Working Paper

INTERNATIONAL MONETARY FUND

WP/11/46

IMF Working Paper

Current Account Rebalancing and Real Exchange Rate Adjustment Between the U.S. and Emerging Asia

Isabelle Méjean, Pau Rabanal, and Damiano Sandri

INTERNATIONAL MONETARY FUND

 WP/11/46

IMF Working Paper

Research Department

Current Account Rebalancing and Real Exchange Rate Adjustment Between the U.S. and Emerging Asia[1]

Prepared by Isabelle Méjean, Pau Rabanal, and Damiano Sandri

Authorized for distribution by Gian Maria Milesi-Ferretti

March 2011

Abstract

A reduction in the U.S. current account deficit vis-à-vis emerging Asia involves a shift in demand from U.S. to emerging Asia tradable goods and a change in international relative prices. This paper quantifies the required adjustment in the terms of trade and real exchange rates in a three-country open economy model of the U.S., China, and other emerging Asia. We compare scenarios where both Chinese and other emerging Asian export prices change by the same proportion to the case where export prices remain constant in one country and increase in the other. Our results are robust to different assumptions about elasticities of substitution and to introducing a high degree of vertical fragmentation in production in the model.

JEL Classification Numbers: F41, F47
Keywords: Rebalancing, Real Exchange Rates, Intermediate Inputs
Author's E-Mail Address: isabelle.mejean@polytechnique.edu, prabanal@imf.org, dsandri@imf.org

[1] We thank Olivier Blanchard, Gian Maria Milesi-Ferretti, Steven Barnett, Rudolfs Bems, Malhar Nabar, Naghwa Riad, and Mika Saito for very helpful comments.

Contents

Page

List of Tables

List of Figures

I. INTRODUCTION

The large current account imbalances between the U.S. and emerging Asia play an important role in the current debate on sustaining the recovery from the Great Recession and ensuring global stability.[2] Some fear that these imbalances are driven by distortions that inefficiently depress demand for U.S. goods while generating overheating in emerging Asia. Furthermore, there are concerns about a possible abrupt adjustment which may threaten global stability. Others believe instead that these imbalances do not pose major risks and will smoothly unwind over time. In this paper, we do not take a stand on this argument, but exclusively focus on how international relative prices (namely, the terms of trade and real exchange rates) have to adjust to accommodate an eventual rebalancing. A reduction in global imbalances has to involve lower U.S. consumption and higher consumption in emerging Asia. Given the consumption bias towards domestically produced goods, this generates a relative increase in the demand for emerging Asia's tradable goods and a reduction in the demand for U.S. tradables. Therefore, to shift demand back towards U.S. tradables and keep production quantities constant, a relative appreciation of Asian goods is needed. Our purpose is to quantify the extent of this price adjustment.

To clarify the contribution of the paper, we want to emphasize two important remarks. First, we are not suggesting a causal effect from real exchange rates to rebalancing. A reduction in current account imbalances essentially depends on intertemporal considerations affecting saving and investment decisions. In the context of our model, we can solve for the changes in relative prices without having to specify which factors will be responsible to generate such an adjustment in net savings. There is currently little consensus about the drivers of global imbalances, with some commentators emphasizing the large U.S. government deficit and low households' saving rates, and others pointing out factors responsible for particularly high net savings in emerging Asia. For example, Song, Storesletten and Zilibotti (2010) and Sandri (2010) attribute high corporate savings and capital outflows from China to financial underdevelopment. Korinek and Servén (2010) interpret instead high net exports as a deliberate strategy of Chinese authorities to benefit from externalities in the tradable sector.[3] We avoid this complex debate by leaving unspecified which factors will trigger rebalancing. Our interest is instead in learning about the relative price adjustment that needs to occur to support a new equilibrium with narrower imbalances. Second, we provide estimates for the required appreciation of *real* exchange rates and terms of trade in emerging Asia. This adjustment can be equally achieved with an appreciation of nominal exchange rates or a positive inflation differential with respect to the U.S, and our model has no implications for which of these two channels needs to be predominant.

To study the impact of rebalancing on relative prices, we build on Obstfeld and Rogoff (2007), OR from now onwards. In their paper, OR develop a two-country endowment economy to quantify the magnitude of the real dollar depreciation vis-à-vis the rest of the world associated with a closing of the U.S. current account deficit. Their calculations suggest that the required U.S. dollar real depreciation would be around 30 percent. We borrow OR's methodology, but extend

---

[2]See Blanchard and Milesi-Ferretti (2009).

[3]On the household side, Du and Wei (2010) point out that high savings are needed to compete in a tight market for weddings.

the model to a three country set-up, including the U.S., China, and other emerging Asia (OEA) which is viewed as a close competitor to many Chinese products.[4] This allows us to address a common concern that a unilateral appreciation by China (either through domestic inflation or a revaluation of the nominal exchange rate) would play little role in shifting U.S. demand towards domestic goods, since U.S. households can easily substitute Chinese goods with similar imports from OEA.[5] With a third country in OR's framework, we are able to compare the effect of a unilateral Chinese appreciation with a symmetric appreciation of all emerging Asia.[6]

More specifically, we follow OR's strategy of solving for the terms of trade and the relative price of tradable to nontradable goods in each country as a function of underlying preference parameters and calibrated current account balances. Starting from this equilibrium, we study how much relative prices have to adjust in response to exogenous changes in current account positions when: (i) only Chinese export prices increase, (ii) only OEA export prices increase, and (iii) both Chinese and OEA export prices increase together by the same proportion. This approach is built on the assumption that countries can somehow control their relative prices, and may allow for an appreciation of their goods prices either through higher inflation or by revaluing their nominal exchange rate. Whether the appreciation is unilateral or symmetric has important implications for the bilateral current account positions between China and the U.S. and emerging Asia and the U.S.

We find that a reduction of the U.S. current account deficit by one percent of GDP vis-à-vis emerging Asia must be associated with an improvement in the terms of trade of emerging Asia by 15 percent and with a similar depreciation of the U.S. real exchange rate. However, if OEA countries resist appreciation, China would need to bear a much larger appreciation to accommodate the same reduction in the U.S. deficit. A similar result applies if China resists appreciation of its terms of trade and the burden of adjustment rests on OEA export prices. We also find that a symmetric appreciation by all emerging Asia involves smaller current account surpluses for both China and OEA. However, if one country resists appreciation, then that country's current account surplus with the U.S. increases, because while the U.S. deficit falls in the aggregate, U.S. consumers substitute more expensive imports from one country for cheaper goods from the other. This substitution effect is not accounted for in a standard two-country model of the current account, and it is particularly strong due to the high substitutability between goods produced by China and OEA.

Besides the high substitutability with goods from OEA, a second argument is often put forward to suggest that a unilateral Chinese appreciation would be ineffective to shift U.S. consumption away from imports. This second argument is related to the presence of input-output (IO) linkages in China's trade with the U.S., which dampens the effect of a Chinese currency appreciation on final export prices (see Ahmed, 2009; and García-Herrero and Koivu, 2010). This is because a

---

[4]OEA includes Hong Kong Special Administrative Region (SAR), India, Indonesia, Republic of Korea, Macau SAR, Malaysia, Philippines, Singapore, Taiwan Province of China (POC), Thailand, and Vietnam.

[5]Obstfeld and Rogoff (2005) also consider a three-country model, but focusing on U.S., Europe, and Asia. Our work differs from theirs in two main aspects. First, the choice of countries is different. Second, unlike Obstfeld and Rogoff (2005) who impose the same elasticity between all tradable goods, we consider different elasticities for U.S. domestic and foreign tradables, and for U.S. imports from China and OEA.

[6]Throughout the paper we use the term emerging Asia to refer to China and OEA.

unilateral Chinese appreciation does not affect the U.S. dollar price of the intermediate inputs that China imports and re-exports to the U.S. To assess the relevance of this feature of international trade, we extend the model to incorporate input-output linkages within emerging Asia. If the structure of vertical integration is asymmetric, with only China importing intermediate goods from OEA, we find that a larger unilateral appreciation by China is needed, but the quantitative difference is small.

However, our empirical analysis does not support this one-way view of input-output linkages, since OEA also imports intermediate goods from China. When the model incorporates more realistic two-way input-output linkages within all emerging Asia, the required appreciation by China falls between the case of one-way and no input-output linkages. Quite interestingly, this is because a unilateral Chinese appreciation also increases the price of exports from OEA to the U.S. by raising the costs of intermediate inputs imported from China. This reduces the scope for the U.S. to substitute Chinese imports with goods from OEA, and forces a stronger expenditure switching of consumption towards U.S. goods.

Finally, we would like to acknowledge some limitations of our approach (discussed more extensively in Section IV.B) that could be interestingly addressed in future research. First, the model is an endowment economy and therefore cannot explain how the supply of goods reacts to exchange rate fluctuations. It would be interesting to study how labor supply and investment decisions between the tradable and nontradable sectors in all countries adjust during the rebalancing process, and how they affect current account positions. In addition, large changes in international relative prices or nominal exchange rates would induce some firms to relocate production across countries thereby providing an additional channel through which current account positions can change in the long run. Second, we consider imbalances between the U.S. and emerging Asia in isolation from the rest of the world. Our setting is thus silent about the consequences of an appreciation in emerging Asia with respect to non-U.S. trading partners. The model could be extended to include other countries for a more complete assessment of global rebalancing.

The paper is organized as follows. In Section II we present the model which we calibrate in Section III. In Section IV we consider the implications of rebalancing for exchange rates and bilateral current account balances. In Section V, we extend the model to incorporate input-output linkages and discuss how they influence the relation between trade flows and exchange rates. In Section VI we conclude.

II. THE MODEL

In this section we present our model which is largely based on OR. We first discuss a simplified two-country version with only tradable goods to easily explain the mapping between trade balances and exchange rates that we exploit in the rest of the paper. Then, we describe the full-blown version of the model based on three countries and including also nontradable goods.

