Rising China, anxious Asia?
An empirical assessment in Bayesian-DSGE model with vertical and processing trade

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Abstract
This paper is thus motivated to investigate the ties that bind China to East and Southeast Asia, and to probe into the mechanism through which China's economic expansion has influenced its Asian neighbors. By using a Bayesian estimated two-region dynamic stochastic general equilibrium model that incorporates the simultaneous presence of vertical and processing trade, we show that vertical trade in intermediate inputs substantially arises alongside processing trade between China and East Asia in the aftermath of China's WTO accession. Nonetheless, vertical trade between China and the developing Southeast Asia is trivial over the same time span. More interestingly, when processing trade *per se* prevails macroeconomic fluctuations are mainly driven by own shocks. To the contrary, the emergence of vertical trade alongside processing trade will give rise to cross-border influence of TFP and IST shocks to countries specializing at midstream production and leading the vertical trade. The impulse response analysis indicates that China's integration into regional production network as a dominant player in processing trade has been benign to the advanced East Asian economies through vertical trade, but malign to the developing Southeast Asian economies that have to compete in processing trade.

Keywords: Vertical trade; processing trade; China; Asia; macroeconomic interdependence; dynamic stochastic general equilibrium model
JEL classification: F41, F44

1 Introduction

The rise of China as the manufacturing powerhouse and exporting platform has been much talked about in recent years. It deserves such incomparable attention, particularly from its Asian neighbors, given the fact that China's rise especially in the aftermath of accession to World Trade Organization (WTO) has tremendously overhauled regional production network by positioning itself as the destination for final assembly of parts and components shipped from Asian neighbors into consumer goods for exporting to the United States, Euro Area and the rest of the world (see, for instance, Athukorala and Menon 2010; Athukorala 2005, 2007; Athukorala and Yamashita, 2006, 2008, 2009; Hayakawa, 2007).

To regional economies, of which production and trade have been vertically the most integrated in the world[1], the emergence of China has posed both opportunity and threat. On the one hand, rapid expansion of China's processing exports implies greater demand for parts and components from its Asian neighbours. Ianchovichina and Walmsley (2005), for instance, calibrate and simulate on a multicountry, multisector model, and show that China's WTO accession has crowded in Japan and the newly industrialized economies in East Asia that supply materials to China. Eichengreen et al.

[1] Using a dataset that comprises 79 countries and 121 different manufacturing products broken down at 4-digit level of the International Standard Industrial Classification (ISIC), rev. 3.1 over the period of 1967 to 2005, Amador and Cabral (2009) show that out of top 10 countries with vertical specialization activities, 8 are from East and Southeast Asia.

(2007) also find that China's growth is beneficial to advanced East Asian economies exporting capital-intensive goods but not to developing Southeast Asian countries[2] exporting labor-intensive goods (see also Park and Shin 2010; Haltmaier et al. 2007).

On the other hand, growing China would place enormous competitive pressure on the developing Asian economies by displacing its former exports of labor-intensive manufacturing goods to the United States and Euro Area (Eichengreen et al. 2007, Roland-Holst and Weiss 2004). Equally intriguing is the finding that points to favorable effect of China's growth on the developing Southeast Asia not the advanced East Asia. Aheame et al. (2003), for instance, by using industry-level data have found that in many industries China and ASEAN-4 have both gained market share at the expense of the Newly Industrialized Economies (NIEs) (see also Greenaway et al. 2008).

On balance, whether China's export expansion has crowded out its Asian neighbors remains an open question. Figure 1 neatly illustrates this comrade-or-competitor conjecture. Expanding East and Southeast Asian trade with China particularly following China's accession into WTO in 2001 is obviously accompanied by declining exporting and importing with the United States. Take an example. In the first quarter of year 1990, export to China only accounted for 2.3 percent of Malaysian total exports to the world, out of which U.S. alone has digested 18 percent. Just prior to China's WTO

[2] Asia neighbors in our context refer to Japan, the Republic of Korea, Hong Kong, Taiwan, Singapore, Indonesia, Malaysia, Philippines, and Thailand, of which the first five is categorized as advanced East Asian economies (EA5) and the latter four is grouped as developing Southeast Asian economies (SEA4).

accession, the relative importance of China steadily climbed to 8 percent while U.S. share still firmly stood at 20 percent. However, within the subsequent eight years China turns out to be the one that has digested 18 percent of Malaysian exports, in conjunction with a nose-diving fall in the share of exports to U.S. to a historical low level of 11 percent.

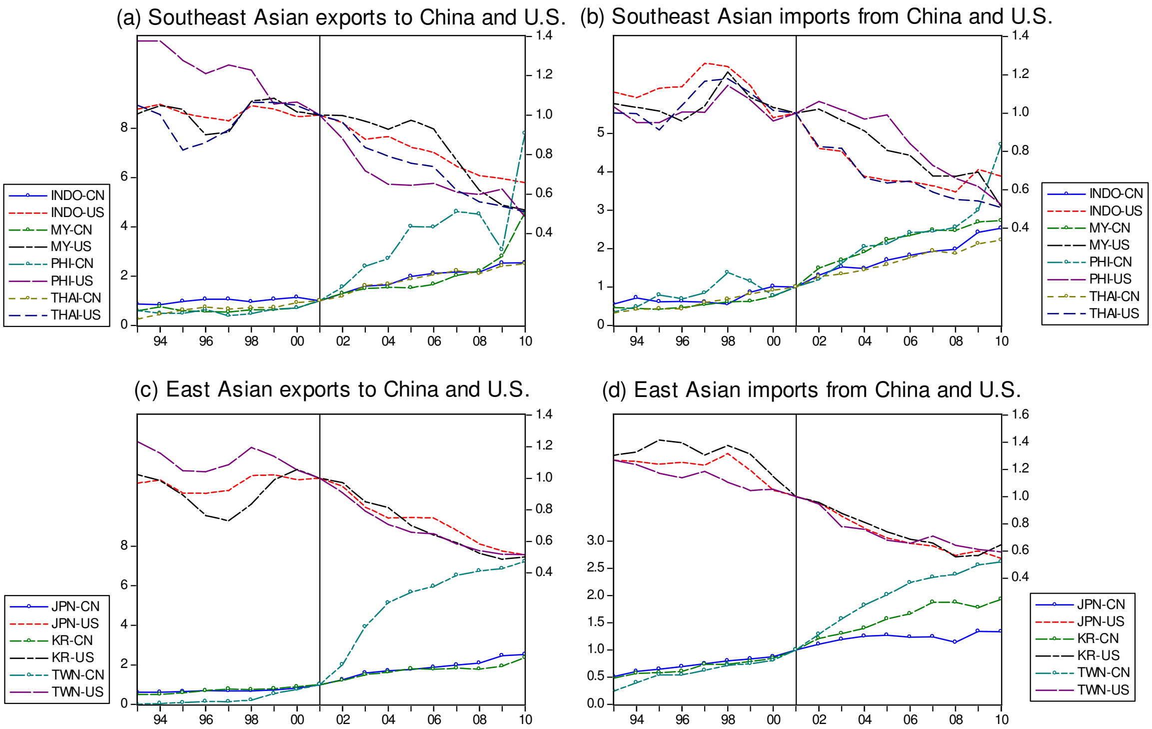

Fig. 1 Rising trade of Asia with China along with falling trade with the United States

Indecisive empirical findings on the influence of China's rise on its Asian neighbor, in conjunction with unambiguous contraction in Asian trade with the United States, have been a sufficient motivation. This paper thus attempts to address two simple questions: what are the ties that bind China to East and Southeast Asia? Whether China's economic expansion has influenced, if yes how, its Asian neighbors?

The novelty of this paper can be comprehended in two aspects. Firstly, it provides a structural interpretation on the ties that bind China and East and Southeast Asia through the lens of Bayesian estimated two-region, three processing-stage dynamic stochastic general equilibrium model developed in Wong and Eng (forthcoming). We find that for a sample over the first quarter of year 2001 to the fourth quarter of year 2008 vertical trade in intermediate inputs substantially arises in parallel with processing trade between China and East Asia[3]. In particular, East Asia imports and processes upstream outputs to fabricate parts and components for re-exporting. Subsequent re-manufacturing of the imported materials in China results in consumer goods for final re-exporting. Nonetheless, one could not find non-trivial vertical trade between China and the developing Southeast Asia over the same post Chinese WTO accession period. Both regions continue vertically specializing at downstream production, and engaging in processing trade against each other.

This in a way reflects different responses of East and Southeast Asia toward the rise of China. When we estimate the model over the period starting from 1987, which hence includes 56 quarters of China's isolation from world production and trade prior to WTO

[3] Back-and-forth trade in intermediate inputs is known as vertical trade. Importing parts and components for re-manufacturing as consumer goods for final exporting is defined as processing trade. See Wong and Eng (forthcoming) for further discussion.

accession, China and East and Southeast Asia are still predominantly coupled through processing trade. In other words, as a response to China's integration into world economy, the advanced East Asia has spontaneously climbed up the ladder of the production chain by vertically specializing at midstream production with China vertically specializes at downstream production. In contrast, the developing Southeast Asia largely fails to upgrade its technical ability, and thus is forced to compete with China in processing export.

Secondly, we find that total factor productivity (TFP) and investment-specific technological (IST) shock have been the dominant source of macroeconomic fluctuation, particularly over medium and long time horizon. Nonetheless, should processing trade *per se* prevails macroeconomic fluctuations are mainly driven by own shocks. To the contrary, the emergence of vertical trade alongside processing trade will give rise to cross-border influence of TFP and IST shocks to countries specializing at midstream production and leading the vertical trade. Most interestingly, the impulse response analysis indicates that China's integration into regional production network as a dominant player in processing trade has been benign to the advanced East Asian economies through vertical trade, but malign to the developing Southeast Asian economies that have to compete in processing trade.

The discussion is organized as follows. Section 2 lays out a basic two-region, three processing-stage dynamic stochastic general equilibrium model that allows us to simultaneously take into account head-to-head competition and arm-in-arm complementary in the interaction between China and East/Southeast Asia. The model is estimated in Section 3 using Bayesian approach. Ties that bind China and East/Southeast Asia are detailed in this section. Last but not least, Section 4 takes a look at how China influences its Asian neighbors by decomposing the forecast errors into a variety of structural shocks and through impulse-response analysis. Section 5 concludes.

2 A macroeconomic model of vertical and processing trade

The interaction between China and East and Southeast Asia is investigated by using a two-country New Keynesian model with vertical and processing developed in Wong and Eng (forthcoming). In this section the two-region, three-processing-stage model that allows for vertical and processing trade is detailed. The model also incorporates investment adjustment cost, partial price and nominal wage indexation, habit persistence, staggered price mechanism, and the U.S. dollar pricing in export market. Because decisions made by Chinese and the rest of Asian firms and households are analogous in such a two-region model, discussion is thus mainly devoted to China, denoted by C, as home economy.

Although modeling vertical trade in intermediate inputs through three processing-stage model allows us to seriously take into account complementarity between China and the rest of Asia, it is not without caveat. In particular, such a two-region prototype can easily overlook the influence of the rest of the world, particularly the role of the U.S. and Euro Area absorption for both Chinese and the rest of Asian exports. To overcome this limitation, on the one hand we allow the spillover of U.S. monetary policy shock to both regions through uncovered interest rate parity condition[4], and on the other hand at empirical front, we use observable aggregate exports and imports series, rather than bilateral trade series, in estimating the model to accommodate for the potential third-country influence on respective economies through trade.

2.1 Firm's cost minimization problem

There are three stages of production before a material turns into finished goods. Upstream production consists of a continuum of firm j that uses plant-specific capital $K_{t-1}^{C}\left(=\left[\int_{j\in J} K_{t-1}^{C}(j)^{(\varepsilon_K-1)/\varepsilon_K}dj\right]^{\frac{\varepsilon_K}{\varepsilon_K-1}}\right)$ of type $j\in J$ and differentiated labor $N_t^C\left(=\left[\int_{i\in I} N_t^C(i)^{1/\mu_{N,t}^C}di\right]^{\mu_{N,t}^C}\right)$ of a variety $i\in I$, where ε_K and $\mu_{N,t}^C$, respectively, is a measure of constant elasticity of substitution between capitals and time-varying wage mark-up, to produce plant-specific materials $Y_{1C,t}(j)$ at date t in Cobb-Douglas production mode. Firm j can only alter its total capital stocks over time by varying the rate of investment I_t^C with investment adjustment cost $S(I_t^C/I_{t-1}^C)$.

[4] A more satisfactory way to deal with third-country effect is to lay out a three-region model. This is, however, out of the scope of the study, but deserves serious attentions in future research.

In line with Mandelman et al. (2011), plant-specific capital stock, in the presence of a specific investment adjustment cost function, accumulates according to the form of

$$K_t^C = (1-\delta)K_{t-1}^C + \mathrm{u}_{I,t}^C I_t^C \left\{1 - \frac{\Psi}{2}\left(\frac{\gimel_{I,t-1}^C I_{t-1}^C}{\gimel_{I,t}^C I_t^C}\right)\left(\frac{\gimel_{I,t}^C I_t^C}{\gimel_{I,t-1}^C I_{t-1}^C} - \Lambda^C\right)^2\right\} \tag{1}$$

where Ψ denotes the parameter governing investment adjustment cost, Λ^C indicates long-run investment growth in China, δ is the rate of depreciation, and $\gimel_{I,t}^C$ is the first-order autoregressive investment-specific technology (IST) shock. The processed outputs will be demanded by the differentiated midstream firms *j* located domestically $\left(Y_{1C,t}^C(j)\right)$ and the rest of Asia $\left(Y_{1C,t}^A(j)\right)$ as materials[5]. For the sake of simplicity, I assume that output market for upstream production is tightly competitive, resulting in nearly infinite elasticity of substitution between varieties. Price thus approximates real marginal cost, and is symmetry across manufacturing plants.

A mass continuum of midstream monopolistically competitive firm j, $j \in J$, imports upstream processed materials $M_{1A,t}^C \left(= \left[\int_{j\in J} M_{1A,t}^C(j)^{(\varepsilon_{2t}-1)/\varepsilon_{2t}} dj\right]^{\frac{\varepsilon_{2t}}{\varepsilon_{2t}-1}}\right)$ of plant *j* from East/Southeast Asia for remanufacture. The demand function for $M_{1A,t}^C(j)$ is thus $\left(P_{1A,t}^C(j)/P_{1A,t}^C\right)^{-\varepsilon_{2t}} M_{1A,t}^C$, where $P_{1A,t}^C$ is the home price of Chinese imported materials

[5] Subscripted notations "*C*" and "*A*" refer to the destination for production, of which *C* denotes China while *A* the rest of Asia. Should they appear as superscripts, destination for transaction is referred to.

from the rest of Asia, and $\varepsilon_{2t} > 1$ is the time-varying demand elasticity of substitution between varieties[6]. In combination with local inputs $Y^C_{1C,t}\left(=\left[\int_{j\in J} Y^C_{1C,t}(j)^{(\varepsilon_{2t}-1)/\varepsilon_{2t}}dj\right]^{\frac{\varepsilon_{2t}}{\varepsilon_{2t}-1}}\right)$, of which the demand function takes the form $\left(P^C_{1C,t}(j)/P^C_{1C,t}\right)^{-\varepsilon_{2t}}Y^C_{1C,t}$, the resultant output $\left(Y_{2C,t}\right)$ will be partially exported to East/Southeast Asia for further processing. Such back-and-forth trade in intermediate inputs – importing materials for re-exporting as processed intermediate inputs – is defined as vertical trade.

Lastly at downstream production, monopolistically competitive producers j of measure J combines a variety of home $Y^C_{2C,t}\left(=\left[\int_{j\in J} Y^C_{2C,t}(j)^{(\varepsilon_{3t}-1)/\varepsilon_{3t}}dj\right]^{\frac{\varepsilon_{3t}}{\varepsilon_{3t}-1}}\right)$ and imported intermediate goods $M^C_{2A,t}\left(=\left[\int_{j\in J} M^C_{2A,t}(j)^{(\varepsilon_{3t}-1)/\varepsilon_{3t}}dj\right]^{\frac{\varepsilon_{3t}}{\varepsilon_{3t}-1}}\right)$ using the CES technology. Market clearing condition requires the final output $\left(Y_{3C,t}\right)$ to be consumed locally $\left(C^C_{C,t}\right)$, shipped abroad $\left(Y^A_{3C,t}\right)$, and reinvested (I^C_t). Importing manufactured intermediate inputs for processing and re-exporting as final goods is called processing trade.

As such, firm j's problem, from upstream to downstream, can be formulated as minimizing the cost of production subject to the production technology:

[6] For $n = 1,2$, $M^C_{nA,t}$ is c.i.f imports of China from the rest of Asia. On the flip side, $Y^C_{nA,t}$ is the f.o.b exports of the rest of Asia to Asia. Following Ravn and Mazzenga (2004) that measure transportation cost as the wedge between c.i.f imports and f.o.b. imports, which happens to be the export in our two-region model, this chapter formalizes transportation cost as $\tau^C_{n,t} = \frac{M^C_{nA,t}}{Y^C_{nA,t}} - 1$. $\tau^C_{n,t}$ is assumed to follow first-order autoregressive process.

