes statistical significance at the 5% level, and the figures in square brackets are estimated probability values.