A. Simplified version with two countries and only tradable goods

Consider a two-period model in which the home country derives utility from consuming both domestic $C_{H,t}$ and foreign goods $C_{F,t}$ according to

$$u\left(\overbrace{\left(\alpha^{\frac{1}{\eta}}C_{H,t}^{\frac{\eta-1}{\eta}}+(1-\alpha)^{\frac{1}{\eta}}C_{F,t}^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}}^{C_t}\right)+\beta u\left(\overbrace{\left(\alpha^{\frac{1}{\eta}}C_{H,t+1}^{\frac{\eta-1}{\eta}}+(1-\alpha)^{\frac{1}{\eta}}C_{F,t+1}^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}}^{C_{t+1}}\right) \quad (1)$$

where β is the intertemporal discount factor, η is the elasticity of substitution between domestic and foreign goods, and α controls the degree of home bias. The home country is endowed with home goods $Y_{H,t}$ and $Y_{H,t+1}$ and maximizes its flow of utility subject to the budget constraint:

$$P_{H,t}Y_{H,t}-\overbrace{(P_{F,t}C_{F,t}+P_{H,t}C_{H,t})}^{P_tC_t}=\frac{1}{I}\left[\overbrace{(P_{F,t+1}C_{F,t+1}+P_{H,t+1}C_{H,t+1})}^{P_{t+1}C_{t+1}}-P_{H,t+1}Y_{H,t+1}\right] \quad (2)$$

where I is the gross nominal interest rate, and P_H and P_F are the prices of home and foreign goods. Conceptually we can think about the optimization problem as involving one intertemporal decision about how to allocate consumption expenditures *between* the first and second period by maximizing a utility function $u(C_t)$ with standard properties

$$\max\left[u(C_t)+\beta u(C_{t+1})\right] \qquad \text{subject to} \qquad P_{H,t}Y_{H,t}-P_tC_t=\frac{1}{I}(P_{t+1}C_{t+1}-P_{H,t+1}Y_{H,t+1}) \quad (3)$$

and two static decisions about how to distribute expenditures between domestic and foreign goods *within* each period

$$\max\left[\alpha^{\frac{1}{\eta}}C_{H,t}^{\frac{\eta-1}{\eta}}+(1-\alpha)^{\frac{1}{\eta}}C_{F,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \quad \text{s.t.} \quad P_tC_t=P_{F,t}C_{F,t}+P_{H,t}C_{H,t} \quad (4)$$

$$\max\left[\alpha^{\frac{1}{\eta}}C_{H,t+1}^{\frac{\eta-1}{\eta}}+(1-\alpha)^{\frac{1}{\eta}}C_{F,t+1}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \quad \text{s.t.} \quad P_{t+1}C_{t+1}=P_{F,t+1}C_{F,t+1}+P_{H,t+1}C_{H,t+1}$$

The first order conditions for the intratemporal problem imply the following consumption ratios and price definitions for periods t and $t+1$

$$\frac{C_{F,t}}{C_{H,t}} = \frac{(1-\alpha)}{\alpha}\phi_t^{-\eta} \quad (5)$$

$$P_t = P_{H,t}\left(\alpha+(1-\alpha)\phi_t^{1-\eta}\right)^{\frac{1}{(1-\eta)}} \quad (6)$$

where $\phi_t = P_{F,t}/P_{H,t}$ are the terms of trade. Assuming a constant relative risk aversion utility function $u()$ with parameter ρ, the first order condition for the intertemporal problem implies

$$\frac{C_{t+1}}{C_t} = \left[\beta R \left(\frac{\alpha + (1-\alpha)\phi_t^{1-\eta}}{\alpha + (1-\alpha)\phi_{t+1}^{1-\eta}} \right)^{\frac{1}{(1-\eta)}} \right]^{1/\rho} \tag{7}$$

where $\pi = P_{H,t+1}/P_{H,t}$ is domestic inflation, and $R = I/\pi$ is the real interest rate. This Euler equation determines the profile of aggregate consumption over time and therefore the trade balance:

$$TB_{H,t} = P_{H,t}Y_{H,t} - \overbrace{(P_{F,t}C_{F,t} + P_{H,t}C_{H,t})}^{P_tC_t}$$

which normalizing by home GDP ($P_{H,t}Y_{H,t}$), can be rewritten as:

$$tb_{H,t} = 1 - \phi_t \frac{C_{F,t}}{Y_{H,t}} + \frac{C_{H,t}}{Y_{H,t}} \tag{8}$$

We close the world general equilibrium model by considering a foreign country which solves an analogous problem to the home country. The first order conditions for the foreign country involve the following the intratemporal optimality conditions in each period and the intertemporal Euler equation:

$$\frac{C^*_{H,t}}{C^*_{F,t}} = \frac{(1-\alpha^*)}{\alpha^*}\phi_t^{\eta} \tag{9}$$

$$\frac{C^*_{t+1}}{C^*_t} = \left[\beta^* \frac{I}{\pi^*} \left(\frac{\alpha^* + (1-\alpha^*)\phi_t^{\eta-1}}{\alpha^* + (1-\alpha^*)\phi_{t+1}^{\eta-1}} \right)^{\frac{1}{(1-\eta)}} \right]^{1/\rho} \tag{10}$$

where the asterisk (*) denotes variables for the foreign country. By combining the home and foreign first order conditions, the home intertemporal budget constraint, and the resource constraints in each period

$$Y_{H,t} = C_{H,t} + C^*_{H,t} \tag{11}$$

$$Y^*_{F,t} = C_{F,t} + C^*_{F,t} \tag{12}$$

it is possible to solve for the optimal consumption allocations within each period and over time, the relative prices ϕ_t and ϕ_{t+1} and the interest rate I. The general equilibrium solution pins down the trade balance which essentially depends on differences in the discount factor or growth rates between the home and foreign country.[7]

In this paper, we do not take a stand on which of these parameters is responsible for generating adjustments in the intertemporal profile of consumption and hence in the trade balance. We instead exclusively focus on the within-period equilibrium by analyzing how the terms of trade have to adjust to clear the within-period equilibrium for a given trade balance ($tb_{H,t}$). Formally,

[7] Another possible factor driving the U.S. deficit outside the model may be related to the effect of uncertainty on the U.S. savings rate. See Lee, Rabanal, and Sandri (2010).

the within period equilibrium at time t has to satisfy the following system of equations: (5), (8), (9), (11), and (12) for any given value of the trade balance. We want to emphasize that these equilibrium conditions have to hold independently of the intertemporal factors (that we abstract from) determining the trade balance.

In the context of this simple model, we can derive an analytic expression for the mapping between the trade balance and relative prices:

$$tb_{H,t} = 1 + \frac{\left[(1-\alpha^*)\phi_t^{\eta}\frac{Y_{F,t}^*}{Y_{H,t}} - \alpha^*\right]\left[\alpha + (1-\alpha)\phi_t^{1-\eta}\right]}{\alpha^* + \alpha - 1}$$

With home bias in consumption (α and α^* larger than 0.5) and $\eta \geq 1$, it can be shown that an improvement of the home trade balance requires an increase in ϕ, i.e. a worsening of the terms of trade (making domestic goods cheaper relative to foreign goods). The intuition behind this result is straightforward. An improvement in the home trade balance, implies lower home consumption and higher foreign consumption. Since consumption bundles are tilted towards local goods, holding constant ϕ, the home country would mostly reduce the demand for home goods C_H while the foreign country disproportionately increases the demand for foreign goods C_F^*. This would generate a negative net demand for home goods and a positive net demand for foreign goods. Therefore, to restore equilibrium, home goods have to depreciate to strengthen their relative demand. The higher is the substitutability between domestic and foreign goods, the lower is the required depreciation.

B. Three country version of Obstfeld and Rogoff (2007)

We now proceed to describe the full version of our model which differs from the simple model in the previous section for the extension to three countries and the inclusion of nontradable goods. The key elements of the model are the following:

- The world is composed of three endowment economies: the U.S., China, and OEA.
- In all countries households consume nontradable and tradable goods.
- The U.S. trades with both China and OEA, while for simplicity China and OEA do not trade among themselves.[8]
- The degree of substitutability between U.S.-produced and Asia-produced goods is assumed to be low, while tradable goods produced by China and OEA are highly substitutable. This means that a small change in export prices between China and OEA can induce a large expenditure switching effect.

[8]In Section V, we relax this assumption allowing China and OEA to trade in intermediate inputs.

1. U.S. households

Households in the U.S. (home country) maximize their consumption index, which is composed of domestic nontradables, domestic tradables, and foreign tradables. The aggregate consumption index C is given by:

$$C = \left[\gamma^{\frac{1}{\theta}} C_T^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_N^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}$$

where θ is the elasticity of substitution between tradable and nontradable goods, γ is a preference parameter that pins down the fraction of tradable goods in the consumption basket, C_N is the consumption of nontradables and C_T represents consumption of tradable goods.[9] Tradable goods can be either home-produced or imported:

$$C_T = \left[\alpha^{\frac{1}{\eta}} C_H^{\frac{\eta-1}{\eta}} + (1-\alpha)^{\frac{1}{\eta}} C_F^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

where η is the elasticity of substitution between home and foreign goods, α is the consumption bias towards home-produced goods that pins down the fraction of home goods in the tradable consumption basket, C_H represents consumption of home tradable goods and C_F represents consumption of imported tradable goods.

Finally, the U.S. imports foreign tradable goods produced in China ($C_{F,C}$) or OEA ($C_{F,O}$) countries:

$$C_F = \left[\beta^{\frac{1}{\xi}} C_{F,C}^{\frac{\xi-1}{\xi}} + (1-\beta)^{\frac{1}{\xi}} C_{F,O}^{\frac{\xi-1}{\xi}}\right]^{\frac{\xi}{\xi-1}}$$

where β is the consumption bias for Chinese goods in the import basket and ξ is the elasticity of substitution between Chinese and OEA goods.