Upstream firm:

$$\min_{K_t^C, N_t^C, I_t^C} \left(r_{K,t}^C + \delta\right) K_{t-1}^C + W_t^C N_t^C + \gimel_{I,t}^C I_t^C \left\{ \frac{\Psi}{2} \left(\frac{\gimel_{I,t-1}^C I_{t-1}^C}{\gimel_{I,t}^C I_t^C} \right) \left(\frac{\gimel_{I,t}^C I_t^C}{\gimel_{I,t-1}^C I_{t-1}^C} - \Lambda^C \right)^2 \right\} \tag{2}$$

s.t.

$$Y_{1C,t} = e^{Z_t^C} (K_{t-1}^C)^{\alpha} (N_t^C)^{1-\alpha} \tag{3}$$

Midstream firm:

$$\min_{Y_{1C,t}^C, M_{1A,t}^C} P_{1C,t}^C Y_{1C,t}^C + P_{1A,t}^C M_{1A,t}^C \tag{4}$$

s.t.

$$Y_{2C,t} = \left[(1 - \kappa_2^C)^{1/\vartheta} \left(Y_{1C,t}^C \right)^{(\vartheta-1)/\vartheta} + (\kappa_2^C)^{1/\vartheta} \left(M_{1A,t}^C \right)^{(\vartheta-1)/\vartheta} \right]^{\vartheta/(\vartheta-1)} \tag{5}$$

Downstream firm:

$$\min_{Y_{2C,t}^C, M_{2A,t}^C} P_{2C,t}^C Y_{2C,t}^C + P_{2A,t}^C M_{2A,t}^C \tag{6}$$

s.t.

$$Y_{3C,t} = \left[(1 - \kappa_3^C)^{1/\vartheta} \left(Y_{2C,t}^C \right)^{(\vartheta-1)/\vartheta} + (\kappa_3^C)^{1/\vartheta} \left(M_{2A,t}^C \right)^{(\vartheta-1)/\vartheta} \right]^{\vartheta/(\vartheta-1)} \tag{7}$$

where the parameters κ_2^C and κ_3^C indicate the share of imported intermediates in midstream and downstream production, respectively. As will be elaborated in next section, these parameters are informative about the degree of vertical specialization in China and the rest of Asia. Besides, the parameter $\vartheta > 0$ denotes the elasticity of substitution between home and imported intermediate inputs. Z_t^C is an Hicks-neutral TFP shock that follows first-order autoregressive process, and $r_{K,t}^C$ denotes the real return on capital.

2.2 First-order and market clearing conditions

Solving for firm's cost minimization problem, one can derive the following efficiency conditions:

$$1+r_{K,t}^{C}=\frac{\alpha RMC_{1C,t}Y_{1C,t}}{K_{t-1}^{C}}+1-\delta \tag{8}$$

$$W_{t}^{C}=\frac{(1-\alpha)RMC_{1C,t}Y_{1C,t}}{N_{t}^{C}} \tag{9}$$

$$RMC_{1C,t}\left\{\frac{\gimel_{I,t}^{C}I_{t}^{C}}{\gimel_{I,t-1}^{C}I_{t-1}^{C}}-\Lambda^{C}\gimel_{I,t}^{C}\right\}= \beta E_{t}RMC_{1C,t+1}\left\{\left(\frac{\gimel_{I,t+1}^{C}I_{t+1}^{C}}{\gimel_{I,t}^{C}I_{t}^{C}}\right)^{2}-\Lambda^{C}\left(\frac{\gimel_{I,t+1}^{C}I_{t+1}^{C}}{\gimel_{I,t}^{C}I_{t}^{C}}\right)-\frac{1}{2}\gimel_{I,t}^{C}\left[\left(\frac{\gimel_{I,t+1}^{C}I_{t+1}^{C}}{\gimel_{I,t}^{C}I_{t}^{C}}\right)^{2}-2\Lambda^{C}\left(\frac{\gimel_{I,t+1}^{C}I_{t+1}^{C}}{\gimel_{I,t}^{C}I_{t}^{C}}\right)-(\Lambda^{C})^{2}\right]\right\} \tag{10}$$

$$RMC_{1C,t}=\frac{\left(r_{K,t}^{C}+\delta\right)^{\alpha}\left(W_{t}^{C}\right)^{1-\alpha}}{e^{Z_{t}^{C}}\alpha^{\alpha}(1-\alpha)^{1-\alpha}} \tag{11}$$

$$Y_{1C,t}^{C}=(1-\kappa_{2}^{C})\left(\frac{P_{1C,t}^{C}}{P_{1t}^{C}}\right)^{-\vartheta}Y_{2C,t} \tag{12}$$

$$M_{1A,t}^{C}=\kappa_{2}^{C}\left(\frac{P_{1A,t}^{C}}{P_{1t}^{C}}\right)^{-\vartheta}Y_{2C,t} \tag{13}$$

$$RMC_{2C,t}=P_{1t}^{C} \tag{14}$$

$$Y_{2C,t}^{C}=(1-\kappa_{3}^{C})\left(\frac{P_{2C,t}^{C}}{P_{2t}^{C}}\right)^{-\vartheta}Y_{3C,t} \tag{15}$$

$$M_{2A,t}^{C}=\kappa_{3}^{C}\left(\frac{P_{2A,t}^{C}}{P_{2t}^{C}}\right)^{-\vartheta}Y_{3C,t} \tag{16}$$

$$RMC_{3C,t}=P_{2t}^{C} \tag{17}$$

Eqs. (8) and (9) define the return on capital and wage in terms of marginal product of capital and labor, respectively, which in conjunction with Eq. (3) yield the real marginal cost for upstream production shown in Eq. (11). Eq. (10) shows the investment dynamics. Eqs. (12) and (13) are the isoelastic optimal demand for home and imported upstream processed outputs as materials by midstream production. $P_{1A,t}^{C}\left(= S_{CD,t}P_{1A,t}^{D}\right)$ is the local-currency denominated import price, and is the product of exchange rate defined as home currency per unit of the U.S. dollar $\left(S_{CD,t}\right)$ and Asian export price denominated in the U.S dollar $\left(P_{1A,t}^{D}\right)$. Shown in Eq. (14), the corresponding real marginal cost in midstream production takes the form of utility-based producer price index P_{1t}^{C}

$$P_{1t}^{C} = \left[(1-\kappa_2^C)\left(P_{1C,t}^{C}\right)^{1-\vartheta} + \kappa_2^C\left(P_{1A,t}^{C}\right)^{1-\vartheta}\right]^{1/(1-\vartheta)} \tag{18}$$

By the same token, Eqs. (15) and (16) are optimal demand of downstream production for home and imported midstream processed outputs as intermediates, where $P_{2A,t}^{C} = S_{CD,t}P_{2A,t}^{D}$. The real marginal cost can then be formulated in form of utility-based producer price with constant elasticity of substitution.

$$P_{2t}^{C} = \left[(1-\kappa_3^C)\left(P_{2C,t}^{C}\right)^{1-\vartheta} + \kappa_3^C\left(P_{2A,t}^{C}\right)^{1-\vartheta}\right]^{1/(1-\vartheta)} \tag{19}$$

All the markets clear at each period should the demand meets the supply

Asia	*China*
$Y_{1A,t} = Y_{1A,t}^{A} + Y_{1A,t}^{C}$	$Y_{1C,t} = Y_{1C,t}^{C} + Y_{1C,t}^{A}$

$$Y_{2A,t}\left(= f(Y_{1A,t}^{A}, Y_{1C,t}^{A})\right) = Y_{2A,t}^{A} + Y_{2A,t}^{C} \qquad Y_{2C,t}\left(= f(Y_{1C,t}^{C}, Y_{1A,t}^{C})\right) = Y_{2C,t}^{C} + Y_{2C,t}^{A}$$

$$Y_{3A,t}\left(= f(Y_{2A,t}^{A}, Y_{2C,t}^{A})\right) = C_{A,t}^{A} + Y_{3A,t}^{C} + I_{t}^{A} \quad Y_{3C,t}\left(= f(Y_{2C,t}^{C}, Y_{2A,t}^{C})\right) = C_{C,t}^{C} + Y_{3C,t}^{A} + I_{t}^{C} \tag{20}$$

where $f(.)$ indicates production function. China and East/Southeast Asia are linked vertically and sequentially through production and trade.

2.3 Optimal symmetry pricing decision with U.S dollar denominated trade

According to Calvo pricing mechanism, firms at both midstream and downstream production reoptimize the price should they receive signal at probability $1-\theta_{P,nC}$, where $n = 2,3$. Price-reoptimizing firms j choose $\mathbb{P}_{nC,t}$ to maximize the expected discounted profits $E_t\Pi_{n,t}$ for sales in home and export markets. For home market, the pricing decision for midstream and downstream firm is, respectively, given by

$$E_t\Pi_{2,t}^{home} = E_t\sum_{i=0}^{\infty}\left(\theta_{P,2C}^{C}\beta\right)^{i}\Lambda_{t+i}\left[\frac{\mathbb{P}_{2C,t+i}^{C}(j)-MC_{2C,t+i}}{P_{2,t+i}^{C}}\right]\left[\frac{\mathbb{P}_{2C,t+i}^{C}(j)}{P_{2C,t+i}^{C}}\right]^{-\varepsilon_{2C,t}^{C}} Y_{2C,t+i} \tag{21}$$

$$E_t\Pi_{3,t}^{home} = E_t\sum_{i=0}^{\infty}\left(\theta_{P,3C}^{C}\beta\right)^{i}\Lambda_{t+i}\left[\frac{\mathbb{P}_{3C,t+i}^{C}(j)-MC_{3C,t+i}}{P_{3,t+i}^{C}}\right]\left[\frac{\mathbb{P}_{3C,t+i}^{C}(j)}{P_{3C,t+i}^{C}}\right]^{-\varepsilon_{3C,t}^{C}} C_{C,t+i}^{C} \tag{22}$$

Besides the incorporation of three processing stage, currency denomination in export pricing is another key property that differentiates this model from the typical New Keynesian model. For the latter, price is either set symmetrically for both home and export market in producer currency price or asymmetrically in buyer currency price. But I consider U.S. dollar pricing strategy in exports in that the variability of exchange rates between local currency and the U.S. dollar will not be passed through into foreign price of home export but the export profit in local currency denomination. Firm's expected export profit in home currency under dollar pricing strategy for midstream and downstream output can be presented, respectively, as

$$E_t \Pi_{2,t}^{exp} = E_t \sum_{i=0}^{\infty} \left(\theta_{P,2C}^{A} \beta\right)^{i} \Lambda_{t+i} \left[\frac{S_{CD,t} \mathbb{P}_{2C,t+i}^{D}(j) - MC_{2C,t+i}}{P_{2,t+i}^{C}}\right] \left[\frac{S_{CD,t+i} \mathbb{P}_{2C,t+i}^{D}(j)}{P_{2C,t+i}^{A}}\right]^{-\varepsilon_{2C,t}^{A}} Y_{2C,t+i}^{A} \quad (23)$$

$$E_t \Pi_{3,t}^{exp} = E_t \sum_{i=0}^{\infty} \left(\theta_{P,3C}^{A} \beta\right)^{i} \Lambda_{t+i} \left[\frac{S_{CD,t} \mathbb{P}_{3C,t+i}^{D}(j) - MC_{3C,t+i}}{P_{3,t+i}^{C}}\right] \left[\frac{S_{CD,t+i} \mathbb{P}_{3C,t+i}^{D}(j)}{P_{3C,t+i}^{A}}\right]^{-\varepsilon_{3C,t}^{A}} C_{C,t+i}^{A} \quad (24)$$

In what follows we assume that all firms producing all types of goods are symmetric in price setting. Solving for optimal reset price for both home and export markets of middle- and downstream production gives us

$$\mathbb{P}_{2C,t+i}^{C} = \left(\frac{\varepsilon_{2C,t}^{C}}{\varepsilon_{2C,t}^{C} - 1}\right) \left(\sum_{i=0}^{\infty} \left(\theta_{P,2C}^{C} \beta\right)^{i} \Lambda_{t+i} MC_{2C,t+i}\right) \quad (25)$$

$$\mathbb{P}_{3C,t+i}^{C} = \left(\frac{\varepsilon_{3C,t}^{C}}{\varepsilon_{3C,t}^{C} - 1}\right) \left(\sum_{i=0}^{\infty} \left(\theta_{P,3C}^{C} \beta\right)^{i} \Lambda_{t+i} MC_{3C,t+i}\right) \quad (26)$$

$$\mathbb{P}_{2C,t+i}^{D} = \left(\frac{\varepsilon_{2C,t}^{A}}{\varepsilon_{2C,t}^{A} - 1}\right) \left(\frac{\sum_{i=0}^{\infty} \left(\theta_{P,2C}^{A} \beta\right)^{i} \Lambda_{t+i} MC_{2C,t+i}}{S_{CD,t}}\right) \quad (27)$$

$$\mathbb{P}_{3C,t+i}^{D} = \left(\frac{\varepsilon_{3C,t}^{A}}{\varepsilon_{3C,t}^{A} - 1}\right) \left(\frac{\sum_{i=0}^{\infty} \left(\theta_{P,3C}^{A} \beta\right)^{i} \Lambda_{t+i} MC_{3C,t+i}}{S_{CD,t}}\right) \quad (28)$$

Optimal reset price responds to nominal marginal cost in each processing stage, both at home and export market. Most interestingly, should the export be priced in the U.S dollar, a nominal depreciation against the U.S dollar raises the home-currency denominated export profit, which, given the export price markup, enables the firm to optimally reduce the export price.

Firms that have received signal for price reoptimization will reset their log-linearized price ($\hat{\wp}^{z}_{nC,t}$) to approximate the optimal Eqs. (25) and (26) for home market and Eqs. (27) and (28) for export market, which results in

$$\hat{\wp}^{z}_{nC,t} = \theta^{z}_{P,nC}\beta E_t \hat{\wp}^{z}_{nC,t+1} + (1 - \theta^{z}_{P,nC}\beta)\hat{\mathbb{P}}^{z}_{nC,t} \tag{29}$$

where $z = C, D$. The remaining firms that do not receive signal for reoptimization will stick to last-period price, out of which a fraction of them ($\gamma^{z}_{p,nC}$) is updated by last-period inflation. Thus, the log-linearized aggregate price level at each date can be written as probability-weighted average of non-optimized and reoptimized price:

$$\hat{p}^{z}_{nC,t} = \theta^{z}_{P,nC}\left(\hat{p}^{z}_{nC,t-1} + \gamma^{z}_{p,nC}\pi^{z}_{nC,t-1}\right) + (1 - \theta^{z}_{P,nC})\hat{\wp}^{z}_{nC,t} \tag{30}$$

By inserting Eq. (30) and its one-period ahead iteration in conjunction with Eq. (25) through (28) into Eq. (29), we can obtain home producer price (PPI) ($n = 2, z = A$) and GDP deflator ($n = 3, z = A$) inflation dynamics, and export price inflation for exported intermediate ($n = 2, z = D$) and consumer goods ($n = 3, z = D$) as well.

$$\pi^{C}_{nC,t} = \left(\frac{\gamma^{C}_{p,nC}}{1+\theta^{C}_{P,nC}\beta\gamma^{C}_{p,nC}}\right)\pi^{C}_{nC,t-1} + \left(\frac{\beta}{1+\theta^{C}_{P,nC}\beta\gamma^{C}_{p,nC}}\right)E_t\pi^{C}_{nC,t+1} + \lambda^{C}_{nC}\left(\widehat{rmc}_{nC,t} + \hat{u}^{C}_{\pi,nC,t}\right) \tag{31}$$

$$\pi^{D}_{nC,t} = \left(\frac{\gamma^{D}_{p,nC}}{1+\theta^{D}_{P,nC}\beta\gamma^{D}_{p,nC}}\right)\pi^{D}_{nC,t-1} + \left(\frac{\beta}{1+\theta^{D}_{P,nC}\beta\gamma^{D}_{p,nC}}\right)E_t\pi^{D}_{nC,t+1} + \lambda^{D}_{nC}\left(\widehat{rmc}_{nC,t} - \hat{s}_{CD,t} + \hat{u}^{D}_{\pi,nC,t}\right) \tag{32}$$

where $\lambda_{nC}^{C}=\frac{(1-\theta_{P,nC}^{C})(1-\theta_{P,nC}^{C}\beta)}{\theta_{P,nC}^{C}\left(1+\theta_{P,nC}^{C}\beta\gamma_{p,nC}^{C}\right)}$, $\lambda_{nC}^{D}=\frac{(1-\theta_{P,nC}^{D})(1-\theta_{P,nC}^{D}\beta)}{\theta_{P,nC}^{D}\left(1+\theta_{P,nC}^{D}\beta\gamma_{p,nC}^{D}\right)}$, and $\hat{u}_{\pi,nC,t}^{Z}$ is an i.i.d price markup shock for $z=A,D$ and $n=2,3$.