Therefore, U.S. households choose the optimal consumption levels for C_N, C_H, $C_{F,C}$, and $C_{F,O}$ subject to the constraints:

$$\begin{aligned} P_H Y_H - \overbrace{(CA_H - iF_H)}^{TB_H} &= P_H C_H + P_{F,C} C_{F,C} + P_{F,O} C_{F,O} \\ P_N Y_N &= P_N C_N \end{aligned}$$

where Y_H is the home endowment of tradable goods, i is the net world interest rate (in terms of the notation we used before $I = 1 + i$), and TB_H, CA_H, and F_H are respectively the trade balance, current account, and the stock of net foreign assets vis-à-vis emerging Asia. The first

[9] If the ratio of equilibrium prices is one, then γ is the fraction of tradable goods in the consumption basket. But this need not be the case in the context of our model.

order conditions imply the following price relationships:

$$\begin{aligned} P &= \left[\gamma P_T^{1-\theta} + (1-\gamma) P_N^{1-\theta}\right]^{\frac{1}{1-\theta}} \\ P_T &= \left[\alpha P_H^{1-\eta} + (1-\alpha) P_F^{1-\eta}\right]^{\frac{1}{1-\eta}} \\ P_F &= \left[\beta P_{F,C}^{1-\xi} + (1-\beta) P_{F,O}^{1-\xi}\right]^{\frac{1}{1-\xi}} \end{aligned}$$

and the consumption ratios

$$\begin{aligned} \frac{C_N}{C_T} &= \frac{(1-\gamma)}{\gamma}\left(\frac{P_N}{P_T}\right)^{-\theta} = \frac{(1-\gamma)}{\gamma} x^{-\theta} \\ \frac{C_F}{C_H} &= \frac{(1-\alpha)}{\alpha}\left(\frac{P_F}{P_H}\right)^{-\eta} = \frac{(1-\alpha)}{\alpha}\left(\beta\phi_C^{1-\xi} + (1-\beta)\phi_O^{1-\xi}\right)^{\frac{-\eta}{1-\xi}} \\ \frac{C_{F,O}}{C_{F,C}} &= \frac{(1-\beta)}{\beta}\left(\frac{P_{F,O}}{P_{F,C}}\right)^{-\xi} = \frac{(1-\beta)}{\beta}\left(\frac{\phi_O}{\phi_C}\right)^{-\xi} \end{aligned}$$

where

$$\begin{aligned} x &= P_N/P_T \\ \phi_C &= P_{F,C}/P_H \\ \phi_O &= P_{F,O}/P_H \end{aligned}$$

2. Chinese and OEA households

The problem solved by Chinese households is analogous to U.S. households with the exception that they do not consume goods from OEA. The Chinese households' consumption basket is given by:

$$C^* = \left[(\gamma^*)^{\frac{1}{\theta^*}}\left(C_T^*\right)^{\frac{\theta^*-1}{\theta^*}} + (1-\gamma^*)^{\frac{1}{\theta^*}}\left(C_N^*\right)^{\frac{\theta^*-1}{\theta^*}}\right]^{\frac{\theta^*}{\theta^*-1}}$$

where all parameters with an asterisk $(*)$ denote the Chinese counterpart to U.S. parameters. C_T^* represents consumption of tradable goods as follows:

$$C_T^* = \left[(\alpha^*)^{\frac{1}{\eta^*}}\left(C_{F,C}^*\right)^{\frac{\eta^*-1}{\eta^*}} + (1-\alpha^*)^{\frac{1}{\eta^*}}\left(C_H^*\right)^{\frac{\eta^*-1}{\eta^*}}\right]^{\frac{\eta^*}{\eta^*-1}}.$$

where $C_{F,C}^*$ is the consumption of home-produced Chinese tradable goods and C_H^* of imported tradable goods from the U.S. No bilateral trade with OEA countries occurs, for simplicity. Chinese households face the following budget constraints:

$$\begin{aligned} P_{F,C}^* Y_H^* - (CA_{F,C}^* - iF_{F,C}^*) &= P_{F,C}^* C_{F,C}^* + P_H^* C_H^* \\ P_N^* Y_N^* &= P_N^* C_N^* \end{aligned}$$

where $Y^*_{F,C}$ is the endowment of tradable goods and prices with an asterisk $(*)$ are expressed in Chinese currency. We assume that the law of one price holds, so that $P^*_H = \frac{P_H}{\Sigma^*}$ where Σ^* is the U.S. Dollar per Renminbi nominal exchange rate. The first order conditions and price definitions are analogous to the ones presented for the U.S.

Households from OEA face an equivalent problem. They price U.S. imports in local currency as $P^{**}_H = \frac{P_H}{\Sigma^{**}}$, where Σ^{**} is the nominal exchange rate. We use a double asterisk $(**)$ to denote variables referring to OEA.

3. Market clearing

To solve for the general equilibrium we impose the resource constraints for both nontradable and tradable goods:

$$
\begin{aligned}
Y_H &= C_H + C^*_H + C^{**}_H \\
Y_{F,C} &= C_{F,C} + C^*_{F,C} \\
Y_{F,O} &= C_{F,O} + C^{**}_{F,O} \\
Y_N &= C_N \\
Y^*_N &= C^*_N \\
Y^{**}_N &= C^{**}_N
\end{aligned}
$$

Furthermore, the sum of the current accounts and of net foreign asset positions has to be equal to zero

$$
\begin{aligned}
CA_H + CA^*_{F,C}\Sigma^* + CA^{**}_{F,O}\Sigma^{**} &= 0 \\
F_H + F^*_{F,C}\Sigma^* + F^*_{F,O}\Sigma^{**} &= 0
\end{aligned}
$$

Similarly to the simplified version of the model discussed in Section II.A, for a given calibration of tradable and nontradable endowments and exogenous current accounts and net foreign asset positions, we can solve for the optimal consumption allocations and relative equilibrium prices between tradables and nontradable goods x, x^*, and x^{**}, and for the terms of trade ϕ_C and ϕ_O. We can also derive values for the U.S. terms of trade with respect to emerging Asia as a whole:

$$
\tau = \frac{P_F}{P_H} = \left(\beta\phi_C^{1-\xi} + (1-\beta)\phi_O^{1-\xi}\right)^{\frac{1}{1-\xi}}
$$

and the bilateral R_C, R_O and trade-weighted R real exchange rates of U.S. vis-à-vis emerging

Asia:

$$
\begin{aligned}
R_C &= \frac{P^*\Sigma^*}{P} = \frac{\left(\gamma^* + (1-\gamma^*)(x^*)^{1-\theta^*}\right)^{\frac{1}{(1-\theta^*)}}}{\left(\gamma + (1-\gamma)x^{1-\theta}\right)^{\frac{1}{(1-\theta)}}} \phi_C \frac{\left(\alpha^* + (1-\alpha^*)(\tau^*)^{1-\eta^*}\right)^{\frac{1}{(1-\eta^*)}}}{\left(\alpha + (1-\alpha)\tau^{1-\eta}\right)^{\frac{1}{(1-\eta)}}} \\
R_O &= \frac{P^{**}\Sigma^{**}}{P} = \frac{\left(\gamma^{**} + (1-\gamma^{**})(x^{**})^{1-\theta^{**}}\right)^{\frac{1}{(1-\theta^{**})}}}{\left(\gamma + (1-\gamma)x^{1-\theta}\right)^{\frac{1}{(1-\theta)}}} \phi_O \frac{\left(\alpha^{**} + (1-\alpha^{**})(\tau^{**})^{1-\eta^{**}}\right)^{\frac{1}{(1-\eta^{**})}}}{\left(\alpha + (1-\alpha)\tau^{1-\eta}\right)^{\frac{1}{(1-\eta)}}} \\
R &= \left(\beta R_C^{1-\xi} + (1-\beta) R_O^{1-\xi}\right)^{\frac{1}{1-\xi}}
\end{aligned}
$$

These equilibrium prices and their changes in response to variations in current accounts rest on the calibration of the model. In particular, we need to calibrate the structural parameters entering consumption aggregates, the shares of tradable and non-tradable outputs and the initial external positions of the countries. We describe in the next section how we proceed for the calibration.

III. CALIBRATION

A. Trade elasticities

In the model, the required size of adjustment in relative prices crucially hinges upon the sensitivity of import and export demands. We thus pay particular attention to the calibration of trade elasticities. Namely, there are two types of elasticities to be calibrated. On the one hand, the η, η^* and η^{**} parameters measure the substitutability between home-produced and imported tradables in the U.S., China, and OEA, respectively. These parameters equal the absolute value of the price elasticity of real imports. On the other hand, the ξ parameter measures the substitutability of Chinese and other Asian goods imported by the U.S. In this subsection, we use insights from the literature estimating the price elasticity of imports to calibrate η, η^* and η^{**}, and we describe how the ξ parameter is estimated from U.S. bilateral import data.

Estimating price elasticities of imports is an old business in international economics. Goldstein and Kahn (1985) survey cross-country evidence. For the U.S., they report long-run price elasticities between -1.03 and -1.73. More recently, Marquez (2002) also surveys the literature on trade equations, pointing out the large uncertainty surrounding these estimates. Based on more than 50 articles published between 1941 and 2001 as well as his own estimates, he reports price elasticities for the U.S. between 0 and -2.5.

In the calibration, we set $\eta = 1.5$, (which implies an elasticity of imports of -1.5) based on the most recent evidence. The empirical literature provides little evidence that the response of Asian imports to a nominal shock is significantly different than U.S. imports.[10] As a consequence, we

[10] See Marquez (2002), Kwack et al. (2007) or Cheung, Chinn and Fujii (2009) for estimates of trade equations using Asian data. In particular, Kwack et al. (2007) provide cross-country evidence. They report estimates between -0.50 and -1.06 for 8 Asian emerging countries (including China at -0.5). Their estimate for the U.S. is not significantly different (-0.93).

choose to calibrate the price elasticity of Asian imports (η^* and η^{**}) in the same way as for the U.S. We also experiment with a somewhat lower value of $\eta = 1$ (which implies an elasticity of imports of -1) for the U.S.

The elasticity of substitution between Chinese and OEA goods, ξ, is estimated using the structural method first proposed by Feenstra (1994) and recently implemented on U.S. data by Broda and Weinstein (2006). The estimation identifies the substitutability between imported varieties using the cross-section of exports toward the U.S. The demand side of the model assumes the U.S. consumption of imports is CES across source countries and the share of each variety in aggregate consumption is affected by random shocks. The supply side explains the price of imports as a function of the quantity produced and a random technological parameter. As shown by Feenstra (1994), the demand and supply equations can be combined into a single reduced-form equation. Its estimation makes it possible to identify the structural demand and supply elasticities. The main advantage of the methodology is that it provides a consistent estimate of the elasticity of substitution without having to rely on instrumentation techniques.

The elasticity of substitution is first estimated at the ISIC sectoral level.[11,12] Sectoral estimates are then aggregated up to the country level using the share of each sector in U.S. imports as weights:

$$\hat{\xi} = \sum_k w_k \hat{\xi}_k$$

where k is an ISIC sector, $\hat{\xi}_k$ the sectoral estimate and w_k the share of sector k in U.S. imports from Asia.[13] This leaves us with an aggregate elasticity of substitution between Chinese and Asian exports of 3.98. The estimate is highly significant, with a standard error of 0.39. Based on this, we use 4 as the benchmark value for ξ in the calibration.

B. Other parameters

The calibration of the model is presented in Table 1. The elasticity between tradables and nontradables (θ) and the consumption bias towards tradables with respect to nontradables (γ) are

[11] The identification either uses the whole cross-section of countries exporting to the U.S. or restricts the sample to Asian exporting countries. The first method maximizes the size of the sample, and indeed the accuracy of the estimation. The second option is consistent with the model, that neglects U.S. imports coming from non-Asian countries. Both methods give similar results at the aggregate level. Here, we report estimates based on the whole sample, that have smaller estimated standard deviations.

[12] The estimation method and data are described in details in Imbs and Méjean (2009).

[13] We also tried using as weights the shares of each sector in i) U.S. imports from China and, ii) U.S. imports from OEA. The comparison of those different weighting schemes helps validating the Armington assumption imposed by the model. According to this assumption, the aggregate elasticity of substitution between U.S. and Chinese goods is the same as between U.S. and OEA goods. Even if it is true at the disaggregated level, it may be the case that China is specialized in goods that are highly substitutable while OEA exports more differentiated products. Such differences in trade structures would in turn induce differences in the aggregate substitutability of their exports with respect to U.S. goods. The comparison of estimates based on the three weighting schemes shows it is not the case, however. Results are very close, whatever the weighting scheme we use because China and OEA have similar export patterns to the U.S.

taken from OR. The home bias in China and OEA is calibrated with the value that OR assign to the rest of the world. Relative to OR calibration, we increase the home bias in the U.S. to achieve a U.S. import share from China and OEA that is consistent with the data. The U.S. bias for Chinese goods relative to OEA goods (β) allows to pin down the U.S. import share from China.

We are considering an endowment economy. Hence, we calibrate each country's endowment based on GDP data. The ratios between nontradable and tradable real GDP ($\sigma = Y_H/Y_N$ in the U.S., $\sigma^* = Y^*_{F,C}/Y^*_N$ in China, and $\sigma^{**} = Y^{**}_{F,O}/Y^{**}_N$) are calibrated to match the share of tradables in nominal GDP. Similarly, the shares for China and OEA in the production of total real tradables (σ_C, σ_O) are chosen to match the relative nominal shares with respect to the U.S. We set the world interest rate to 5 percent as in OR and use actual bilateral data to calibrate the net foreign asset positions and trade balances.

Table 1. Calibration

Parameter	Description	Value	Source
Elasticities			
$\theta, \theta^*, \theta^{**}$	tradables and nontradables	2	OR (2007)
η, η^*, η^{**}	domestic and foreign tradables	1.5	literature
ξ	CH and OEA tradables	4	our estimate
Consumption weights			
$\gamma, \gamma^*, \gamma^{**}$	tradables consumption bias	0.25	OR (2007)
α	home bias for the U.S.	0.85	Import/GDP from CH and OEA
α^*, α^{**}	home bias for CH and OEA	0.925	OR (2007)
β	U.S. import bias for Chinese goods	0.5	62% U.S. import share from CH
Production share ratios			
σ	N/T real GDP in the U.S.	2.8	25% nominal T/GDP in U.S.
σ^*	N/T real GDP CH	0.36	50% nominal T/GDP in CH
σ^{**}	N/T real GDP OEA	0.34	50% nominal T/GDP in OEA
σ_C	CH/U.S. tradable real GDP	0.85	30% CH share in total T GDP
σ_O	OEA/U.S. tradable real GDP	0.68	27% OEA share in total T GDP
Bilateral net foreign asset positions and current accounts			
i	world interest rate	5%	OR (2007)
f	U.S. NFA with CH and OEA (%GDP)	-12.4%	2009 bilateral data
f^*	CH NFA with U.S. (%GDP)	27.3%	2009 bilateral data
tb	U.S. TB with CH and OEA (%GDP)	-1.9%	2009 bilateral data
tb^*	CH TB with U.S. (%GDP)	4.5%	2009 bilateral data

Abbreviations: CH China, OEA other emerging Asia, T tradables, N nontradables, NFA net foreign asset, TB trade balance.

IV. REBALANCING AND RELATIVE PRICES

Given the calibration in Table 1, we solve for the optimal consumption allocation and equilibrium prices. We then consider the adjustment in relative prices that are required to allow for a reduction in the U.S. current account deficit vis-à-vis emerging Asia. More specifically, in Section IV.A we focus on three possible adjustments in relative prices that could take place. In the first case, the bilateral terms of trade of China and OEA with respect to the U.S. change by the same proportion. We view this case as one of symmetric appreciation, where both China and OEA share the burden of the adjustment. In the second and third case, we assume that either China or OEA resists the increase of its export prices and the adjustment falls entirely on the terms of trade of the country not resisting appreciation. We assume that a country can hold its export prices constant by either affecting the nominal exchange rate and/or the local currency price of tradables. We investigate the robustness of our results to a lower elasticity of substitution between domestic and foreign goods in Section IV.B. Finally in Section IV.C we show that if countries resist changes in terms of trade, rebalancing could occur only with a substantial reduction of consumption home bias in emerging Asia.