Turning to firm's real marginal cost function, log-linearizing Eqs. (11), (14), and (17) in conjunction with price index of Eqs. (18) and (19) yields

$$r\widehat{m}c_{1C,t}=\alpha((1+\bar{r}_{K}^{C})/(\bar{r}_{K}^{C}+\delta))\hat{r}_{K,t}^{C}+(1-\alpha)\widehat{w}_{t}^{C}-\hat{z}_{t}^{C} \tag{33}$$

$$r\widehat{m}c_{nC,t}=\hat{p}_{n-1C,t}^{C}+\kappa_{n}^{C}\left(\hat{s}_{CD,t}+\hat{p}_{n-1A,t}^{D}-\hat{p}_{n-1C,t}^{C}\right),\ n=2,3 \tag{34}$$

One can see that, except for the upstream production, pricing decisions at midstream and downstream production over home and foreign countries are closely intertwined.

2.4 Modal-consistent measure of vertical specialization

Following Yi (2003), the degree of vertical specialization of total export for country i over sector h can be measured by

$$VS_{i}=\frac{\sum_{h}\kappa_{h}Export_{h}}{\sum_{h}Export_{h}} \tag{35}$$

Given the structure of two-region, three processing-stage model, for index i denotes China and j denotes EA5 and SEA4, respectively, the vertical-specialization index is rewritten as

$$VS_{i}=\frac{\kappa_{1}^{i}y_{1i}^{j}+\kappa_{2}^{i}y_{2i}^{j}+\kappa_{3}^{i}y_{3i}^{j}}{y_{1i}^{j}+y_{2i}^{j}+y_{3i}^{j}}$$

for China, and

$$VS_{j}=\frac{\kappa_{1}^{j}y_{1j}^{i}+\kappa_{2}^{j}y_{2j}^{i}+\kappa_{3}^{j}y_{3j}^{i}}{y_{1j}^{i}+y_{2j}^{i}+y_{3j}^{i}}$$

for EA5 and SEA4.

2.5 Household

Household i's constrained optimization problem can be illustrated as utility maximization of utility function at Eq. (37) subject to the budget constraint at Eq. (36)

$\max_{c_{C,t}^{C}, c_{A,t}^{C}, c_{t}^{C}, N_{t}^{C}, B_{t}^{C}, B_{t}^{D}} U(C_t^C, N_t^C)$

s.t.

$$P_{3t}^{C}C_{t}^{C}\left(= P_{3C,t}^{C}C_{C,t}^{C} + P_{3A,t}^{C}C_{A,t}^{C}\right) + \left(\frac{S_{CD,t}}{P_{3t}^{C}\omega_{t}^{C}}\right)\left(\frac{B_{t}^{D}}{R_{t}^{D}}\right) + \frac{B_{t}^{C}}{P_{3t}^{C}R_{t}^{C}} W_{t}^{C}N_{t}^{C} + \Pi_{t}^{C} + \left(\frac{S_{CD,t}B_{t-1}^{D} + B_{t-1}^{C}}{P_{3t-1}^{C}}\right) \tag{36}$$

where

$$U(C_t^C, N_t^C) = E_t\left\{\sum_{t=0}^{\infty}\beta^t \text{ʎ}_{U,t}^{C}\left[\frac{(C_t^C - H_t^C)^{1-\sigma}}{1-\sigma} - \text{u}_{N,t}^{C}\frac{(N_t^C)^{1+\chi_N}}{1+\chi_N}\right]\right\} \tag{37}$$

Consumption bundle C_t^C comprises home and imported final goods with constant elasticity of substitution:

$$C_t^C = \left[(\gamma^C)^{1/\varphi}\left(C_{C,t}^{C}\right)^{(\varphi-1)/\varphi} + (1-\gamma^C)^{1/\varphi}\left(C_{A,t}^{C}\right)^{(\varphi-1)/\varphi}\right]^{\varphi/(\varphi-1)} \tag{38}$$

$\text{ʎ}_{U,t}^{C}$ and $\text{u}_{N,t}^{C}$, respectively, is first-order autoregressive preference shock and i.i.d labor supply shock. $H_t^C(= bC_{t-1}^C)$ indicates external habit formation in which b is the parameter that governs the extent of habit persistence. $0 < \beta < 1$ refers to subjective discount factor, σ measures the coefficient of relative risk aversion, and the reciprocal of χ_N indicates the wage elasticity of labor supply. The parameter $\varphi > 1$ is elasticity of substitution between home and imported consumer goods, and γ^C measures home bias in consumption. ω_t^C denotes the exchange-rate risk, implying that home and dollar-denominated bonds are imperfect substitute.

Efficiency conditions can then be derived as

$$C_{C,t}^C = \gamma^C \left(P_{3C,t}^C / P_{3t}^C\right)^{-\varphi} C_t^C \tag{39}$$

$$C_{A,t}^C = (1-\gamma^C)\left(P_{3A,t}^C / P_{3t}^C\right)^{-\varphi} C_t^C \tag{40}$$

$$P_{3t}^C = \left[\gamma^C \left(P_{3C,t}^C\right)^{1-\varphi} + (1-\gamma^C)\left(P_{3A,t}^C\right)^{1-\varphi}\right]^{1/(1-\varphi)} \tag{41}$$

$$(C_t^C - bC_{t-1}^C)^{-\sigma} E_t P_{3t+1}^C \lambda_{U,t}^C = \beta R_t^C (E_t C_{t+1}^C - bC_t^C)^{-\sigma} P_{3t}^C E_t \lambda_{U,t+1}^C \tag{42}$$

$$(N_t^C)^{\chi_N} (C_t^C - bC_{t-1}^C)^{\sigma} \mathrm{u}_{N,t}^C = W_t^{MRS,C} \tag{43}$$

$$S_{CD,t} = E_t S_{CD,t+1} (R_t^{US} / R_t^C) \omega_t^C \tag{44}$$

Eqs. (39) and (40) are optimal demand functions, Eq. (41) is utility-based consumer price index, Eq. (42) is the Euler condition for intertemporal consumption smoothing with habit persistence, Eq. (43) shows the marginal rate of substitution between leisure and consumption, and Eq. (44) refers to uncovered interest parity condition (UIPC). We assume that UIPC shock ω_t^C is i.i.d white noise.

Since labors employed in upstream production are differentiated, households as monopolistic supplier of labor effort are assumed to set nominal wage according Calvo mechanism. In each period, a fraction of households $(1-\theta_W^C)$ can reoptimize their posted nominal wage to approximate wage level that corresponds to marginal rate of substitution between labor supply and consumption. Those who do not receive the signal (θ_W^C) will partially index to last-period wage adjusted for inflation. Hence, nominal wage inflation equation can be derived as

$$\pi_{w,t}^C = \left\{\frac{\gamma_W^C}{1+\theta_W^C\beta\gamma_W^C}\right\}\pi_{W,t-1}^C + \left\{\frac{\beta}{1+\theta_W^C\beta\gamma_W^C}\right\}E_t\pi_{W,t+1}^C + \left\{\frac{(1-\theta_W^C)(1-\theta_W^C\beta)}{\theta_W^C(1+\theta_W^C\beta\gamma_W^C)}\right\}(\mathcal{M}_t + \mathrm{u}_{W,t}^C) \quad (45)$$

where $\mathcal{M}_t = \widehat{w}_t^{MRS,C} - \widehat{w}_t^C$. $\mathrm{u}_{W,t}^C$ is i.i.d wage markup shock.

The model is closed by considering a general form of monetary policy reaction as below:

$$r_t^C = \rho_R^C r_t^C + (1-\rho_R^C)\left(r_{n,t}^C + V_\pi^C \pi_{CPI,t}^C + V_{AD}^C \widehat{ad}_t^C + V_S^C \Delta s_{CD,t}\right) + \mathrm{u}_{R,t}^C \quad (46)$$

where $\widehat{ad}_t^C = \left(\frac{\bar{c}^C}{\overline{ad}^C}\right)\hat{c}_t^C + \left(\frac{\bar{\imath}^C}{\overline{ad}^C}\right)\hat{\imath}_t^C + \left(\frac{\overline{ex}^C}{\overline{ad}^C}\right)\widehat{ex}_t^C - \left(\frac{\overline{\imath m}^C}{\overline{ad}^C}\right)\widehat{\imath m}_t^C$, in which ex^C and im^C , respectively, denotes the total f.o.b export and import. $r_{n,t}^C$ is the natural rate of interest, ρ_R^C measures the interest rate persistence, V_π^C, V_{AD}^C, and V_S^C indicates central bank's responsiveness toward variability in consumer goods price inflation, aggregate demand variability, and rate of change in nominal exchange rates between home currency and U.S. dollar, respectively. $\mathrm{u}_{R,t}^C$ refers to i.i.d white noise to the conduct of monetary policy. Putting exchange rate against U.S dollar rather than foreign currencies into monetary policy reaction function is motivated by the fact that East Asia tends to moderate currency fluctuation against the U.S. dollar (see, for instance, McKinnon and Schnabl, 2004). The triangular relationship between the total trade-weighted currencies of the East/Southeast Asia, Chinese reminbi, and the U.S. dollar is given by $\Delta s_{AC.t} = \Delta s_{AD,t} -$

$\Delta s_{CD,t}$, where $\Delta s_{AD,t}$ is the rate of change in nominal exchange rates between trade-weighted Asian currencies and the U.S. dollar.

3 Estimation

3.1 Bayesian method

The model is confronted with the data using Bayesian methods. As the literature on Bayesian estimation and evaluation has been growing tremendously, its estimation procedure is only briefly sketched here[7]. Bayesian analysis is a powerful, model-coherent way for estimation and inference. The procedure is principally built around the likelihood function of the data derived from the model in conjunction with the prior belief on the probability distribution of the parameters. Bayesian estimation is thus about finding a set of parameters that maximizes the posteriors.

Formally speaking, the model parameters is stacked in a vector of $\mathbb{X}$, and is drawn a priori probability density $\mathcal{P}(\mathbb{X}, \mathcal{M})$. Along with a set of observed data, $\Upsilon^{\mathrm{T}} = \{\mathbb{R}^1, \dots, \mathbb{R}^T\}$, where T denotes the number of periods, the log-linearized model can be estimated by Kalman filter to yield log likelihood function, $\mathcal{L}(\Upsilon|\mathbb{X}, \mathcal{M})$, that describes the density of the data. Likelihood function is thus identical to $\mathcal{P}(\Upsilon|\mathbb{X}, \mathcal{M})$. Given the prior density $\mathcal{P}(\mathbb{X}, \mathcal{M})$ on the one hand, and likelihood $\mathcal{P}(\Upsilon|\mathbb{X}, \mathcal{M})$ on the other hand, we are able to

[7] See, for instance, the influential Smets and Wouters (2003), Fernandez-Villaverde and Rubio-Ramirez (2004), Lubik and Schorfheide (2006), An and Schorfheide (2007), Fernandez-Villaverde (2010), and Schorfheide (2010) for in-depth discussion.

infer the posterior density. According to Bayes's theorem, the posterior distribution of model parameters $\mathcal{P}(\mathbb{X}|\Upsilon,\mathcal{M})$ is formed by combing the likelihood function and prior density in following manner:

$$\mathcal{P}(\mathbb{X}|\Upsilon,\mathcal{M}) = \frac{\mathcal{P}(\Upsilon|\mathbb{X},\mathcal{M})\mathcal{P}(\mathbb{X},\mathcal{M})}{\mathcal{P}(\Upsilon,\mathcal{M})} \quad (47)$$

where $\mathcal{P}(\Upsilon,\mathcal{M})$ is the marginal density of the data, given a specific model:

$$\mathcal{P}(\Upsilon,\mathcal{M}) = \int_{\mathbb{X}} \mathcal{P}(\Upsilon|\mathbb{X},\mathcal{M})\mathcal{P}(\mathbb{X},\mathcal{M})\, d\mathbb{X} \quad (48)$$

Suppose that the marginal density of the data is a constant or equals certain parameter, the posterior kernel can be derived from the numerator of the posterior density

$$\mathcal{K}(\mathbb{X}|\Upsilon,\mathcal{M}) \equiv \mathcal{P}(\mathbb{X}|\Upsilon,\mathcal{M}) \propto \mathcal{P}(\Upsilon|\mathbb{X},\mathcal{M})\mathcal{P}(\mathbb{X},\mathcal{M}) \quad (49)$$

where $\propto$ denotes proportionality. Posterior kernel is simulated to generate draws using Markov Chain Monte Carlo (MCMC) method. Specifically, forty thousand draws are generated using Metropolis-Hastings algorithm, of which half is discarded to attain convergence based on the diagnostics proposed in Brooks and Gelman (1998). The resultant findings provide the point estimates, standard deviations and confidence interval.

3.2 Data and calibration

In finding out how China's macroeconomic dynamics could affect East and Southeast Asian economies differently using a two-region model, I consider nine East Asian economies comprising Japan, Republic of Korea, Hong Kong, Taiwan, Singapore, Malaysia, Indonesia, Philippines, and Thailand, out of which the first five is categorized as advanced East Asian economies (EA5) and the next four is grouped as developing Southeast Asian economies (SEA4). I interpret China as home region, whereas EA5 and SEA4, respectively, as foreign region.

I first estimate the model using the dataset sourced from International Financial Statistics with supplementary data from Economist Intelligence Unit (EIU) database particularly on the case of Taiwan spanning 88 quarters from the first quarter of 1987 to the fourth quarter of 2008. I next re-estimate the model using the sub-dataset ranging from the first quarter of 2001 to the fourth quarter of 2008. The intuition of doing so is straightforward: by comparing the parameter estimates for post China's WTO accession with that of longer time span covering the period of China's isolation from world trading system, one could shed light on the tie binding China and East/Southeast Asia since 2001.

Altogether there are 23 observable total trade-weighted macroeconomic time series: real GDP, real consumption, real investment, labor force, nominal interest rate, nominal exchange rates vis-à-vis the U.S. dollar, producer price index (PPI) inflation, GDP deflator inflation, final goods export deflator inflation, intermediate export price index, and transportation cost for EA5 and SEA4, and U.S. federal funds rate. All the quantity variables are first converted into the U.S dollar adjusted for purchasing power parity, and all data, except for rates of inflation and interest, are logged and detrended using

Hodrik-Prescott Filter with smoothing parameter $\lambda = 1600$. Detrended series are then weighted based on the time-varying fraction of national total trade (export + import) over aggregate regional trade to construct detrended regional series for EA5 and SEA4.

Only a handful of parameters are calibrated. The labor share is set at 0.36. Subjective discount rate equals 0.985, implying 6% steady-state real interest rate per annum. Capital stock depreciates a rate of 2.5% per quarter. Meanwhile, capital adjustment cost is fixed at 0.6 (Mandelman et al. 2011). Because both efficient labor supply shock and inefficient wage markup shock enter nominal wage inflation of Eq. (45), in addition to the lack of measures of the wage for these economies, it complicates the identification of parameters. Monetary policy, for instance, responds differently to efficient and inefficient shock. Interest rate leans with the wind of rising labor supply that increases the natural output but leaning against the wind of rising wage markup that distorts the natural output, despite the fact that nominal wage increases in the aftermath of both shocks (see Smets and Wouter, 2003). To minimize such identification problem I choose not to estimate but to fix the nominal wage indexation at 0.5 and Calvo wage stickiness at 0.75.

Table 1 reports the calibrated steady states. In particular, consumption, investment, export, and import as a share of model-consistent GDP, which ignores public spending, are averaged over 1987Q1 to 2008Q4. Export is decomposed into upstream, intermediate, and consumption goods according to Kim et al. (2011). By assuming a priori that $\gamma_i = \kappa_{3i} = \kappa_{2i} = 0.5$, together with the calculated relative real GDP between China and East/Southeast Asia, the exporting fraction of intermediate and upstream production can be easily calibrated based on the market-clearing condition. Detailed procedure is available upon request.

Table 1. Calibrated steady states, 1987Q1-2008Q4

	China	East Asia	China	Southeast Asia
Historical statistics				
Lambda	0.104	0.024	0.104	0.055
As a share of GDP				
Consumption	0.544	0.668	0.544	0.651
Investment	0.417	0.324	0.417	0.294
Export	0.233	0.057	0.233	0.427
Import	0.193	0.05	0.193	0.372
As a share of export				
Upstream goods	0.283	0.411	0.283	0.411
Midstream goods	0.283	0.411	0.283	0.411
Consumption goods	0.434	0.178	0.434	0.178
Model-based calibration				
As a share of final production				
Home consumed	0.344	0.5	0.314	0.292
Investment	0.528	0.015	0.481	0.264
Foreign consumed	0.128	0.485	0.206	0.445
As a share of intermediate production				
Home downstream production	0.054	0.946	0.586	0.414
Foreign downstream production	0.946	0.054	0.414	0.586
As a share of upstream production				
Home midstream production	0.5	0.5	0.5	0.5
Foreign midstream production	0.5	0.5	0.5	0.5

3.3 Prior and posterior distribution

Due to the limitation of data points relatively to the model parameters available for estimation, a satisfactory implementation needs restriction on the number of parameters for measurement. In particular, prior and posterior for risk aversion coefficient, wage elasticity, home bias in consumption, elasticity of substitution between home and imported intermediate goods, IST and preference shock persistence, and the U.S. monetary policy shock are identical for China, East Asia, and Southeast Asia in respective model.

In addition, constrained by the lack of structural estimates on China, East and Southeast Asian model a priori, the guiding principle of setting the priors is to allow equal probability for all potential parameter value within the theoretically reasonable range in the face of uncertainty about the true value. As such, except for risk aversion coefficient, wage elasticity, and monetary policy reaction function which shall presume only positive value and are thus assumed to be Gamma distributed, and persistence which by definition shall be within the range of (0,1) and is thus beta distributed, all other parameters and shocks are assumed to be uniform distributed.

Table 2 reports the priors, posterior mode, mean, and the 5th and 95th percentiles of the posterior distribution of the parameters and shocks for China-East Asia and China-Southeast Asia models over the period of 1987Q1 throughout 2008Q4[8]. Meanwhile,

[8] Computation is based on Markov chains of 400,000 draws in total, with the first half being discarded as burn-in draws, using Metropolis-Hastings algorithm in Dynare 4.2.1. The models are fitly estimated in that draws of the posterior sampling for means, variances, and third moments for the model parameters

Table 3 illustrates estimates for identical set of parameters and shocks for the period since 2001 the year China joined WTO. There are three noteworthy observations with respect to posterior risk aversion coefficient, elasticity of substitution between home and imported intermediate inputs, and price stickiness.

Firstly, posterior risk aversion coefficient, including the higher end of the probability distribution, is smaller than one for both China-East Asia ($\sigma = 0.584$) and China-Southeast Asia ($\sigma = 0.846$) model. Nonetheless, following China's WTO accession the regions have become more risk adverse. In particular, China-East Asia estimate now becomes 1.38, which is interestingly close to the estimates on Euro Area and the United States which hinge around 1.4 (Smets and Wouters 2003, 2007), while China-Southeast Asia estimate is still below unity at 0.92.

When $\sigma < 1$, the substitution effect of higher real wage on labor supply dominates the negative wealth effect due to smaller marginal utility of consumption, resulting in rising employment, and vice versa. Putting this finding of which $\sigma > 1$ for East Asia while $\sigma < 1$ for Southeast Asia together with another finding to be discussed later that China and East Asia are coupled by vertical trade while China and Southeast Asia are linked through processing trade in the aftermath of China's WTO accession implies that

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within and across sequences converge. Data used is also informative about the posterior distribution of shocks and parameters given the fact that the posterior mode coincides, or at worst still falls within the distribution and without double peaks, with the peak of posterior distribution. Details are available upon request.

technological shock that raises the real wage would lead to falling employment in East Asia but rising employment in Southeast Asia.

Secondly, the posterior elasticity of substitution between home and imported intermediate inputs for China-East Asia and China-Southeast Asia model is 1.792 and 1.802, respectively. This finding is fairly consistent with the estimate on Southeast-East Asia model in Wong and Eng (2011) that give us an elasticity of 1.441. Intriguingly, having elasticity greater than one within a model embracing vertical linkages in production is at odd with the influential view that intermediate inputs from different countries are strong complements that should have less-than-one elasticity. And a low elasticity is an important assumption for the quantitative performance of two-stage international business cycle models (see, for instance, Kose and Yi 2006, Burstein et al. 2008, Arkolakis and Ramanarayanan 2008). But as Wong and Eng (2011) has shown, once the vertical linkages are formulated within a three-stage model that can genuinely generate back-and-forth trade in intermediate inputs, assumption of low elasticity is no longer needed to account for trade-output comovement. This argument is supported by the empirical findings of di Giovanni and Levchenko (2010) in which the elasticity of substitution has neither explanatory power to bilateral trade nor relevancy to the interaction of trade variable with the input-output linkage.

Recall that when vertical linkage at intermediate inputs is virtually absent in both China-East Asia and China-Southeast Asia model in full-sample analysis, they have approximately identical elasticity of substitution at 1.8. Estimates in Table 3, however, suggest that stronger vertical linkage at midstream production does substantially lower the elasticity of substitution. In particular, the elasticity of substitution has been evidently falling when China-East Asia model has higher κ_2 in the aftermath of China's WTO accession ($\vartheta = 1.102$), and is smaller vis-à-vis China-Southeast Asia model ($\vartheta = 1.609$) that has virtually zero κ_2. Because intermediate input tends to be plant- and product-specific, growing vertical trade in intermediate inputs is thus associated with falling price elasticity.

Thirdly, of all price settings estimated for all regions, intermediate export price has been the stickiest while final export price has been the most flexible. Meanwhile, domestic producer price is more flexible than domestic final goods price. For instance, as shown in Table 2, Chinese exporters reoptimizes price for intermediate input in every 8.3 quarters $\left(=\frac{1}{1-0.88}\right)$. To the contrary, export price for final goods is optimally updated in every 2 quarters. The intuition is simple: intermediate inputs are plant-specific and generally traded by foreign affiliates. Such complementarity pins down the frequency of price adjustment. Final goods, however, are substitutable and thus highly competitive in export market, resulting in higher frequency of price adjustment. Should vertical linkage in midstream production intensifies since 2001 onward, average price settings have been more rigid as shown in Table 3.

Table 2. Priors and posteriors for 1987Q1 – 2008Q4 when China is largely closed from world trading system

				China-East Asia[1]				China-Southeast Asia[2]			
	Prior distribution			Posterior distribution				Posterior distribution			
	Type	Mean	Std	Mode	5%	Mean	95%	Mode	5%	Mean	95%
Parameters											
Risk aversion coefficient	Gamma	1.000	0.250	0.573	0.52	0.584	0.647	0.823	0.787	0.846	0.907
Reciprocal of wage elasticity of labor supply	Gamma	3.000	0.250	2.844	2.839	2.874	2.91	3.125	3.049	3.115	3.181
Home bias in consumption	Uniform	0.500	0.289	0.171 (0.782)	0.154 (0.773)	0.185 (0.793)	0.216 (0.811)	0.754 (0.664)	0.726 (0.641)	0.754 (0.665)	0.782 (0.690)
Els between home and imported intermediate goods	Uniform	1.000	0.250	1.772	1.693	1.792	1.885	1.801	1.738	1.802	1.869
Share of imported materials at midstream production	Uniform	0.500	0.289	0.026 (0.184)	0.000 (0.0983)	0.011 (0.157)	0.023 (0.199)	0.000 (0.000)	0.000 (0.000)	0.006 (0.010)	0.014 (0.023)
Share of imported intermediates at downstream production	Uniform	0.500	0.289	0.479 (0.467)	0.385 (0.444)	0.429 (0.480)	0.467 (0.515)	0.319 (0.387)	0.288 (0.335)	0.332 (0.375)	0.381 (0.418)
employment indexation	Uniform	0.500	0.289	0.393 (0.633)	0.314 (0.632)	0.366 (0.674)	0.419 (0.713)	0.399 (0.000)	0.316 (0.000)	0.382 (0.012)	0.443 (0.028)
Producer price indexation	Uniform	0.500	0.289	0.480 (0.439)	0.444 (0.363)	0.487 (0.4057)	0.527 (0.450)	0.496 (0.656)	0.467 (0.604)	0.525 (0.651)	0.579 (0.702)
Final goods price indexation	Uniform	0.500	0.289	0.457 (0.410)	0.457 (0.374)	0.503 (0.416)	0.556 (0.458)	0.965 (0.953)	0.957 (0.942)	0.965 (0.951)	0.973 (0.960)
Intermediate export price indexation	Uniform	0.500	0.289	0.463 (0.494)	0.409 (0.491)	0.479 (0.548)	0.553 (0.598)	0.879 (0.609)	0.809 (0.504)	0.876 (0.592)	0.939 (0.675)
Final goods export price indexation	Uniform	0.500	0.289	0.592 (0.804)	0.554 (0.756)	0.593 (0.802)	0.633 (0.858)	0.582 (0.440)	0.507 (0.378)	0.580 (0.441)	0.645 (0.504)
Employment stickiness	Uniform	0.650	0.202	0.831 (0.873)	0.820 (0.632)	0.832 (0.870)	0.843 (0.880)	0.806 (0.857)	0.789 (0.847)	0.802 (0.856)	0.815 (0.866)

Producer price stickiness	Uniform	0.750	0.144	0.645 (0.830)	0.597 (0.824)	0.622 (0.836)	0.646 (0.847)	0.664 (0.627)	0.653 (0.595)	0.670 (0.613)	0.688 (0.630)
Final goods price stickiness	Uniform	0.750	0.144	0.675 (0.762)	0.663 (0.731)	0.689 (0.750)	0.715 (0.770)	0.872 (0.819)	0.860 (0.800)	0.869 (0.816)	0.879 (0.833)
Intermediate export price stickiness	Uniform	0.750	0.144	0.889 (0.983)	0.864 (0.981)	0.880 (0.983)	0.896 (0.986)	0.845 (0.961)	0.829 (0.954)	0.854 (0.960)	0.879 (0.965)
Final export price stickiness	Uniform	0.750	0.144	0.500 (0.802)	0.500 (0.780)	0.501 (0.794)	0.502 (0.806)	0.500 (0.540)	0.500 (0.509)	0.503 (0.527)	0.506 (0.545)
Policy inertia	Beta	0.700	0.100	0.742 (0.975)	0.680 (0.972)	0.726 (0.976)	0.773 (0.979)	0.933 (0.928)	0.928 (0.917)	0.934 (0.926)	0.940 (0.935)
Policy response to inflation	Gamma	2.500	0.500	2.223 (2.097)	2.213 (2.035)	2.276 (2.103)	2.356 (2.171)	2.357 (2.457)	2.335 (2.394)	2.383 (2.460)	2.431 (2.523)
Policy response to aggregate demand fluctuation	Gamma	0.125	0.050	0.090 (0.499)	0.0457 (0.465)	0.089 (0.527)	0.126 (0.594)	0.176 (0.166)	0.111 (0.111)	0.175 (0.149)	0.236 (0.191)
Policy response to exchange rate variability	Gamma	0.500	0.100	0.496 (0.480)	0.432 (0.393)	0.468 (0.442)	0.508 (0.507)	0.589 (0.530)	0.511 (0.472)	0.565 (0.550)	0.619 (0.638)
TFP shock persistence	Beta	0.800	0.100	0.987 (0.103)	0.986 (0.103)	0.988 (0.108)	0.990 (0.114)	0.128 (0.961)	0.107 (0.945)	0.142 (0.956)	0.171 (0.968)
IST shock persistence	Beta	0.700	0.100	0.567	0.559	0.58	0.604	0.739	0.667	0.725	0.788
Preference shock persistence	Beta	0.700	0.100	0.828	0.796	0.832	0.863	0.328	0.261	0.322	0.381
Shocks											
Total factor productivity	Uniform	0.5	0.2887	0.177 (0.524)	0.139 (0.451)	0.167 (0.513)	0.194 (0.570)	0.323 (0.060)	0.290 (0.044)	0.329 (0.065)	0.372 (0.085)
Investment-specific technology	Uniform	0.5	0.2887	0.200 (0.320)	0.120 (0.274)	0.172 (0.310)	0.230 (0.352)	0.059 (0.098)	0.044 (0.078)	0.061 (0.101)	0.077 (0.123)
Labor supply	Uniform	0.5	0.2887	1.000 (0.826)	0.988 (0.817)	0.995 (0.852)	1.000 (0.886)	1.000 (0.798)	0.970 (0.752)	0.987 (0.794)	1.000 (0.839)
Preference	Uniform	0.5	0.2887	0.563 (0.646)	0.509 (0.653)	0.550 (0.708)	0.591 (0.766)	0.173 (0.123)	0.149 (0.109)	0.177 (0.128)	0.202 (0.146)

Producer price markup	Uniform	0.5	0.2887	0.200	0.129	0.162	0.198	0.213	0.202	0.234	0.267
				(0.336)	(0.331)	(0.393)	(0.452)	(0.208)	(0.154)	(0.181)	(0.209)
Final goods price markup	Uniform	0.5	0.2887	1.000	0.991	0.996	1.000	1.000	0.961	0.982	1.000
				(0.817)	(0.736)	(0.784)	(0.830)	(1.000)	(0.941)	(0.967)	(0.999)
Intermediate export price markup	Uniform	0.5	0.2887	0.525	0.469	0.517	0.571	0.440	0.413	0.472	0.535
				(0.440)	(0.399)	(0.441)	(0.479)	(0.890)	(0.784)	(0.853)	(0.939)
Final export price markup	Uniform	0.5	0.2887	0.190	0.174	0.194	0.215	0.233	0.218	0.246	0.272
				(0.348)	(0.280)	(0.317)	(0.355)	(0.131)	(0.110)	(0.129)	(0.147)
Transportation cost	Uniform	0.5	0.2887	0.119	0.111	0.124	0.136	0.130	0.117	0.133	0.149
				(0.030)	(0.026)	(0.030)	(0.034)	(0.032)	(0.028)	(0.031)	(0.035)
Monetary policy	Uniform	0.5	0.2887	0.025	0.020	0.026	0.032	0.012	0.010	0.012	0.014
				(0.005)	(0.004)	(0.005)	(0.006)	(0.016)	(0.014)	(0.017)	(0.019)
UIPC	Uniform	0.5	0.2887	0.093	0.067	0.090	0.113	0.099	0.084	0.098	0.112
				(0.155)	(0.115)	(0.144)	(0.173)	(0.193)	(0.167)	(0.189)	(0.212)
U.S monetary policy	Uniform	0.5	0.2887	0.011	0.01	0.011	0.013	0.011	0.01	0.011	0.012
Log marginal density				2982.34				3012.15			

Note: All the regions share identical priors. Numbers without bracket parenthesis are for China, which implies that numbers within bracket parenthesis are for East/Southeast Asia. Posterior relative risk aversion coefficient, wage elasticity, elasticity of substitution, IST and preference shock persistence, and the U.S. monetary policy shock are identical for China and East/Southeast Asia.

[1]The posterior distribution is obtained using the Metropolis-Hastings sampling algorithm based on 8 parallel chains of 50,000 draws, of which the first half is discarded as burn-in. Mean for average acceptance rate per chain over 8 chains is 0.333.

[2]The posterior distribution is obtained using the Metropolis-Hastings sampling algorithm based on 10 parallel chains of 20,000 draws, of which the first half is discarded as burn-in. Mean for average acceptance rate per chain over 8 chains is 0.298.

Table 3. Priors and posteriors for 2001Q1 – 2008Q4 when China has integrated into world trading system

				China-East Asia[1]				China-Southeast Asia[2]			
	Prior distribution			Posterior distribution				Posterior distribution			
	Type	Mean	Std	Mode	5%	Mean	95%	Mode	5%	Mean	95%
Parameters											
Risk aversion coefficient	Gamma	1.000	0.250	1.368	1.279	1.381	1.485	0.955	0.809	0.919	1.029
Reciprocal of wage elasticity of labor supply	Gamma	3.000	0.250	3.039	3.026	3.106	3.208	3.314	3.219	3.369	3.569
Home bias in consumption	Uniform	0.500	0.289	0.487	0.468	0.487	0.500	0.759	0.674	0.777	0.869
				(0.350)	(0.336)	(0.359)	(0.386)	(0.820)	(0.773)	(0.846)	(0.918)
Els between home and imported intermediate goods	Uniform	1.000	0.250	1.103	0.889	1.102	1.291	1.480	1.435	1.609	1.766
Share of imported materials at midstream production	Uniform	0.500	0.289	0.231	0.156	0.306	0.455	0.000	0.000	0.025	0.058
				(0.675)	(0.585)	(0.688)	(0.797)	(0.000)	(0.000)	(0.028)	(0.062)
Share of imported intermediates at downstream production	Uniform	0.500	0.289	0.771	0.701	0.808	0.910	0.641	0.588	0.696	0.796
				(0.562)	(0.356)	(0.508)	(0.696)	(0.971)	(0.947)	(0.972)	(1.000)
employment indexation	Uniform	0.500	0.289	0.909	0.721	0.850	1.000	0.561	0.358	0.527	0.686
				(0.037)	(0.004)	(0.081)	(0.135)	(0.462)	(0.112)	(0.316)	(0.561)
Producer price indexation	Uniform	0.500	0.289	0.739	0.546	0.667	0.762	0.934	0.819	0.912	1.000
				(0.815)	(0.710)	(0.829)	(0.994)	(0.681)	(0.585)	(0.761)	(0.940)
Final goods price indexation	Uniform	0.500	0.289	0.297	0.101	0.255	0.375	0.965	0.925	0.953	0.980
				(0.617)	(0.158)	(0.463)	(0.685)	(0.201)	(0.104)	(0.208)	(0.313)
Intermediate export price indexation	Uniform	0.500	0.289	0.529	0.277	0.471	0.654	0.447	0.186	0.397	0.567
				(0.673)	(0.343)	(0.671)	(0.910)	(0.409)	(0.310)	(0.449)	(0.589)
Final goods export price indexation	Uniform	0.500	0.289	0.841	0.679	0.829	0.996	0.810	0.668	0.815	0.984
				(0.527)	(0.346)	(0.509)	(0.638)	(0.883)	(0.797)	(0.914)	(1.000)
Employment stickiness	Uniform	0.650	0.202	0.963	0.955	0.963	0.970	0.971	0.966	0.970	0.974
				(0.888)	(0.877)	(0.888)	(0.898)	(0.834)	(0.809)	(0.835)	(0.861)