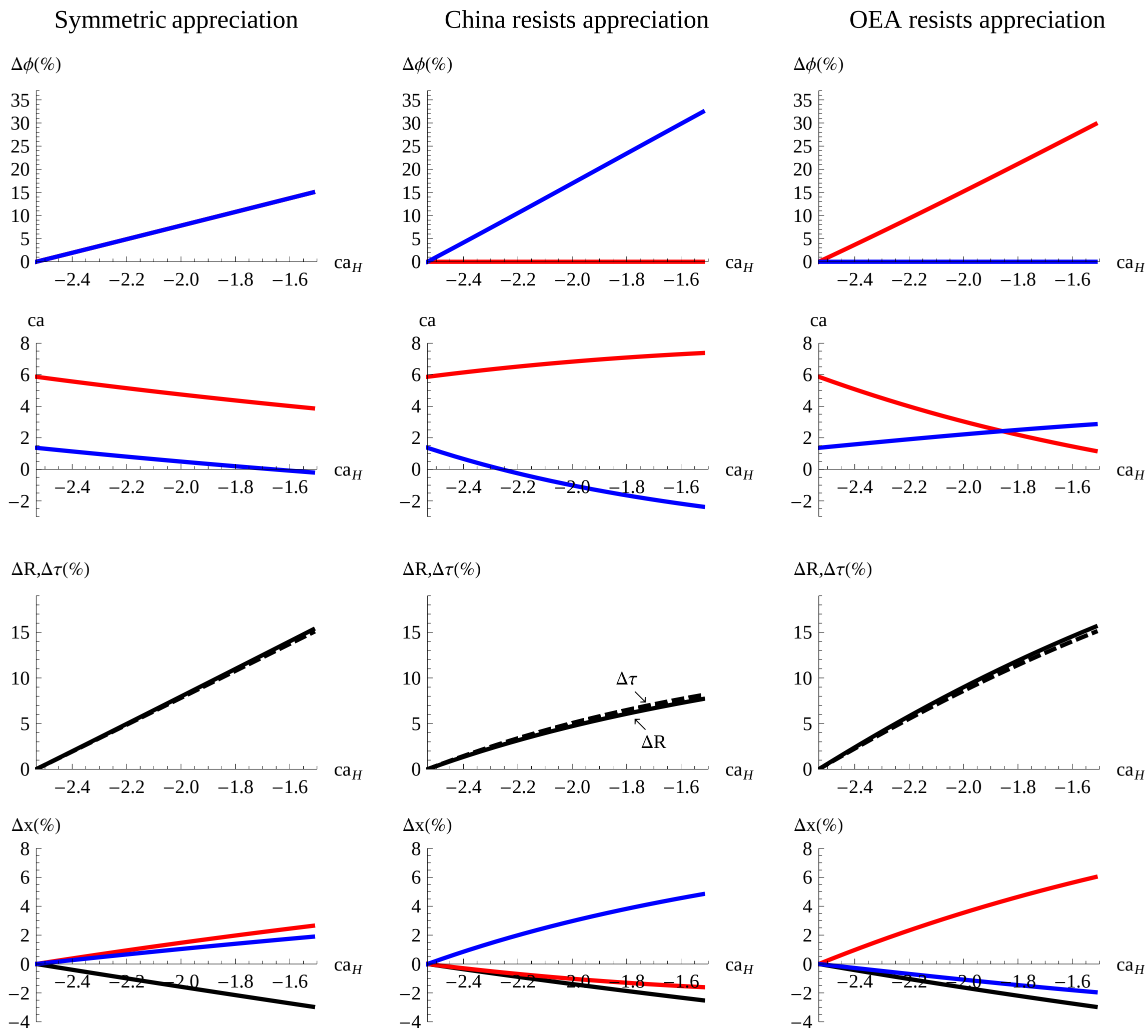
A. Exchange rate adjustment

By how much would Asian export prices have to adjust if the U.S. current account deficit declined? In Figure 1 we show the pattern of adjustment for up to one percent of U.S. GDP. The x-axis in all plots in Figure 1 represents the U.S. current account deficit. As of end-2009, the U.S. had a bilateral current account deficit with Asia of 2.5 percent of U.S. GDP. Hence, we study the implications of a reduction in the deficit to 1.5 percent of GDP. In the left column, we show the adjustment that takes place when tradable goods prices from both China and OEA increase by the same proportion. When the U.S deficit falls by one percent of GDP, the terms of trade in both China and OEA improve by 15 percent. The symmetric increase of emerging Asia's export prices leads to a decline of their bilateral current account surpluses with the U.S. of about 2 percent of their respective GDPs. Hence, China's surplus is brought down from about 6 percent of China's GDP to 4 percent, and OEA's surplus goes from 1.5 percent of GDP to a small deficit. Due to this rebalancing, Chinese and OEA households consume more of their tradable goods, and due to a positive wealth effect they also demand more non-tradables which are in fixed supply. As a result the relative price of non-tradables (x^* and x^{**}) must increase in China and OEA, and due to the same mechanism, it must decline in the U.S. However, these changes are modest and the final outcome is that the U.S. trade-weighted terms of trade (τ) worsen and the real exchange rate (R) depreciates by similar amounts (in the third row of Figure 1, an increase denotes depreciation from the U.S. point of view).

In the middle column, we present the case when China resists changes in its terms of trade and all the burden of adjustment falls on the terms of trade of OEA economies, ϕ_O.[14] In this case, OEA's relative prices must increase by 32 percent to support the new equilibrium. More interestingly, the current account surplus of China *increases* due to the large relative price changes: the U.S.

[14]We do not take a stand on how Chinese authorities would be able to control export prices.

Figure 1. Responses to a reduction in the U.S. current account deficit



Black, red and blue colors identify respectively the U.S., China, and OEA.

imports more Chinese tradables, even when it is reducing its overall deficit. This large expenditure switching implies that the OEA countries move from a surplus of about 1.5 percent of GDP to a deficit of 2.5 percent of GDP. Due to these large price swings, both Chinese and U.S. households consume less tradable goods, which leads them to also reduce consumption of non-tradables, and hence in both countries the relative price of nontradables falls. By the same mechanism, the relative price of nontradables increases in OEA. The overall effect is that the U.S. real exchange rate depreciation is smaller than that of the terms of trade. In the third column of Figure 1 we present the opposite case when all the adjustment occurs through the price of Chinese exports, which increases by about 30 percent. In this case, the Chinese current account surplus almost vanishes vis-à-vis the U.S., while expenditure switching leads to a larger OEA surplus with the U.S. (from 1.5 to 2.9 percent of GDP).

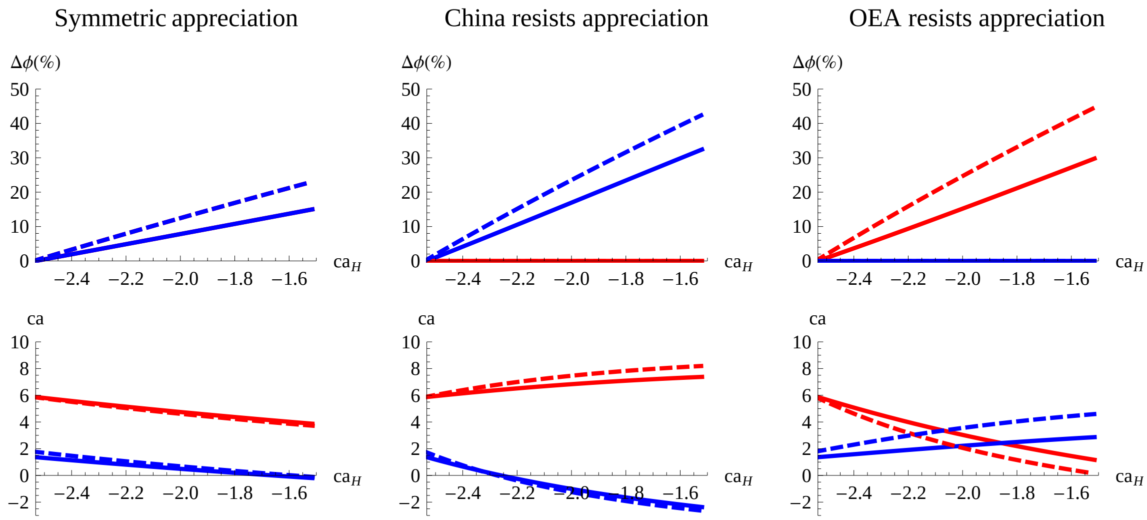
B. Robustness

First, we consider the robustness of our results to a lower elasticity of substitution between domestic and foreign goods in the U.S. while keeping Asian elasticities unchanged (Figure 2). Namely, we set $\eta = 1$ and $\eta^{*} = \eta^{**} = 1.5$. If the U.S. import demand is less sensitive to price changes, as suggested in some empirical literature (see for example Hooper, Johnson and Marquez, 1998), then the implied increase in the price of emerging Asia exports to the U.S. has to be larger for the same reduction of the U.S. current account deficit to occur (short dash lines in Figure 2). Under $\eta = 1$, an improvement in emerging Asia's terms of trade of about 23 percent is needed to accommodate a reduction in the U.S. current account deficit of one percent of GDP. When only China lets its export prices increase, the required improvement in its terms of trade is about 45 percent, while when only OEA appreciates, the required improvement in the terms of trade is about 42 percent.

Second, our results are obtained from a simple endowment economy model which does not allow for supply effects. If factors of production could move between the nontradable and tradable sectors, we would expect smaller changes in the relative prices of nontradable to tradable goods than predicted in our model. In the extreme case of perfect mobility of factors across sectors (or infinite elasticity of substitution in consumption between tradable and nontradable goods) the relative price of nontradables to tradables would actually remain constant. This would imply smaller adjustments in real exchange rates, but would not affect our predictions for the terms of trade. Similarly, if we were to allow for reallocation of production across countries, the terms of trade would adjust by smaller amounts. More in general, the larger is the reallocation occurring through production, the smaller is the required adjustment in relative prices.

Finally, we have considered the adjustment between the U.S. and emerging Asia leaving aside the rest of the world. If we were to include the rest of the world in the model, a key issue would be whether this new player would also allow for a change in export prices. For a given reduction in the U.S. current account deficit, the associated change in emerging Asia's export prices and current account balances would be smaller if export prices in other parts of the world were also allowed to increase. Conversely, if the rest of the world resisted appreciation, the terms of trade of emerging Asia would actually improve by more than predicted in our model and the real exchange rate would appreciate by more since U.S. households could substitute Asian goods with

Figure 2. Sensitivity to lower U.S. elasticity between domestic and foreign goods



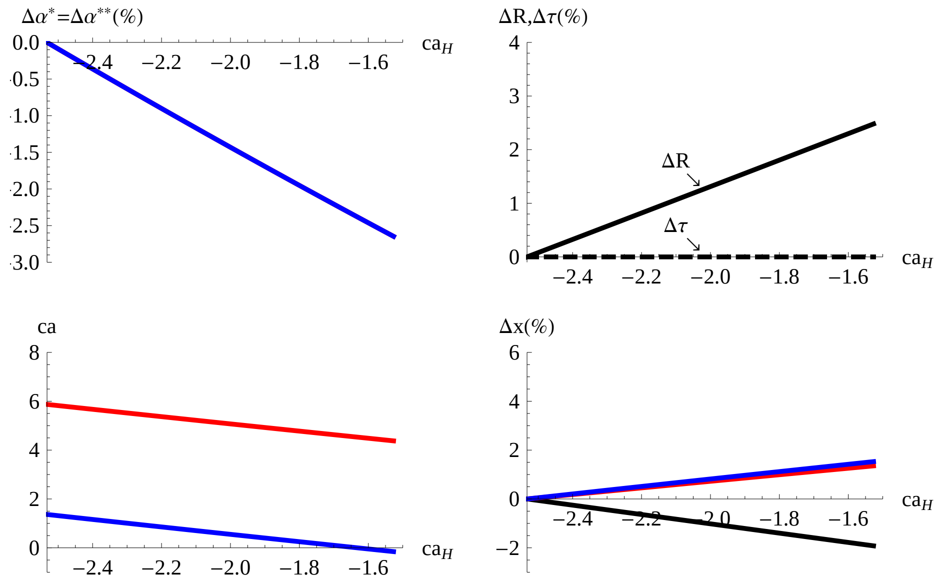
Black and red colors identify respectively the U.S. and China. Continuous lines for "benchmark calibration", and short dashes for "lower U.S. elasticity"

imports from other countries. This last scenario would involve a larger contraction in the current account surpluses of emerging Asia.