Producer price stickiness	Uniform	0.750	0.144	0.703	0.677	0.714	0.750	0.742	0.716	0.751	0.788
				(0.840)	(0.789)	(0.823)	(0.849)	(0.792)	(0.767)	(0.792)	(0.817)
Final goods price stickiness	Uniform	0.750	0.144	0.887	0.870	0.886	0.902	0.907	0.885	0.902	0.920
				(0.610)	(0.586)	(0.636)	(0.693)	(0.899)	(0.876)	(0.894)	(0.911)
Intermediate export price stickiness	Uniform	0.750	0.144	0.982	0.979	0.984	0.990	0.950	0.934	0.953	0.973
				(0.992)	(0.988)	(0.992)	(0.995)	(0.945)	(0.927)	(0.949)	(0.973)
Final export price stickiness	Uniform	0.750	0.144	0.782	0.748	0.777	0.809	0.654	0.603	0.657	0.708
				(0.869)	(0.847)	(0.864)	(0.879)	(0.637)	(0.566)	(0.629)	(0.688)
Policy inertia	Beta	0.700	0.100	0.953	0.930	0.948	0.969	0.933	0.912	0.930	0.947
				(0.995)	(0.981)	(0.990)	(0.996)	(0.823)	(0.758)	(0.817)	(0.880)
Policy response to inflation	Gamma	2.500	0.500	2.572	2.333	2.502	2.682	2.453	2.362	2.558	2.774
				(2.392)	(2.168)	(2.341)	(2.472)	(2.423)	(2.232)	(2.395)	(2.565)
Policy response to aggregate demand fluctuation	Gamma	0.125	0.050	0.032	0.014	0.048	0.082	0.036	0.019	0.047	0.074
				(0.161)	(0.068)	(0.164)	(0.263)	(0.051)	(0.019)	(0.063)	(0.106)
Policy response to exchange rate variability	Gamma	0.500	0.100	0.586	0.454	0.557	0.639	0.552	0.355	0.508	0.655
				(0.573)	(0.401)	(0.558)	(0.691)	(0.786)	(0.483)	(0.664)	(0.830)
TFP shock persistence	Beta	0.800	0.100	0.913	0.901	0.915	0.930	0.271	0.177	0.258	0.335
				(0.874)	(0.864)	(0.905)	(0.962)	(0.939)	(0.927)	(0.936)	(0.946)
IST shock persistence	Beta	0.700	0.100	0.618	0.571	0.638	0.716	0.779	0.693	0.774	0.861
Preference shock persistence	Beta	0.700	0.100	0.685	0.611	0.677	0.749	0.263	0.226	0.295	0.364
Shocks											
Total factor productivity	Uniform	0.5	0.2887	0.077	0.057	0.077	0.097	0.260	0.202	0.255	0.309
				(0.501)	(0.287)	(0.406)	(0.529)	(0.087)	(0.073)	(0.098)	(0.122)
Investment-specific technology	Uniform	0.5	0.2887	0.088	0.054	0.080	0.107	0.033	0.021	0.033	0.045
				(0.243)	(0.172)	(0.235)	(0.296)	(0.047)	(0.032)	(0.054)	(0.075)
Labor supply	Uniform	0.5	0.2887	0.199	0.028	0.176	0.313	0.948	0.844	0.918	1.000
				(0.922)	(0.856)	(0.915)	(1.000)	(0.846)	(0.523)	(0.776)	(1.000)
Preference	Uniform	0.5	0.2887	0.114	0.084	0.133	0.178	0.167	0.119	0.163	0.207
				(0.417)	(0.274)	(0.421)	(0.581)	(0.131)	(0.097)	(0.145)	(0.191)
Producer price markup	Uniform	0.5	0.2887	0.108	0.091	0.140	0.191	0.161	0.106	0.190	0.284
				(0.668)	(0.452)	(0.581)	(0.735)	(0.683)	(0.575)	(0.783)	(1.000)

Final goods price markup	Uniform	0.5	0.2887	1.000	0.970	0.987	1.000	0.696	0.587	0.747	0.921
				(1.000)	(0.973)	(0.989)	(1.000)	(0.964)	(0.776)	(0.890)	(1.000)
Intermediate export price markup	Uniform	0.5	0.2887	0.536	0.476	0.661	0.863	0.201	0.146	0.234	0.324
				(0.562)	(0.446)	(0.612)	(0.853)	(0.230)	(0.155)	(0.269)	(0.388)
Final export price markup	Uniform	0.5	0.2887	0.383	0.278	0.362	0.454	0.120	0.076	0.125	0.173
				(0.609)	(0.451)	(0.571)	(0.687)	(0.091)	(0.046)	(0.095)	(0.140)
Transportation cost	Uniform	0.5	0.2887	0.069	0.057	0.073	0.090	0.070	0.058	0.074	0.089
				(0.013)	(0.011)	(0.014)	(0.016)	(0.032)	(0.026)	(0.033)	(0.040)
Monetary policy	Uniform	0.5	0.2887	0.004	0.003	0.005	0.007	0.009	0.006	0.009	0.011
				(0.003)	(0.002)	(0.003)	(0.004)	(0.008)	(0.006)	(0.009)	(0.012)
UIPC	Uniform	0.5	0.2887	0.058	0.046	0.064	0.082	0.052	0.041	0.056	0.071
				(0.047)	(0.032)	(0.051)	(0.067)	(0.039)	(0.029)	(0.042)	(0.055)
U.S monetary policy	Uniform	0.5	0.2887	0.009	0.007	0.009	0.011	0.009	0.007	0.009	0.012
Log marginal density				1575.54				1580.78			

Note: All the regions share identical priors. Numbers without bracket parenthesis are for China, which implies that numbers within bracket parenthesis are for East/Southeast Asia. Posterior relative risk aversion coefficient, wage elasticity, elasticity of substitution, IST and preference shock persistence, and the U.S. monetary policy shock are identical for China and East/Southeast Asia.

[1]The posterior distribution is obtained using the Metropolis-Hastings sampling algorithm based on 8 parallel chains of 50,000 draws, of which the first half is discarded as burn-in. Mean for average acceptance rate per chain over 8 chains is 0.292.

[2]The posterior distribution is obtained using the Metropolis-Hastings sampling algorithm based on 8 parallel chains of 50,000 draws, of which the first half is discarded as burn-in. Mean for average acceptance rate per chain over 8 chains is 0.343.

3.4 Finding the tie that binds China and East/Southeast Asia

3.4.1 Before China's WTO accesion

China is linked to East and Southeast Asia largely at downstream production. For China, share of imported upstream materials for midstream production is de facto zero, whereas share of imported intermediate inputs for downstream production from East and Southeast Asia, respectively, is 0.429 and 0.332 (see Table 2). Based on the fraction of intermediates and final goods in total export of China, East Asia, and Southeast Asia shown in Table 1, in conjunction with the posterior mean of κ_2 and κ_3 in Table 2, it can be easily calculated using Eq. (35) that China has the vertical-specialization index of 0.189 and 0.146 corresponding to East and Southeast Asia. On the flipside, East and Southeast Asia, respectively, has an index of 0.15 and 0.071 with respect to China. By decomposing the vertical specialization index into midstream and downstream production, as shown in Table 4, it can be seen that China, and East and Southeast Asia are indeed vertically specialized at downstream production. That Chinese producers process the imported intermediate inputs for reexporting as final goods ready for consumption fits the consensus that China emerges dramatically as the destination for final assembly in the regional production network (see, for instance, Athukorala 2005, 2007; Athukorala and Yamashita, 2006, 2008, 2009; Hayakawa, 2007).

Table 4. Vertical specialization index

	Vertical specialization index							
	China-East Asia				China-Southeast Asia			
	Full sample		Post China's WTO accession		Full sample		Post China's WTO accession	
	China	East Asia	China	East Asia	China	Southeast Asia	China	Southeast Asia
Midstream production	0.003	0.061	0.087	**0.283**	0.001	0.004	0.007	0.012
Downstream production	**0.186**	**0.085**	**0.35**	0.09	**0.144**	**0.067**	**0.302**	**0.173**
Aggregate	0.187	0.146	0.437	0.373	0.145	0.071	0.309	0.185

Note: Bold numbers indicate the stage of production at which each region vertically specializes. Computation is based on Eq. (35) in association with calibration in Table 1 and estimates in Tables 2 and 3.

3.4.2 After China's WTO accession

Closer scrutiny at time span after year 2001 tells a different tale. Accession into WTO not only re-positions and enhances China as the "factory of last chain" for regional production network in China-East Asia model (the share of intermediate inputs imported from East Asia for Chinese downstream production is the eye-opening 0.808 as compared to 0.429 in full-sample estimates), China seems to have climbed up the ladder in the chains of production by importing upstream materials from East Asia at substantial share ($\kappa_2 = 0.306$ for 2001Q1-2008Q4 estimates as compared to $\kappa_2 = 0.011$ in full-sample estimates) for manufacturing and re-exporting back to East Asia for subsequent processing. Equally fascinating is the large fraction of imported Chinese upstream materials for midstream production in East Asia ($\kappa_2 = 0.688$).

This growing vertical trade in intermediate inputs between China and East Asia on the one hand reflects the symbiotic relationship in production between two regions, and on the other hands suggests how drastic the progress of technical ability of Chinese manufacturers can be in processing more skill-intensive imports from the advanced East Asia. Such conjecture is coherent with the empirical finding that there is large increase in the skill content of processes imports of China in 2005 as compared to 1992 (Amiti and Freund 2010).

To the contrary, one could not observe such production and trade relationship between China and Southeast Asia. Neither China nor Southeast Asia imports at non-trivial share intermediate inputs from each other for processing at midstream level ($\kappa_2 = 0.025$ for China and $\kappa_2 = 0.028$ for Southeast Asia). The tie remains at downstream production, where in conjunction with local inputs, China and Southeast Asia import intermediates from each other for final production and re-exporting of consumption goods.

3.4.3 China complements East Asia but competes with Southeast Asia

By probing deeper into the nature of vertical specialization, we can clear the cloud on what integration of China into regional production and trade network would imply for East and Southeast Asia. As reported in Table 4, China vis-à-vis East Asia has an overall vertical specialization index of 0.437, which can be decomposed to 0.087 and

0.35, respectively, for midstream and downstream production[9]. Compared to East Asia that demonstrates vertical specialization index of 0.283 and 0.09, respectively, at midstream and downstream production, it is obvious that China and East Asia are comrades that complement each other in which East Asia specializes at midstream production to produce intermediate goods to be traded vertically with China which specializes at downstream production for processing export.

Tale becomes different once turning our attention to Southeast Asia. In comparison to China which has vertical specialization index of 0.007 and 0.302 at respective midstream and downstream production, Southeast Asia demonstrates 0.012 and 0.173. This indicates that both China and Southeast Asia specialize at downstream production of consumption goods. As such, we can infer that China and Southeast Asia are head-to-head competitors for consumer goods market.

Simply put, the rise of China has instigated crowding-in effect in markets for intermediates goods, and is thus beneficial to more advanced East Asian economies. But crowding-out effect is to be felt in consumer goods market, and export of developing Southeast Asian can be displaced by Chinese exports (see Eichengreen et al. 2007).

4 Evaluating macroeconomic interdependence between China and Asia

[9] By taking into account the pervasive processing trade in China, Koopman et al. (2008) derive a mathematical programming procedure, in conjunction with the conventional input-output table, to produce an estimated share of foreign content in China's exports at about 50%, close to our estimates of 35%.

Having found that China and the advanced East Asia are complements through vertical trade in intermediate inputs, while China and the developing Southeast Asia are competitors in processing trade, it is worthy of note to know to what extent such different production and trade relationships could have affected the macroeconomic interdependence between China and East/Southeast Asia. In this section I first investigate the source of shocks to the variability of selective Chinese and East/Southeast Asian macroeconomic variables over the period of 1987Q1 to 2008Q4. A comparison to the source of shocks in post China's WTO accession easily allows us to appreciate the role of vertical trade vis-à-vis processing trade in coupling China to this region. We last take stock on the way Chinese TFP shock is propagated across regions.

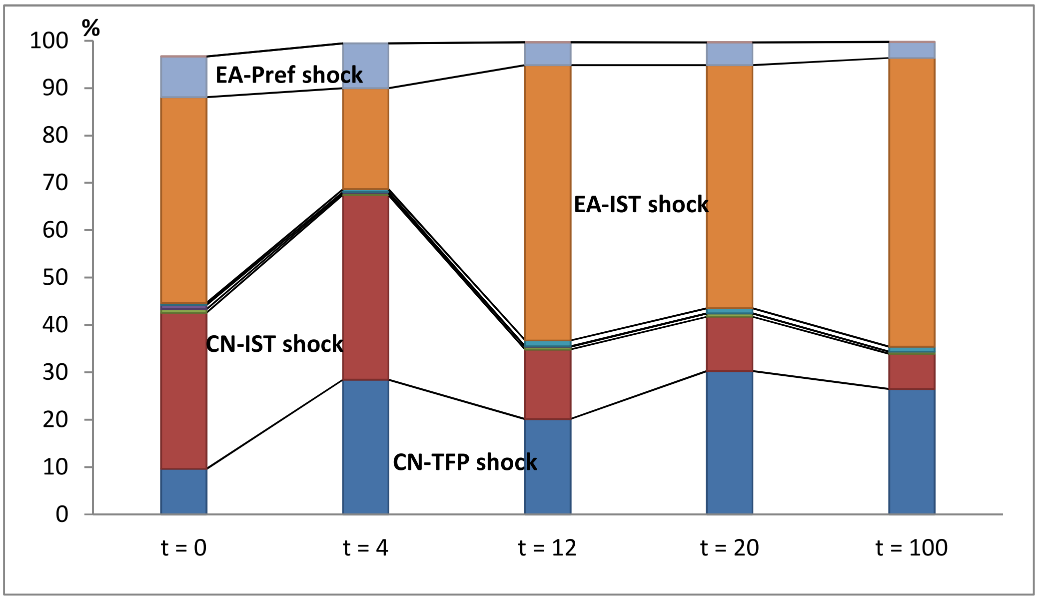
4.1 Source of shocks

Figures 2 throughout 5 depict the forecast error variance decomposition of GDP, PPI inflation, CPI inflation, and interest rate for China and East Asia over 1988Q1 to 2008Q4. Overall, Chinese total factor productivity (TFP) and East Asian investment-specific technological (IST) shocks are two major sources of variability across regions. For instance, variability of China's GDP can be accounted for by both Chinese and East Asian IST shock, of which over the longer time horizon, the latter dominates alongside Chinese own TFP shock (see Figure 2a). Meanwhile, variability of East Asian GDP can be explained to non-trivial extent by own TFP shock at short time horizon, but mostly by own IST shock together with Chinese TFP shock over long time horizon (see Figure 2b).

Although price markup shock explains contemporaneous forecast error in both China's and East Asian PPI inflation, over the medium and long time horizon, it is again East Asian IST and Chinese TFP shock that account for the forecast error in Chinese and East Asian PPI inflation over the medium and long time horizon (see Figure 3). Chinese TFP shock also has been an important source of Chinese and East Asian CPI inflation variability (see Figure 4).

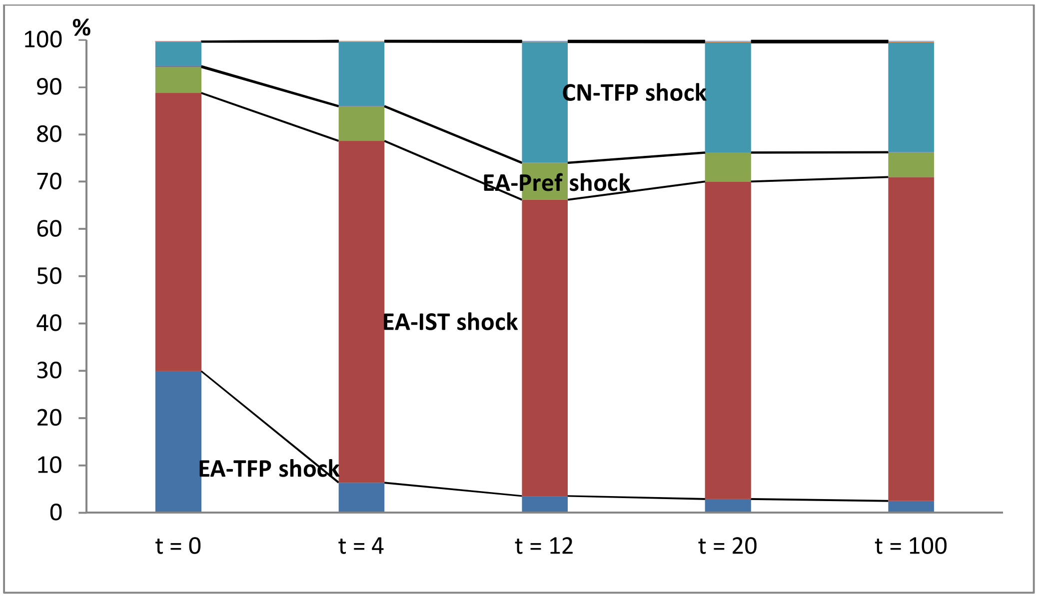
Given the role of Chinese TFP and East Asian IST shock in explaining the variability of GDP and CPI inflation, not to speak as the determinants of natural interest rate, it is expected to observe the dominant role of Chinese TFP along with East Asian IST shock playing greater role over the medium and long time horizon in accounting for interest rate variability in China and East Asia (see Figure 5).

Tales, again, are different in China-Southeast Asia estimates. The weak linkage in production and trade leads to trivial role of external shocks in explaining own macroeconomic variability. For instance, Figures 6 to 9 show that forecast error in GDP can be accounted for by respective own TFP and IST shock; PPI inflation variability is largely explained by own price markup shock; Chinese CPI inflation variability is reasoned by own TFP shock particularly over long time horizon; Southeast Asian CPI



inflation variability is largely attributed to own TFP shock in conjunction with own IST and preference shock, although one third of contemporaneous forecast error can be accounted for by Chinese TFP shock; and lastly, interest rate variability is without exception a local phenomenon.

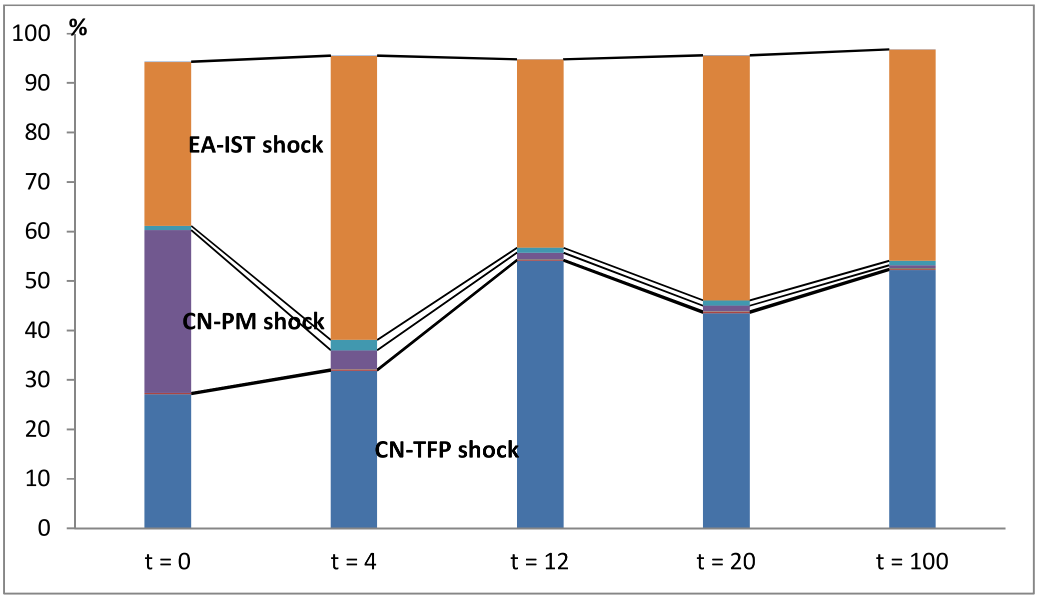
(a)



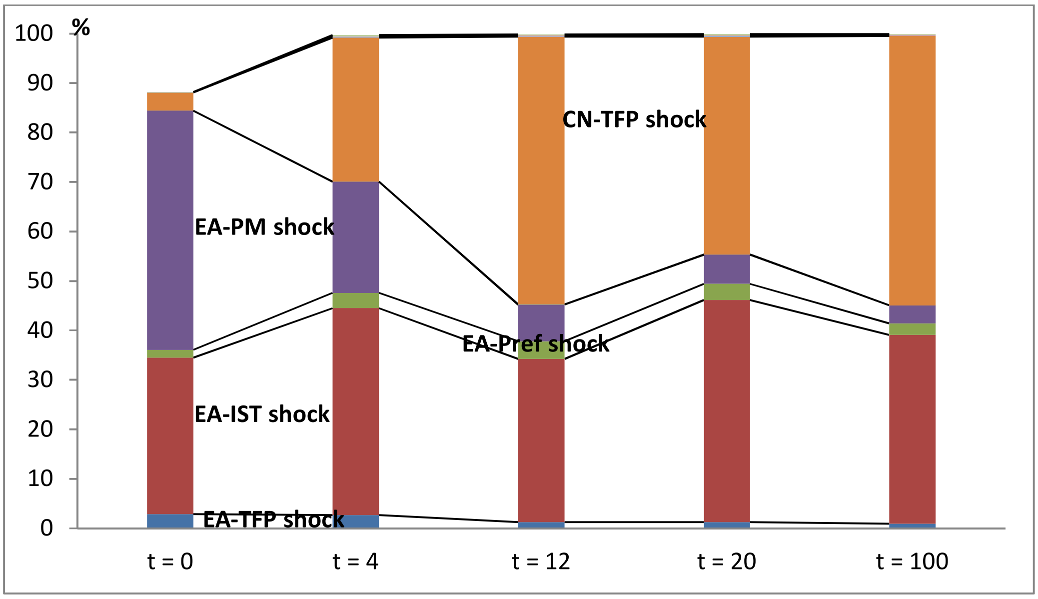
(b)

Fig. 2. Forecast error variance decomposition, GDP: (a) China; (b) East Asia

Note: CN: China; EA: East Asia; TFP: total factor productivity; IST: Investment-specific technology; Pref: preference



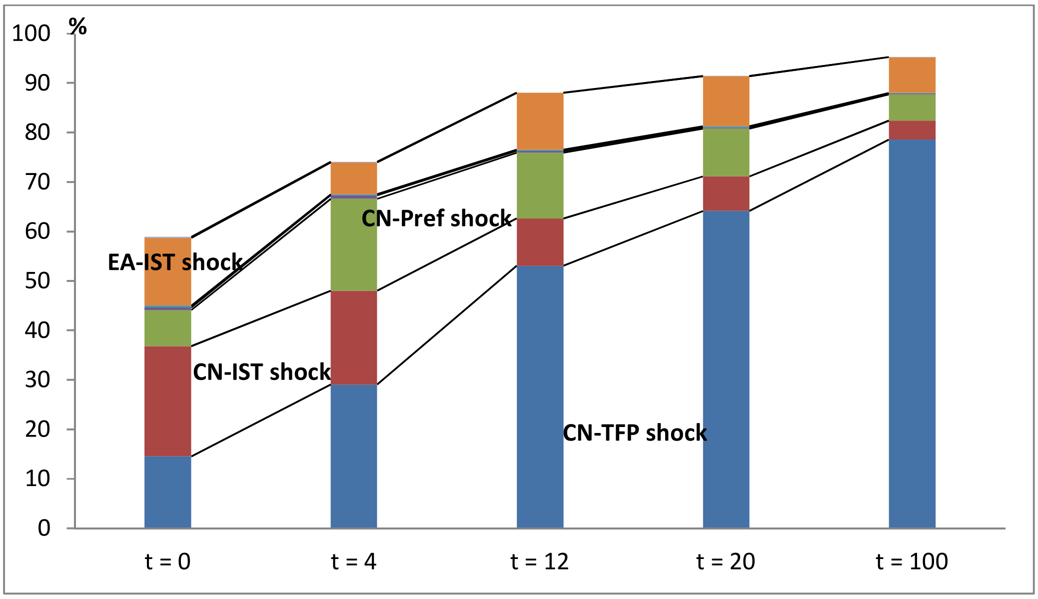
(a)



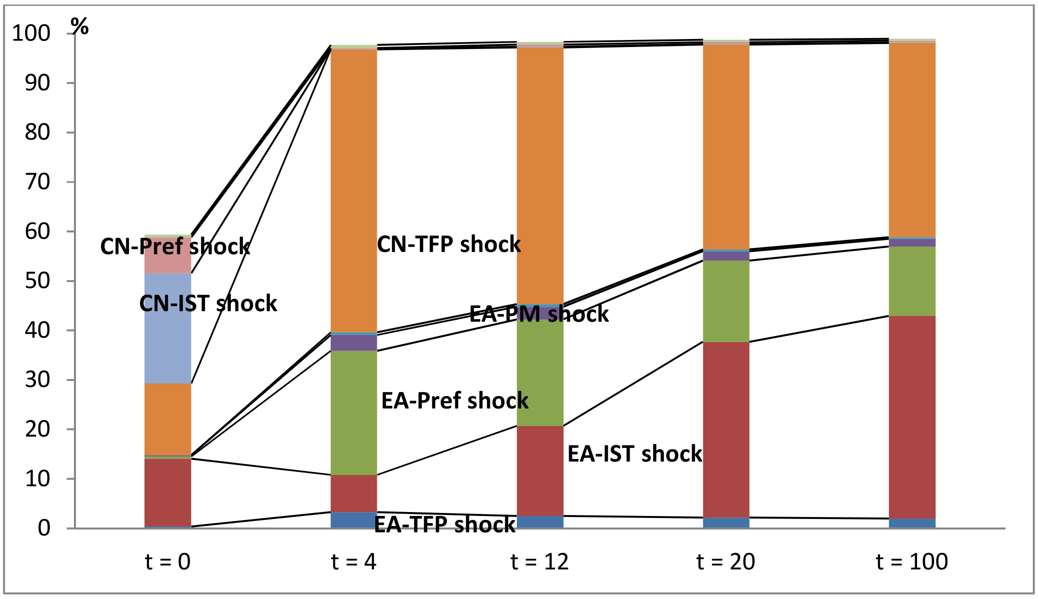
(b)

Fig. 3. Forecast error variance decomposition, PPI inflation: (a) China; (b) East Asia

Note: CN: China; EA: East Asia; TFP: total factor productivity; IST: Investment-specific technology; Pref: preference; PM: price markup



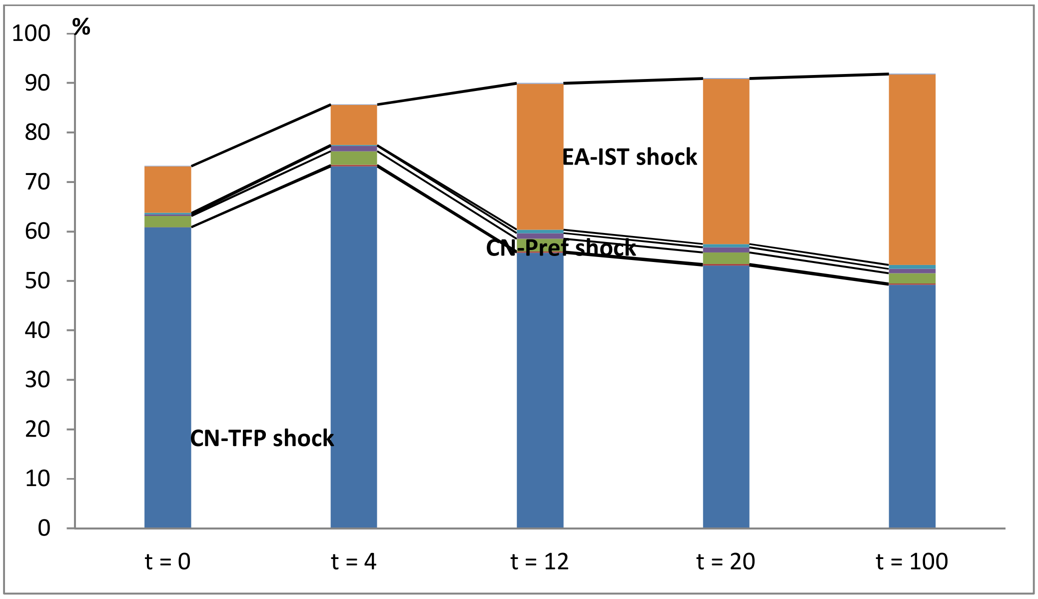
(a)



(b)

Fig. 4. Forecast error variance decomposition, CPI inflation: (a) China; (b) East Asia

Note: CN: China; EA: East Asia; TFP: total factor productivity; IST: Investment-specific technology; Pref: preference; PM: price markup



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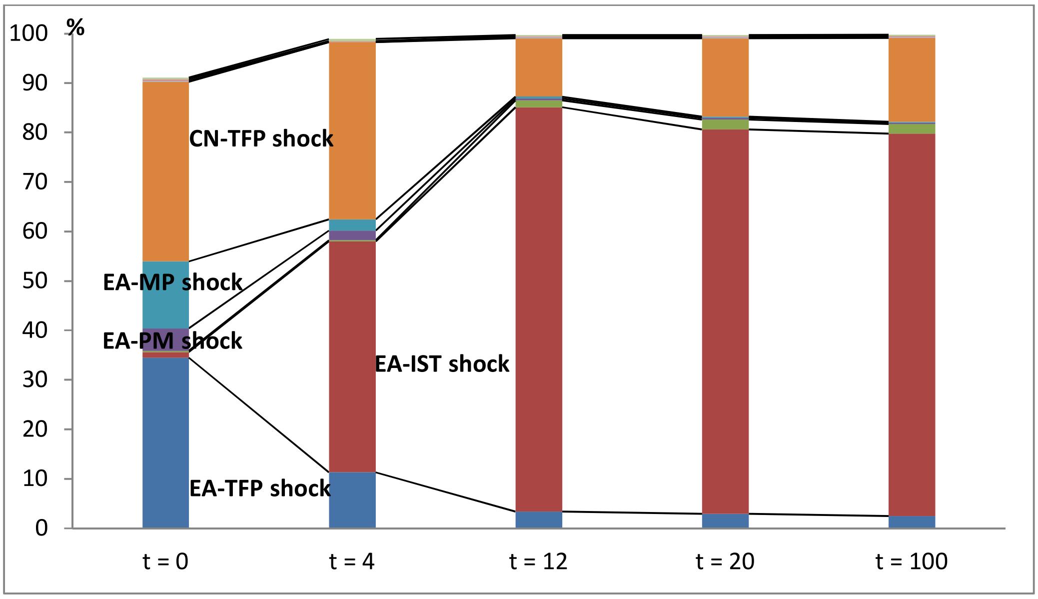


(b)

Fig. 5. Forecast error variance decomposition, interest rate: (a) China; (b) East Asia

Note: CN: China; EA: East Asia; TFP: total factor productivity; IST: Investment-specific technology; Pref: preference; PM: price markup