C. Change in home bias

Until now, we have shown that a reduction in the U.S. current account deficit with respect to emerging Asia would require a substantial improvement in emerging Asia's terms of trade in order to shift demand towards U.S. goods. In this section, we show that if the Chinese and OEA authorities are not willing to allow their relative export prices to adjust, rebalancing would need to be accommodated by a fairly large reduction in consumption home bias in emerging Asia which would strengthen the demand for U.S. goods. Such a reduction in emerging Asia's home bias could arise from an improvement in the income level that leads to increased demand for higher-quality goods produced in the U.S. This effect is obviously outside the scope of the model, where preference parameters are exogenous, but we wanted to suggest a possible reason of why the α's would change.

Figure 3. Change in home bias required to accommodate a reduction in the U.S. deficit



Black, red and blue colors identify respectively the U.S., China, and OEA.

Figure 3 shows the required reduction in home bias in emerging Asia (captured by a decline in α^* and α^{**}) to accommodate a reduction in the U.S. current account deficit holding terms of trade constant, $\Delta\tau = \Delta\phi_C = \Delta\phi_O = 0$. If the basket of Chinese and OEA tradables included about 3 percent more of goods produced in the U.S., the effect on the bilateral trade balances would be very similar to that obtained under a 15 percent appreciation and no change in the preference parameters. The real effective exchange rate of the U.S. dollar still declines, because of changes in the prices of nontradables to tradables. As in the previous experiment, increased consumption of tradable goods in Asia leads to increased consumption of nontradables. With a fixed supply of nontradable goods, nontradable prices must rise in China.

V. Introducing input-output linkages

A. Evidence

So far, we have exclusively considered trade in final goods. This neglects potential adjustment channels occurring through trade in intermediate inputs. Recent studies have pointed out the large growth of international fragmentation of production processes induced by falling trade costs. [15] This phenomenon seems especially pronounced in Asia. Dean, Fung, and Wang (2007) estimate that 35 percent of the value of China's aggregate exports is attributable to imported inputs in

[15] Hummels, Ishii and Yi (2001) estimate that vertical specialization grew by about 30 percent between 1970 and 1990, explaining more than 30 percent of the world growth of exports.

2002. Their results moreover suggest that OEA is a major supplier of intermediate inputs to China. According to their estimations, more than half of the value of imported inputs in China's exports comes from Japan, Hong Kong SAR, Taiwan POC, Republic of Korea, or Singapore. Koopman, Wang, and Wei (2008) argue that these numbers based on input-output tables actually underestimate the extent of vertical fragmentation since they are derived assuming the same production function for domestic and exported goods. But China's special treatment of processed goods implies that exported goods are likely more intensive in intermediate inputs than goods sold on the domestic market. Accounting for the possibility that technology functions are different for exported and domestic goods, they find that the share of intermediate inputs in the value of Chinese aggregate exports is at about 50 percent.

International fragmentation is likely to affect the relation between trade imbalances and real exchange rates. With input-output linkages, a unilateral Chinese appreciation has a smaller effect on the price of Chinese exports, since the production costs related to intermediate inputs remain constant in U.S. dollar terms. García-Herrero and Koivu (2010) discuss how vertical integration modifies the sensitivity of China's trade to exchange rate movements. They argue that the use of Asian imported inputs in the production of China's final good exports explains why Chinese imports drop as a result of an appreciation of the Renminbi. Ahmed (2009) estimates the sensitivity of Chinese exports to exchange rate changes, distinguishing between processed and unprocessed exports. He shows that an appreciation of the Renminbi against the currencies of OEA's trading partners has no impact on Chinese exports of processed goods, while it reduces exports of non-processed goods. When the appreciation is instead against developed countries, both types of exports drop. These results are consistent with a model in which China imports inputs from OEA to be incorporated in the production of processed goods. However, Ahmed (2009) does not perform the same exercise for exports of OEA countries, so it is difficult to know if the same effect takes place.

Overall, this evidence suggests that an evaluation of the required appreciation in emerging Asia has to account for production linkages within Asia. Input-output linkages are indeed likely to affect the quantitative response of our model to variations in exchange rates. Until now our model has implied that an exchange rate adjustment in Asia is transmitted one for one to the U.S. terms of trade. But the pass-through of exchange rate shocks into the price of final goods is no longer complete when some of the exporters' marginal cost is constant in U.S. dollars. Said otherwise, the elasticity of the terms of trade to an exchange rate shock is not necessary unitary when production processes are internationally segmented. Instead, the magnitude of price adjustments depends on the extent of input/output linkages as well as on the geographical patterns of production.

B. Extension of the model

In order to evaluate quantitatively the impact of input-output linkages on external adjustments, we augment the model with a supply dimension. Each country is now endowed with an exogenous quantity of inputs, used as the only productive factor. Factors are sector-specific, i.e. inputs necessary to produce tradables cannot be used for nontradables. The technology in the non-traded good sector is linear and produces one unit of good per unit of input. Therefore, endowments in non-traded inputs determine the quantity produced and consumed in each country.[16] In the traded good sector we instead assume that production is internationally segmented, so that countries can trade in intermediate inputs.

We assess the relevance of input-output linkages using cross-country evidence derived from the Global Trade Analysis Project (GTAP) database. GTAP puts together input-output tables produced in more than 100 countries, including the U.S., China, and 10 Asian emerging countries. From these data, it is possible to calculate the import content in a country's production and exports, by sector and at the aggregate level. Our measure of foreign input content uses the method proposed by Hummels, Ishii, and Yi (2001). They define a country's *vertical integration* as the "use of imported inputs in producing goods that are exported". Our model does not differentiate between tradable goods and those that are only exported. Therefore, we adapt Hummels, Ishii, and Yi (2001)'s indicator of vertical integration. Namely, we aggregate the import content across sectors using their shares in tradable output rather than in total exports. This means that we quantify the use of imported inputs in tradable *production* rather than in *exports* only. As in Hummels, Ishii, and Yi (2001), we account for the possibility that domestic inputs incorporated in the production of some sectors are produced with imported inputs.

Using GTAP data, we obtain an import content in U.S. tradables of 15 percent. This share is larger for Asian countries: 23 percent in China and 34 percent in OEA.[17] Our empirical analysis reveals two key findings. First, international fragmentation is much more pronounced for Asian countries than for the U.S. Therefore, we include in the model only intermediate input linkages within Asia, assuming that the U.S. does not use intermediate inputs from Asia for the production of final goods. The production of U.S. tradables simply equals the U.S. endowment of intermediate goods:

$$Y_H = Q_H$$

Second, vertical specialization is an important feature in both China and OEA. Therefore, we assume that the production function for tradable goods in China and OEA are:

$$\begin{aligned} Y^*_{F,C} &= Q^{\mu^*}_{C,C} Q^{1-\mu^*}_{O,C} \\ Y^{**}_{F,O} &= Q^{\mu^{**}}_{O,O} Q^{1-\mu^{**}}_{C,O} \end{aligned}$$

where $Q_{i,j}$ denotes the intermediate input from country i used in the production of final good in country j, and μ^* and μ^{**} are the shares of domestic intermediate inputs in the production of the final good. This symmetric specification of input-output linkages between China and OEA distinguishes us from the previous literature that usually assumes one-way input-output linkages,

[16] We neglect the potential role of imported inputs in the production of non-traded goods based on evidence. Namely, we use GTAP IO tables, define non-traded goods as being sectors with less than 10 percent of world output exported and compute the mean share of imported inputs in the production of the U.S., China and emerging Asia. Whatever the country, we find this share is always lower than 10 percent in non-traded good sectors while it is at least twice as large in traded good sectors.

[17] The figure obtained for China is slightly smaller than what is reported by Dean, Fung, and Wang (2007) that use export data to aggregate sectoral import contents. When we reproduce Hummels, Ishii, and Yi (2001) method and compute the import content into aggregate *exports*, we find 16, 33 and 40 percent for the US, China and OEA, respectively. Koopman, Wang, and Wei (2008) give even bigger numbers since they distinguish between processed and unprocessed exports.

with only China importing inputs from Asia (see for instance Ahmed, 2009; and García-Herrero and Koivu, 2010). This one-way input-output specification is equivalent to assuming $\mu^{**} = 1$ in our model.

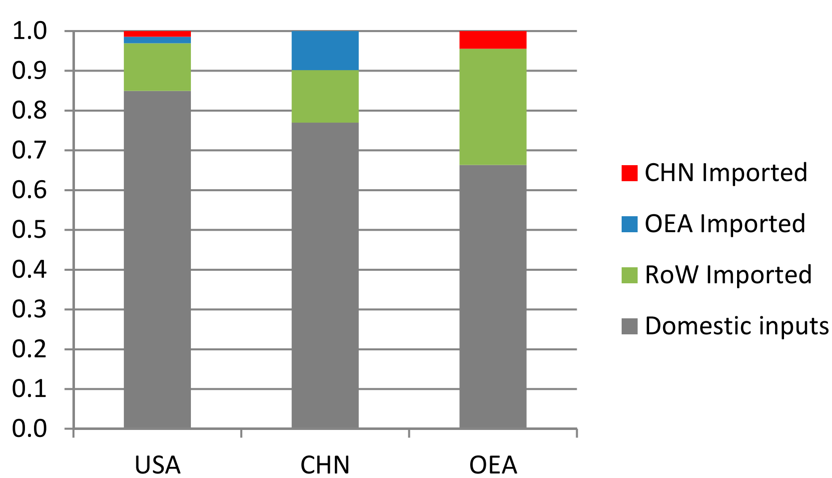
Neglecting OEA's use of intermediate inputs would be justified in the present context if imports of inputs by OEA countries were not involving China. Given our focus on a unilateral Chinese appreciation in the next few sections, any input-output linkage that does not involve China is irrelevant. Results by Bems, Johnson and Yi (2010) however suggest this is not the case. They develop a new methodology that combines IO tables with bilateral trade data to estimate the sources of a country's imports of intermediate goods. Their results suggest that China is a non-negligible provider of OEA imported inputs, and vice versa. Namely, 42 percent of Chinese imports of intermediate inputs come from OEA while only 8 percent are imported from the U.S. For emerging Asia, the relative share of China and the U.S. in intermediate inputs is more balanced, each country accounting for approximatively 15 percent of aggregate imports (13 percent from China, and 16 percent from the US).