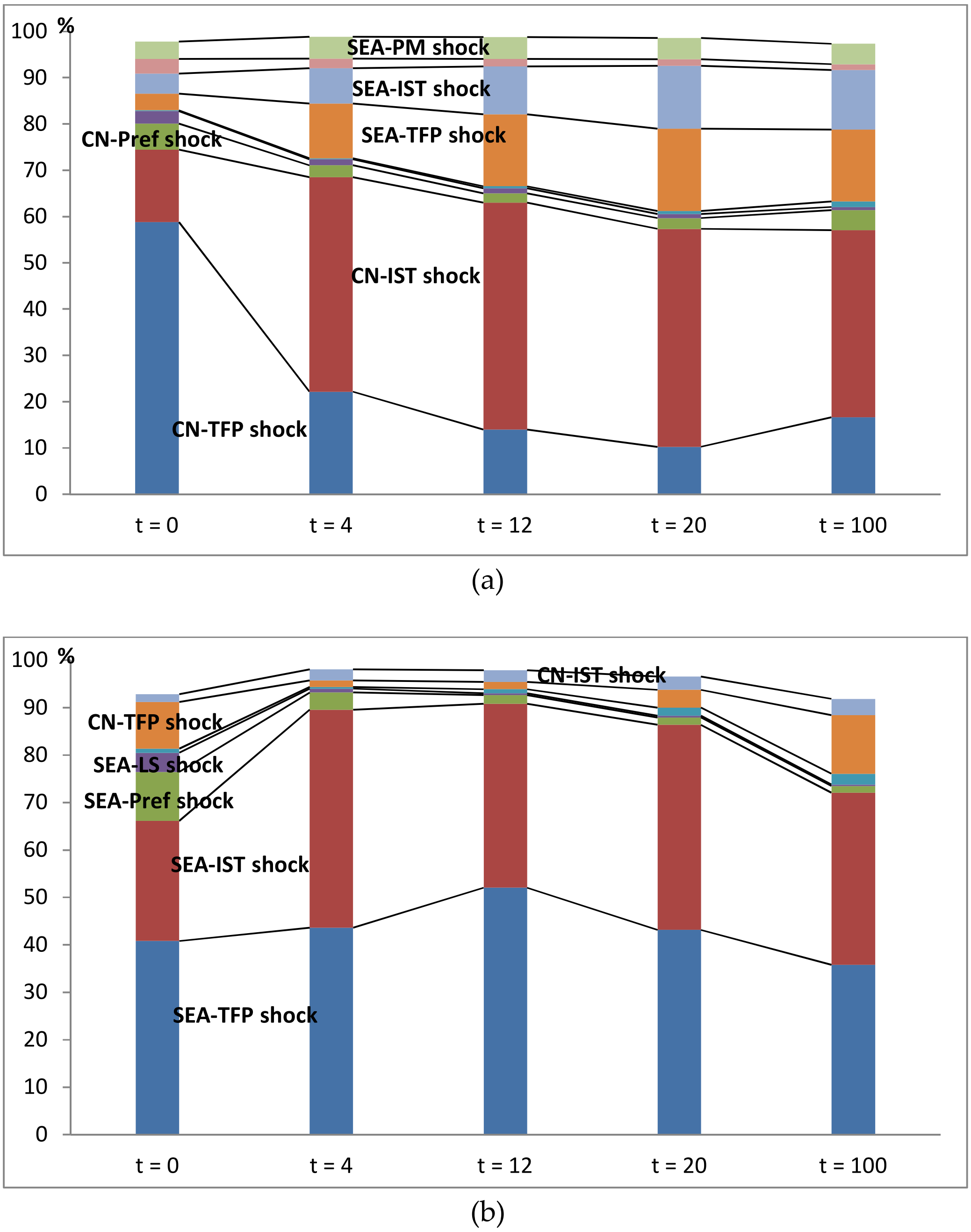
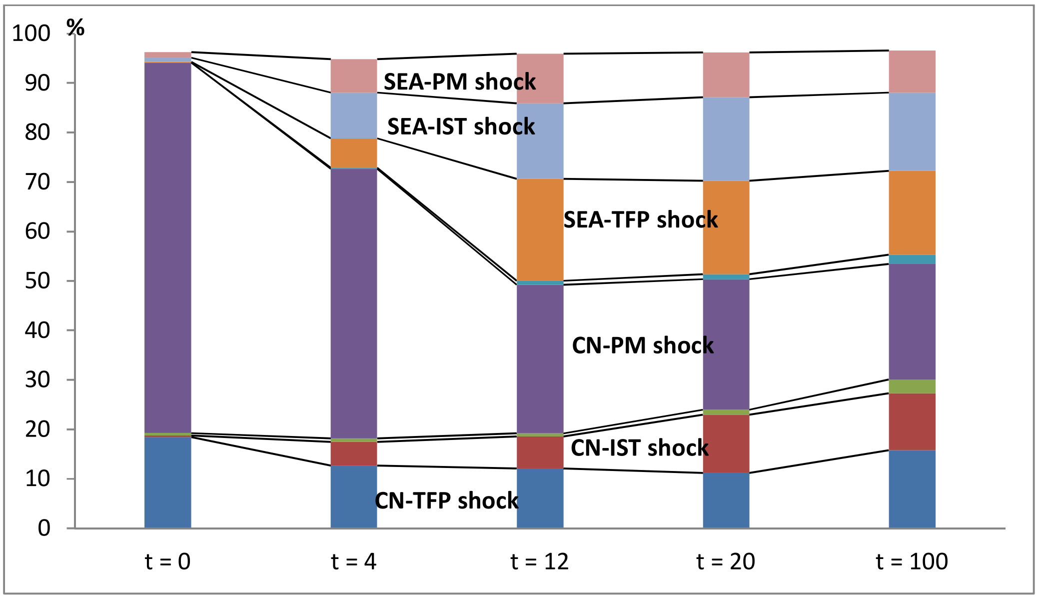


Fig. 6. Forecast error variance decomposition, GDP: (a) China; (b) Southeast Asia

Note: CN: China; SEA: Southeast Asia; TFP: total factor productivity; IST: Investment-specific technology; Pref: preference; LS: labor suppy; PM: price markup



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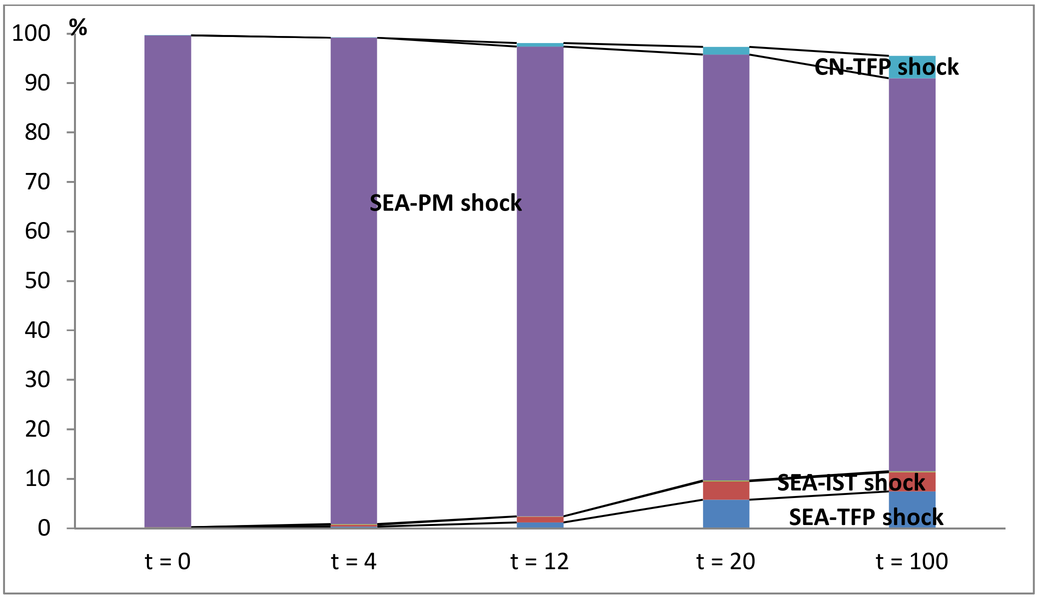
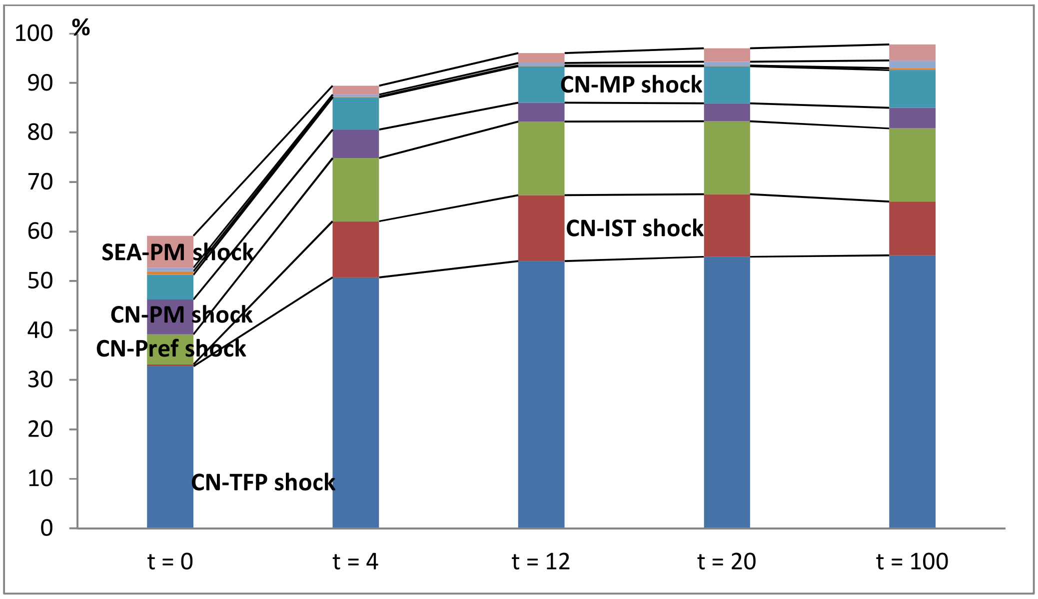


(b)

Fig. 7. Forecast error variance decomposition, PPI inflation: (a) China; (b) Southeast Asia

Note: CN: China; SEA: Southeast Asia; TFP: total factor productivity; IST: Investment-specific technology; PM: price markup



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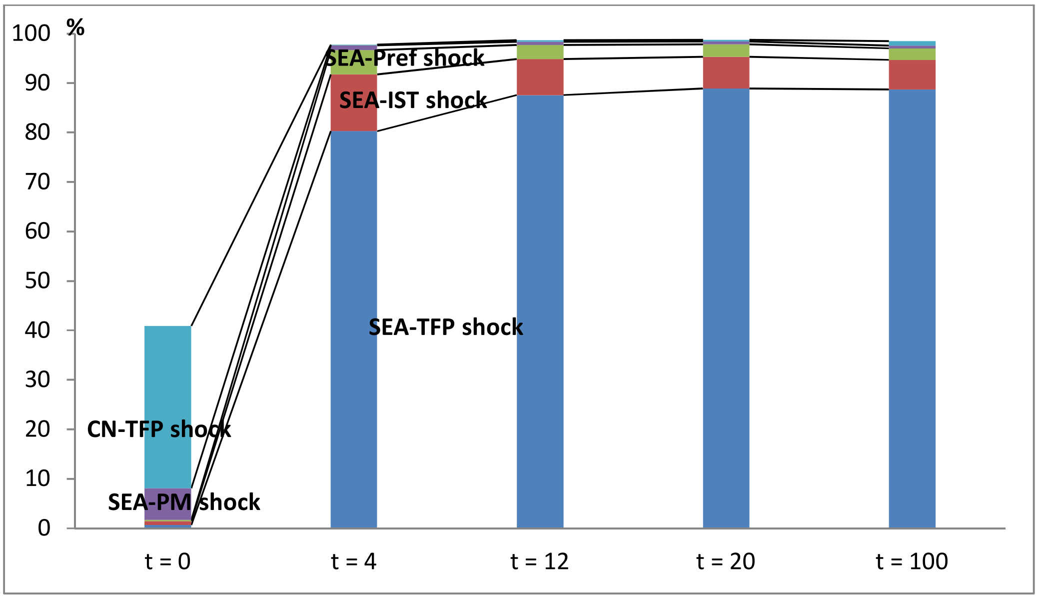
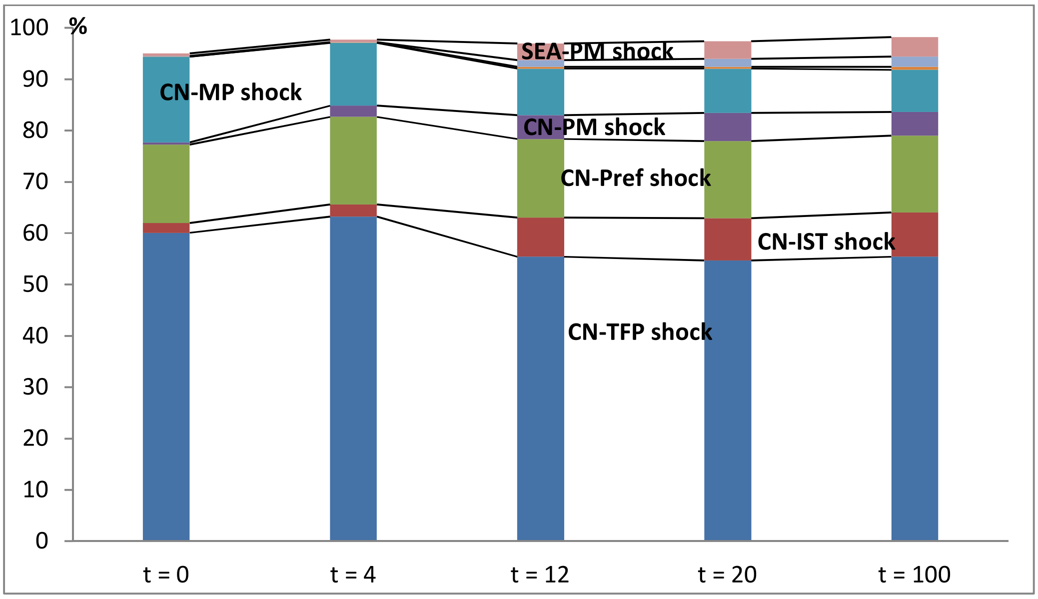


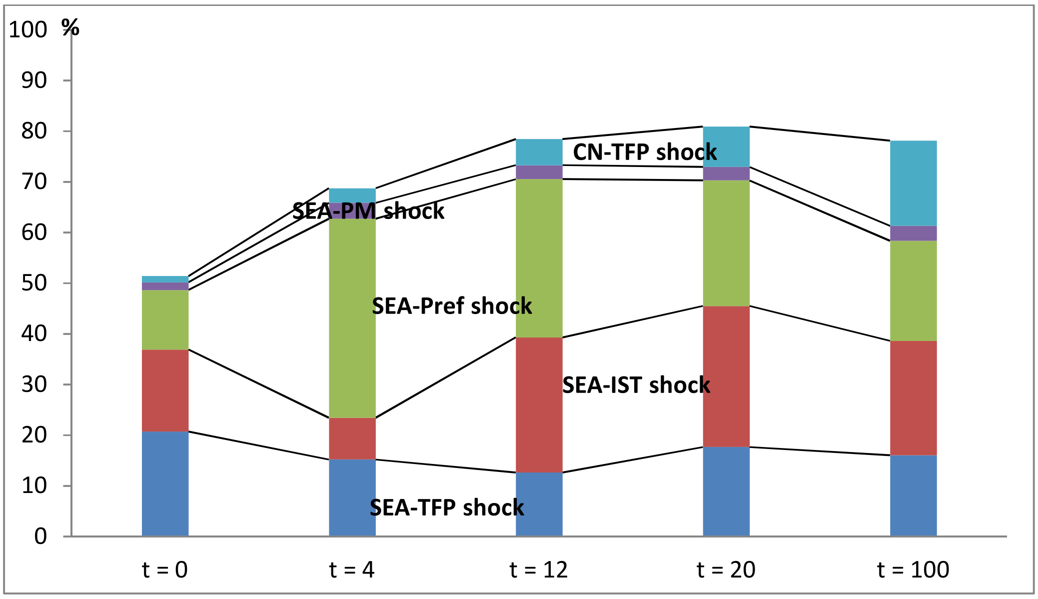
(b)

Fig. 8. Forecast error variance decomposition, CPI inflation: (a) China; (b) Southeast Asia

Note: CN: China; SEA: Southeast Asia; TFP: total factor productivity; IST: Investment-specific technology; PM: price markup; Pref: preference; MP: monetary policy



(a)



(b)

Fig. 9. Forecast error variance decomposition, interest rate: (a) China; (b) Southeast Asia
Note: CN: China; SEA: Southeast Asia; TFP: total factor productivity; IST: Investment-specific technology; PM: price markup; Pref: preference; MP: monetary policy

4.2 A reassessment when vertical trade arises

A comparison between China-East Asia and China-Southeast Asia model, which shows diverse production and trade linkage in post Chinese WTO accession, gives us a clue on how the emergence of vertical trade in intermediate input contrasted with processing trade *per se* could impinge on the source of shock.

Table 5 elucidates the forecast error decomposition of variables identical to previous section over the 2001Q1 to 2008Q4. A glance at the numbers for China-Southeast Asia model (see Table 5b), in which these two regions are still linked at processing trade, gives an impression that macroeconomic variability is still largely home-shock driven. For example, over long time horizon, own TFP and IST shock account for 57% and 72%, respectively, of GDP variability in China and Southeast Asia. Own price markup shock explains nearly 80% of Southeast Asian PPI inflation variability, at the same time in combination with own TFP and IST shock it explains 50% of China's PPI inflation variability. Own TFP shock accounts for 89% of Southeast Asian CPI inflation variability, whereas shocks to own TFP, IST and preference combined explain 80% of China's CPI inflation, 78% of China's interest rate variability, and 58% of Southeast Asian interest rate variability.

But the source of shocks for China-East Asia estimates has changed following the rise of vertical trade in intermediate inputs. East Asia, by vertically specializing at midstream production and supplying the materials for China's processing exports, becomes the dominant source of shock for its own region and China. In particular, East Asian TFP and IST shock have evidently accounted for the variability of GDP, PPI inflation, and interest rate over medium and long time horizon of China and itself.

In conclusion, TFP and IST shock in general continue to be the dominant source of shock, particularly over medium and long run. Nonetheless, should processing trade *per se* prevails macroeconomic fluctuations are mainly driven by own shocks. To the contrary, the emergence of vertical trade alongside processing trade shall give rise to cross-border influence of TFP and IST shock to countries specializing at midstream production and leading the vertical trade.