To close the model we need to add new market clearing conditions for intermediate goods, given each country's endowment of intermediate inputs (Q_C and Q_O respectively for China and OEA):

$$\begin{aligned} Q_C &= Q_{C,C} + Q_{C,O} \\ Q_O &= Q_{O,O} + Q_{O,C} \end{aligned}$$

Regarding the calibration of model, using GTAP data and the results on the sources of intermediate inputs provided by Bems, Johnson and Yi (2010), we split the value of tradable production into its different cost components, due to domestic inputs, and foreign inputs coming from China, OEA, and the rest of the world. This break down is shown in Figure 4. These numbers confirm the limited role of intermediate inputs in the U.S. relative to emerging Asia, and the presence of significant intermediate input linkages between China and OEA.

Figure 4. Shares of domestic and imported intermediate inputs in tradable production



The prices of final goods in U.S. dollars exported by the U.S., China and OEA are related to the prices of intermediate inputs in the three countries as follows:

$$
\begin{aligned}
P_H &= P_{H,Q} \\
P_{F,C} &= \frac{(\Sigma^* P^*_{C,Q})^{\mu^*} (\Sigma^{**} P^{**}_{O,Q})^{1-\mu^*}}{(\mu^*)^{\mu^*} (1-\mu^*)^{1-\mu^*}} \\
P_{F,O} &= \frac{(\Sigma^{**} P^{**}_{O,Q})^{\mu^{**}} (\Sigma^* P^*_{C,Q})^{1-\mu^{**}}}{(\mu^{**})^{\mu^{**}} (1-\mu^{**})^{1-\mu^{**}}}
\end{aligned}
$$

Two comments are in order. First, it is clear from this expression that if there is an appreciation of one percent by China (either through an increase in the nominal exchange rate Σ^*, or in the local currency price of intermediate goods $P^*_{C,Q}$), then the price of final Chinese goods increases by μ^* percent. Second, in the presence of two-way linkages, a Chinese appreciation also affects the price of final goods produced in OEA and shipped to the U.S.

Our model does not allow for intermediate inputs coming from the rest of the world, so we assimilate them to domestic inputs. This leads to the following parameter values $\mu^* = 0.902$ and $\mu^{**} = 0.956$. The results are virtually unchanged if we instead calibrate the shares of domestic and foreign inputs by neglecting inputs coming from the rest of the world.

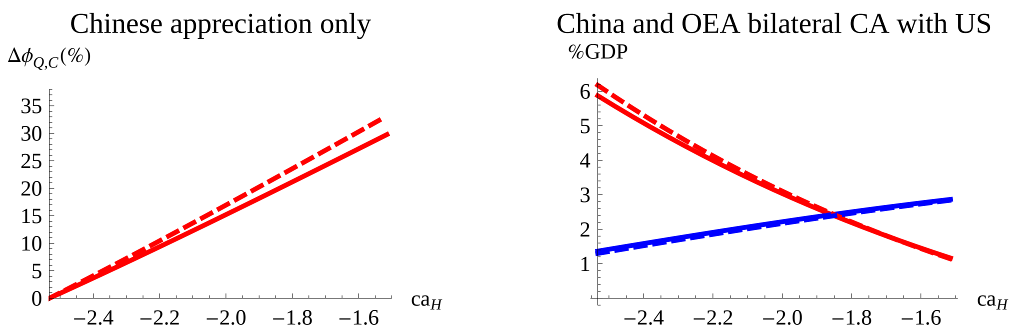
Finally, we calibrate the endowment of intermediate inputs in China and OEA (Q_C and Q_O), in order to sustain in equilibrium the same production quantities of tradable goods (and thus their relative prices) as in the version of the model without IO linkages. We therefore add IO linkages, while preserving the same structure and equilibrium in the market for final consumption goods. We denote the price of the Chinese intermediate inputs relative to U.S. inputs by $\phi_{C,Q} = \Sigma^* P^*_{C,Q}/P_H$, and consider how much they have to adjust to allow for rebalancing with the U.S. For comparison purposes with the previous literature that neglects the role of input-output linkages for OEA, we are also going to consider the case of one-way linkages from OEA to China, setting therefore $\mu^{**} = 1$.

C. Exchange rate adjustment with input-output linkages

We first analyze the case with one-way linkages, setting $\mu^* = 0.902$ and $\mu^{**} = 1$. This is the "popular story" that many researchers and market commentators have in mind, and that assumes that only Chinese exports to the U.S. are produced with foreign intermediate inputs. The concern is that a Chinese appreciation would be ineffective to increase the relative price of Chinese goods and shift demand towards U.S. tradables due to the limited pass-through. This implies that once we consider intermediate linkages, a much larger Chinese appreciation may be needed to accommodate a reduction in the U.S. deficit. Our analysis suggests that this concern is quantitatively not relevant, since the share of OEA inputs in China tradable production is actually fairly small, about 10 percent.

Figure 5 shows indeed that rebalancing with one-way IO linkages would be associated with only a slightly larger Chinese appreciation relative to the previously considered model without intermediate inputs. For example, to allow for a reduction in the U.S. deficit of 1 percent of U.S. GDP, Chinese intermediate goods prices should increase by 33 percent instead of 30 percent.

Figure 5. Sensitivity to one-way IO linkages with a unilateral Chinese appreciation

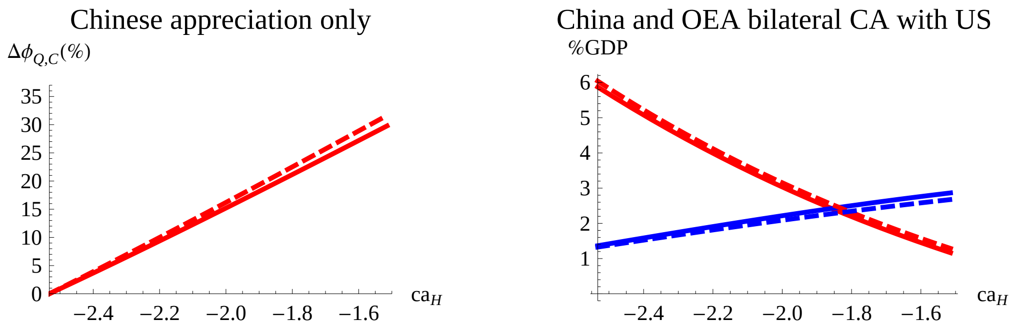


Dashed and continuous lines represent respectively the model with and without IO linkages. Black, red and blue colors identify respectively the U.S., China, and OEA.

We would like to stress that this one-way view of IO linkages is at odds with the empirical evidence for two main reasons. First, this one-way IO model by construction predicts large CA deficits of China vis-a-vis OEA while bilateral trade flows are fairly balanced in the data.[18] Second, our previous empirical analysis reveals important two-way IO linkages between China and OEA. With two-way IO linkages ($\mu^* = 0.902$ and $\mu^{**} = 0.956$), Figure 6 shows that the required unilateral Chinese appreciation is close to the one in the model without IO and smaller than in the one-way case. What is the intuition behind this result? With one way linkages, final export prices from OEA are not affected by a Chinese appreciation and thus U.S. consumers substitute Chinese imports with OEA imports. With two-way linkages, OEA final goods prices also increase when China increases the price of its intermediate goods. Therefore, the relative price change of OEA final goods with respect to Chinese final goods is smaller with two-way linkages than with one-way linkages, and U.S. consumers do not substitute one final good for the other, leaving the bilateral current accounts unchanged with respect to the case of no-IO linkages. Therefore, the main message of this exercise is that the presence of IO linkages, especially when considering the two-way case, has only a very limited impact on the required appreciation to accommodate a reduction of the U.S. current account deficit.

[18] Using ComTrade import declarations for China from OEA and for OEA from China, we estimated that China was running a deficit with respect to OEA of 1 percent of its GDP in 2005. The deficit turned into a surplus of 1 percent in 2007.

Figure 6. Sensitivity to two-way IO linkages with a unilateral Chinese appreciation



Dashed and continuous lines represent respectively the model with and without IO linkages. Black, red and blue colors identify respectively the U.S., China, and OEA.

VI. Concluding remarks

In this paper we have provided a quantitative answer to the question of how real exchange rates, terms of trade and bilateral trade flows between the U.S., China, and OEA would change following a reduction in the U.S. current account deficit. Neglecting trade in intermediate inputs, our results suggest that a joint improvement in the terms of trade of all emerging Asia of about 15 percent would accommodate a reduction in the U.S. current account of 1 percent of GDP. A larger appreciation is required if only China allows its export prices to increase, since U.S. households would largely substitute Chinese goods in favor of OEA tradables.

We have also considered the sensitivity of our results to the presence of input-output linkages within emerging Asia. If we only include intermediate inputs from OEA used in the production of Chinese tradables (one-way linkages) in the model, the required Chinese appreciation is slightly larger. This is because the price of Chinese exports would increase only in proportion to the share of domestic inputs in total production. However, our data analysis does not provide much support for this one-way description of input-output linkages, since OEA also imports intermediate inputs from China. When also considering Chinese intermediate inputs in OEA production (two-way linkages), the impact of IO linkages on the required terms of trade adjustment is more muted since an appreciation by China also increases the price of OEA's final good exports.