Table 5. Forecast error variance decomposition in post Chinese WTO-accession (%)

(a) China-East Asia

	China						East Asia					
	Home Shock			Foreign shock			Home shock					Foreign shock
	TFP	IST	Pref	TFP	IST	PM	TFP	IST	Pref	L	PM	TFP
						GDP						
t = 0	1.65	4.99	0.04	78.84	12.99	0.20	71.04	27.67	0.94	0.11	0.02	0.05
t = 4	1.57	5.23	0.02	84.95	7.34	0.14	74.62	24.58	0.57	0.03	0.02	0.07
t = 12	1.66	3.43	0.01	75.99	18.24	0.09	77.81	21.50	0.46	0.02	0.03	0.08
t = 20	0.96	2.51	0.01	81.33	14.68	0.06	77.10	22.28	0.36	0.02	0.02	0.09
t = 100	0.78	2.06	0.01	77.28	19.45	0.06	76.42	22.97	0.34	0.02	0.02	0.09

	China						East Asia					
	Home shock				Foreign shock		Home shock				Foreign shock	
	TFP	IST	PM	MP	TFP	IST	TFP	IST	PM	MP	TFP	IST
						PPI inflation						
t = 0	4.41	0.35	43.23	0.10	19.16	22.20	6.83	2.21	89.99	0.01	0.14	0.01
t = 4	0.86	0.08	2.46	0.02	68.11	25.86	64.17	14.47	20.61	0.00	0.04	0.04
t = 12	0.93	0.24	0.80	0.02	80.69	16.08	83.79	10.00	5.68	0.01	0.02	0.03

t = 20	1.47	0.37	0.61	0.02	77.90	18.67	80.64	13.74	4.92	0.02	0.14	0.09
t = 100	1.69	0.36	0.57	0.02	77.28	19.19	80.10	14.41	4.65	0.02	0.26	0.10
						CPI inflation						
t = 0	45.64	23.11	0.29	2.78	7.07	0.05	7.07	0.05	0.11	0.00	45.64	23.11
t = 4	52.72	17.21	0.23	1.90	4.82	0.30	91.95	3.44	1.88	0.60	0.01	0.00
t = 12	61.33	13.28	0.18	1.44	5.98	0.70	92.70	3.59	1.56	0.48	0.01	0.00
t = 20	63.22	12.38	0.17	1.34	5.95	1.02	92.94	3.55	1.49	0.45	0.01	0.00
t = 100	63.68	12.01	0.16	1.30	6.29	1.13	92.72	3.78	1.48	0.45	0.01	0.00
						Interest rate						
t = 0	18.24	1.98	0.26	7.33	17.05	0.06	17.14	23.19	13.58	32.55	0.00	0.00
t = 4	13.17	19.03	0.75	11.12	13.66	3.68	13.30	51.81	14.37	12.03	0.06	0.01
t = 12	8.32	22.44	0.33	3.56	47.06	7.50	13.33	61.95	11.32	5.66	0.11	0.04
t = 20	12.93	20.70	0.28	2.89	44.64	9.79	49.15	38.52	5.56	2.69	0.23	0.08
t = 100	14.65	17.79	0.25	2.47	46.13	11.17	59.11	31.49	4.17	2.01	0.28	0.08

(b) China-Southeast Asia

	China						Southeast Asia					
	Home shock				Foreign shock		Home shock				Foreign shock	
	TFP	IST	Pref	L	TFP	IST	TFP	IST	Pref	L	TFP	IST
						GDP						
t = 0	58.77	15.68	5.64	2.71	3.60	4.39	40.83	25.26	10.37	4.05	9.88	1.62
t = 4	22.16	46.35	2.53	1.38	11.87	7.62	43.65	45.94	3.63	0.75	1.38	2.29
t = 12	13.98	49.05	2.00	1.05	15.51	10.34	52.05	38.73	1.87	0.39	1.56	2.48
t = 20	10.22	47.12	2.35	0.88	17.84	13.49	43.14	43.22	1.57	0.35	3.72	2.83
t = 100	16.63	40.37	4.36	0.72	15.58	12.84	35.78	36.29	1.42	0.29	12.31	3.47

	China								Southeast Asia				
	Home shock					Foreign shock			Home shock				Foreign shock
	TFP	IST	Pref	PM	R	TFP	IST	PM	TFP	IST	Pref	PM	TFP
							PPI inflation						
t = 0	18.45	0.33	0.46	74.87	0.01	0.20	0.83	1.13	0.20	0.02	0.02	99.43	0.01
t = 4	12.71	4.75	0.70	54.48	0.25	5.94	9.23	6.77	0.35	0.41	0.08	98.31	0.02
t = 12	12.10	6.48	0.58	30.06	0.83	20.61	15.25	10.02	1.19	1.18	0.10	94.95	0.69
t = 20	11.22	11.72	1.04	26.37	0.99	18.89	16.91	9.08	5.77	3.74	0.16	86.11	1.52
t = 100	15.80	11.51	2.80	23.32	1.87	16.99	15.79	8.49	7.47	3.85	0.18	79.48	4.52
							CPI inflation						
t = 0	32.77	0.31	6.13	7.07	4.95	0.71	0.73	6.44	0.71	0.73	0.24	6.44	32.77
t = 4	50.75	11.31	12.81	5.73	6.55	0.10	0.45	1.73	80.25	11.50	4.89	1.03	0.10
t = 12	54.01	13.34	14.84	3.89	7.37	0.08	0.50	2.02	87.56	7.34	2.82	0.64	0.26
t = 20	54.88	12.65	14.77	3.64	7.49	0.13	0.76	2.68	88.90	6.44	2.48	0.57	0.33
t = 100	55.22	10.79	14.85	4.11	7.66	0.43	1.47	3.28	88.73	5.97	2.29	0.56	0.88

						Interest rate							
t = 0	60.08	1.90	15.26	0.44	16.69	0.07	0.10	0.52	20.71	16.18	11.74	1.58	1.23
t = 4	63.21	2.42	17.04	2.18	12.26	0.04	0.09	0.47	15.23	8.19	39.31	3.15	2.90
t = 12	55.43	7.65	15.29	4.64	9.08	0.34	1.27	3.27	12.63	26.67	31.26	2.72	5.17
t = 20	54.70	8.26	14.97	5.52	8.62	0.38	1.49	3.47	17.69	27.82	24.76	2.67	7.99
t = 100	55.39	8.62	15.03	4.59	8.21	0.61	1.96	3.79	16.07	22.58	19.72	2.95	16.86

Note: TFP: total factor productivity, IST: investment-specific technology, Pref: preference, PM: price markup, R: monetary policy

4.3 Shocks propagation

Consider there is a favorable shock to China's total factor productivity. Figure 10 depicts the impulse response of East and Southeast Asia to China's TFP shock. Solid blue lines with dots correspond to East Asia, and dashed read lines correspond to Southeast Asia over the period of 1987Q1 to 2008Q4. Recall that in full sample estimates the tie that binds China and East/Southeast Asia is processing trade, with stronger linkage between China and East Asia. It is thus expected to observe approximately identical responses from East and Southeast Asia, with the former shows a larger magnitude.

Evidently, East and Southeast Asia could not benefit from favorable China's TFP shock. Hours worked, investment, export, and import have fallen in response to the shock. That trade activities have contracted suggests that specializing at the same chain of production – in this case downstream production with processing trade – will lead to rivalry between China and Asia. Favorable shock to China's TFP thus beggars thy its

Asian neighbors. Although PPI inflation has declined gradually, CPI inflation has risen on impact and only falls in gradual, which can be attributed to nominal depreciation on impact. Short-term interest rate also rises gradually and reaches the peak after a year.

Figure 11 illustrates the dynamic response of East and Southeast Asia to China's TFP shock after China's accession to WTO. This is a period where vertical trade takes place alongside processing trade between China and East Asia, while China and Southeast Asia continue to be coupled by processing trade. Have the responses to China's TFP shock been different between East and Southeast Asia?

The answer is yes. For the case of East Asia, hours worked and investment rise in response to positive China's TFP shock. Because higher total factor productivity reduces real marginal cost of Chinese upstream products, the cost of imported Chinese intermediate inputs shall fall, thus contributing to lower PPI inflation in East Asia. The falling PPI inflation gradually feeds into lower domestic inflation and thus CPI inflation.

That matters the most is certainly the vertically, sequentially linked trade and production. China's consumption expansion following a rise in natural rate of interest would bolster the demand for own and East Asian consumer goods, which together create demand for East Asian midstream and upstream outputs through input-output structure. This spillover effect is propagated by China's demand for East Asian export of upstream outputs in consequence of the expansion in China's midstream production. At the end, East Asian GDP rises. In short, favorable China's TFP shock prospers thy its

East Asian neighbor. For the case of Southeast Asia, however, dynamic responses are about the same as that of full-sample analysis. Hours worked falls, investment declines, export and import though increasing on impact tumble and are out of trough only after 7th quarter, CPI inflation rises, and in consequence, GDP plunges. Vertical production linkage and trade in intermediate inputs are the key characteristic that propagates the repercussion effect of a small shock across the borders in same direction.

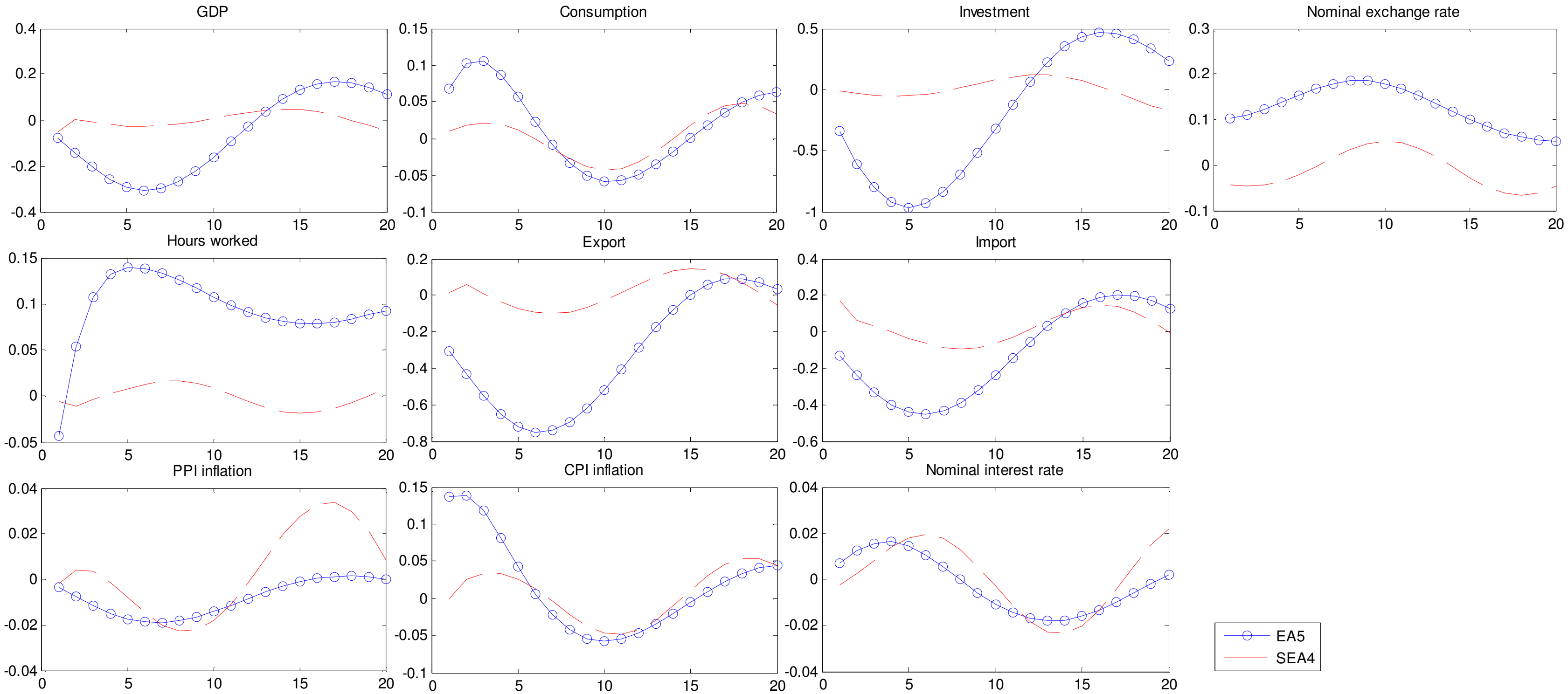


Fig. 10. Dynamic response of East and Southeast Asia to Chinese TFP shock for 1987Q1 to 2008Q4

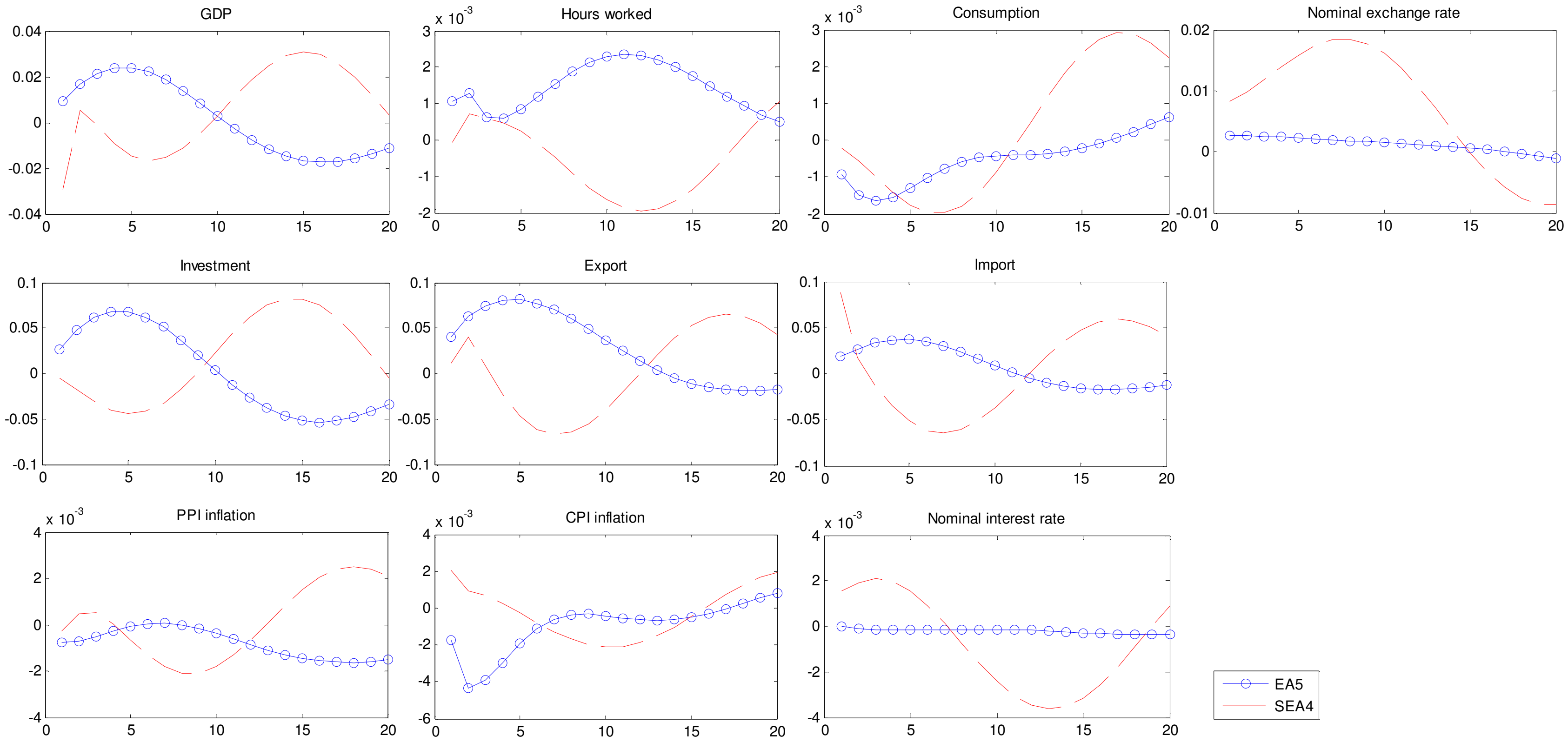


Fig. 11. Dynamic response of East and Southeast Asia to Chinese TFP shock in post China's WTO accession

5 Concluding remarks

Motivated by the inconclusive empirical finding on the influence of China's economic expansion on East and Southeast Asia, this paper revisits this topical issue using a two-region dynamic stochastic general equilibrium model with three processing stages. Because such model, when taking to the data with Bayesian approach, allows us to embrace the simultaneous presence of vertical and processing trade, we are able to revisit this unresolved issue with satisfactory confidence from several vantage points of view.

In particular, this paper shows that following China's integration into regional production network, macroeconomic interdependence between China and East Asia has been different from that between China and Southeast Asia. East Asia has vertically specialized at midstream production while China specializes at downstream production. This enables vertical trade in intermediate inputs in parallel with processing trade. As such, total factor productivity and investment-specific technology shock to East Asian economies would spill over to China, substantially shaping its macroeconomic fluctuations. Equally true is the fact that China's productivity advance would prosper her East Asian neighbors. To the contrary, because China and Southeast Asia continue specializing vertically at downstream production, and thus are coupled through processing trade with negligible back-and-forth vertical trade in intermediate inputs, macroeconomic fluctuations can largely be accounted for by domestic shocks. In addition, China's productivity advance could beggar-thy her Southeast Asian neighbors.

Probably the most important limitation of this two-region prototype is that it can easily overlook the influence of the rest of the world, particularly the role of the United States and Euro Area absorption for both China's and the rest of Asian exports. As a matter of fact, economic expansion grounded on vertical specialization depends heavily on extra-regional trade in final goods, and this dependence has actually increased over the years. Speaking of which China and Southeast Asia are competitors in processing export, China's growth could be beneficial to Southeast Asia should third-country's appetite for consumer goods grow more than proportionately. To overcome this limitation, this paper allows for the spillover of U.S. monetary policy shock to both regions through uncovered interest rate parity condition. To deal more satisfactorily with third-country effect one needs a multi-country, multi-processing stage model. This deserves serious attentions in future research.

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