Several directions are promising for future research. First, the model is an endowment economy, but we should expect the supply of goods to react to real exchange rate fluctuations. Larger adjustment in real quantities are likely to imply smaller movements in relative prices both across sectors and countries. Second, the model only focuses on the bilateral current accounts between the U.S. and emerging Asia. Incorporating other countries would surely offer a more complete picture of the rebalancing process on a global scale. We have here considered a reduction in the U.S. current account deficit vis-à-vis emerging Asia by only 1 percent of GDP. It would be interesting to study how the rest of the adjustment can be shared with the other trading partners. As our multi-country model has shown, the resulting equilibrium would crucially depend on how relative prices are allowed to adjust by each country.

APPENDIX I. SYSTEM OF EQUATIONS

The first order conditions and market clearing conditions to solve the model without input-output linkages are the following:

$$
\begin{array}{lrcl}
\text{U.S. consumption:} & C_T & = & \gamma(P_T/P)^{\theta}C \\
 & C_N & = & (1-\gamma)(P_N/P)^{\theta}C \\
 & C_H & = & \alpha(P_T/P_H)^{\eta}C_T \\
 & C_F & = & (1-\alpha)(P_T/P_F)^{\eta}C_T \\
 & C_{F,C} & = & \beta(P_F/P_{F,C})^{\xi}C_F \\
 & C_{F,O} & = & (1-\beta)(P_F/P_{F,C})^{\xi}C_F \\
\text{China consumption:} & C_T^* & = & \gamma^*(P_T^*/P^*)^{\theta^*}C^* \\
 & C_N^* & = & (1-\gamma^*)(P_N^*/P^*)^{\theta^*}C^* \\
 & C_{F,C}^* & = & \alpha^*(P_T^*/P_{F,C}^*)^{\eta^*}C_T^* \\
 & C_H^* & = & (1-\alpha^*)(P_T^*/P_H^*)^{\eta^*}C_T^* \\
\text{OEA consumption:} & C_T^{**} & = & \gamma^{**}(P_T^{**}/P^{**})^{\theta^{**}}C^{**} \\
 & C_N^{**} & = & (1-\gamma^{**})(P_N^{**}/P^{**})^{\theta^*}C^{**} \\
 & C_{F,O}^{**} & = & \alpha^{**}(P_T^{**}/P_{F,O}^{**})^{\eta^*}C_T^{**} \\
 & C_H^{**} & = & (1-\alpha^{**})(P_T^{**}/P_H^{**})^{\eta^*}C_T^{**} \\
\text{Resource constraints:} & Y_N & = & C_N \\
 & Y_N^* & = & C_N^* \\
 & Y_N^{**} & = & C_N^{**} \\
 & Y_H & = & C_H + C_H^* + C_H^{**} \\
 & Y_{F,C}^* & = & C_{F,C} + C_{F,C}^* \\
 & Y_{F,O}^* & = & C_{F,O} + C_{F,O}^{**} \\
\text{Budget constraints:} & P_H Y_H & = & CA_H - iF_H + P_H C_H + P_{F,C}C_{F,C} + P_{F,O}C_{F,O} \\
 & P_{F,C}^* Y_H^* & = & CA_{F,C}^* - iF_{F,C}^* + P_{F,C}^* C_{F,C}^* + P_H^* C_H^* \\
\text{Market clearing:} & 0 & = & CA_H + CA_{F,C}^*\Sigma^* + CA_{F,O}^{**}\Sigma^{**} \\
 & 0 & = & F_H + F_{F,C}^*\Sigma^* + F_{F,O}^*\Sigma^{**}
\end{array}
$$

Solving the model with IO linkages requires these additional equations:

$$\begin{aligned}
\mu^* P^*_{F,C}(Q_{O,C}/Q_{C,C})^{1-\mu^*} &= P^*_{C,Q}\\
(1-\mu^*)P^*_{F,C}(Q_{C,C}/Q_{O,C})^{\mu^*} &= P^*_{O,Q}\\
\mu^{**}P^*_{F,O}Q^{\mu^{**}-1}_{O,O}Q^{1-\mu^{**}}_{C,O} &= P^{**}_{O,Q}\\
(1-\mu^{**})P^*_{F,O}Q^{\mu^{**}}_{C,C}Q^{-\mu^{**}}_{C,O} &= P^{**}_{C,Q}\\
Q_C &= Q_{C,C}+Q_{C,O}\\
Q_O &= Q_{O,O}+Q_{O,C}\\
Y_{F,C} &= Q^{\mu^*}_{C,C}Q^{1-\mu^*}_{O,C}\\
Y_{F,O} &= Q^{\mu^{**}}_{O,O}Q^{1-\mu^{**}}_{CO}
\end{aligned}$$

where $P^*_{C,Q}$ and $P^{**}_{O,Q}$ are respectively the price of Chinese and OEA intermediate inputs in local currencies. Notice that by combining the first order conditions for the demand of intermediate inputs we obtain the following price of Chinese exports to the U.S.:

$$P_{F,C} = \frac{(\Sigma^* P^*_{C,Q})^{\mu^*}(\Sigma^{**}P^{**}_{O,Q})^{1-\mu^*}}{\mu^*(1-\mu^*)^{1-\mu^*}}$$

which shows that an increase in the costs of domestic inputs would be passed to the price of final tradable goods only in proportion to the share of domestic intermediate inputs used in the production process.

References

Ahmed, S., 2009. “Are Chinese Exports Sensitive to Changes in the Exchange Rate?,” International Finance Discussion Papers, 987 (Washington, DC: Board of Governors of the Federal Reserve System).

Bems, R., R. Johnson, and K.-M. Yi, 2010, “Demand Spillovers and the Collapse of Trade in the Global Recession” IMF Working Paper 10/142 (Washington, DC: International Monetary Fund).

Blanchard, O., and G. M. Milesi-Ferretti, 2009, “Global Imbalances: In Midstream?,” IMF Staff Position Note 09/29 (Washington, DC: International Monetary Fund).

Broda, C. and D. Weinstein, 2006, “Globalization and the Gains from Variety,” *The Quarterly Journal of Economics*, Vol. 121, No. 2, pp. 541-585.

Cheung, Y-W., M. Chinn, and E. Fujii, 2009, “China’s Current Account and Exchange Rate,” NBER Working Paper 14673 (Cambridge, MA: National Bureau of Economic Research).

Dean, J., K. C. Fung, and Zhi Wang, 2007, “Measuring the Vertical Specialization In Chinese Trade,” U.S. International Trade Commission Working Paper 2007-01-A, (Washington, DC: U.S. International Trade Commission).

Du, Q., and S.-J. Wei, 2010, “A Sexually Unbalanced Model of Current Account Imbalances,” NBER Working Paper 16000 (Cambridge, MA: National Bureau of Economic Research).

Feenstra, R., 1994, “New Product Varieties and the Measurement of International Prices,” *American Economic Review*, Vol. 84, No. 1, pp. 157-177.

García-Herrero, A., and T. Koivu, 2010, “Impact of China’s exchange-rate policy on trade in Asia,” in *The U.S.-Sino Currency Dispute: New Insights from Economics, Politics and Law*, ed. by Simon Evenett, VoxEU.org.

Goldstein, M., and M. Kahn, 1985, “Income and price effect in foreign trade,” in Handbook of International Economics, ed. by J. Ronald and P. Kenen, pp. 1042–1099 (Amsterdam: North-Holland).

Hooper, P., K. Johnson, and J. Marquez, 1998, “Trade Elasticities for G-7 Countries,” International Finance Discussion Papers 609 (Washington, DC: Board of Governors of the Federal Reserve System).

Hummels, D., J. Ishii, and K.-M. Yi, 2001, “The Nature and Growth of Vertical Specialization in World Trade,” *Journal of International Economics*, Vol. 54, No. 1, pp. 75-96.

Imbs, J., and I. Méjean, 2009, “Elasticity Optimism”, CEPR Discussion Paper 7177 (London, UK: Centre for Economic Policy and Research).

Koopman, R., Z. Wang, and S.-J. Wei, 2008, “How Much of Chinese Exports is Really Made In China? Assessing Domestic Value-Added When Processing Trade is Pervasive”, NBER Working Paper 14109 (Cambridge, MA: National Bureau of Economic Research).

Korinek, A., and L. Servén, "Undervaluation Through Foreign Reserve Accumulation: Static Losses, Dynamic Gains," World Bank Policy Research Working Paper No. 5250 (Washington, DC: The World Bank).

Kwack, S., C. Ahn, Y. Lee and D. Yang, 2007, "Consistent Estimates of World Trade Elasticities and an Application to the Effects of Chinese Yuan (RMB) Appreciation", *Journal of Asian Economics*, Vol. 18, No. 2, pp. 314-330.

Lee, J., P. Rabanal, and D. Sandri, 2010, "U.S. Consumption after the 2008 Crisis," IMF Staff Position Note 10/01 (Washington, DC: International Monetary Fund).

Marquez, J., 2002, "Estimating Trade Elasticities," *Advanced Studies in Theoretical and Applied Econometrics*, Vol. 39 (Boston; Dordrecht and London: Kluwer Academic).

Obstfeld, M. and K. Rogoff, 2005, "Global Current Account Imbalances and Exchange Rate Adjustments," *Brookings Papers on Economic Activity*, Vol. 2005, No. 1, pp. 67-123.

Obstfeld, M. and K. Rogoff, 2007, "The Unsustainable U.S. Current Account Position Revisited," in *G7 Current Account Imbalances: Sustainability and Adjustment*, ed. by Richard H. Clarida (Chicago, IL: University of Chicago Press).

Song, M., K. Storesletten, and F. Zilibotti, 2010, "Growing like China," forthcoming, *American Economic Review.*

Sandri D., 2010, "Growth and Capital Flows with Risky Entrepreneurship," IMF Working Paper No. 10/37 (Washington, DC: International Monetary Fund).