Asia's Vertical Trade Integration, Exchange Rate, and China's Export Dynamics

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Abstract

This paper examines how China's exports are affected by exchange rate shocks from countries who supply intermediate inputs to China. We build a simple small open economy model with intermediate goods trade to show that due to the intraregional trade in intermediate goods, a devaluation of other Asian currencies does not necessarily damage China's exports, as imported intermediate goods could become cheaper. This channel through intermediate good costs depends critically on the share of intermediate goods in China's export and the degree of exchange rate pass-through in the imported intermediate goods prices. If prices for intermediate goods are not very stikcy, the effect through this channel could be large and China's total exports could benefit. We find the above findings do not depend on the choice of currency invoicing between RMB and the US dollar or the choice between fixed and flexible exchange rate regimes.

JEL classification: F3, F4

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1 Introduction

While the RMB/US exchange rate experienced limited volatilities in recent years, the volatilities between RMB and other Asian currencies have been very high. The Korean Won, for instance, depreciated against RMB by 40 percent from August 2008 to February 2009 before reversing the trend afterwards. How would large movements of emerging Asia's currencies against RMB affect China's exports? This paper tries to address the question from a theoretical perspective.

The conventional trade models are not capable for answering the question. This is because trade in East Asia is to a large extent vertically integrated - China's exports contain substantial amount of inputs imported mostly from other East Asian economies. This East Asian supply chain is particularly dominant in electronic products, as illustrated by Koopman, Wang, and Wei (2008). Conventional trade models do not consider vertically integrated trade. In such models, a devaluation of other countries' currencies would lead to a loss of competitiveness in China's exports as Korean and Chinese export goods compete in the world market - a direct channel which is the conventional wisdom. But if China's exports use Korean inputs, a depreciation of Korean Won could lower production costs for China's exports. If China's exports contain a lot of imported inputs, this indirect channel could be large and may (partly) offset the direct channel. In other words, a depreciation of Korean Won could even lead to higher competitiveness for Chinese exports. Such a channel seems straightforward and has been discussed informally in academia and among policy makers, but there is no theoretical study on this issue.

This paper sets up a dynamic general equilibrium model with vertical trade structure and studies how exchange rate shocks from other Asian economies affect China's exports. The main finding is that the effect depends critically on the share of intermediate goods in China's export and the degree of exchange rate pass-through in intermediate good prices. Intuitively, consider a company in China who uses imported LCD monitors from Korea to assemble computers and exports the computers to the US. Suppose the Korean Won depreciates against RMB and the US dollar by 10 percent, and the RMB/US exchange rate stays unchanged. If the price for monitors in RMB terms declines substantially due to the depreciation of Korean Won, (i.e., the degree of exchange rate pass through is high), the production cost for the computers would decline, which makes China's computer exports more competitive. On the other hand, if the price for monitors barely changes in RMB terms, depreciation of Korean Won would have no effect on the competitiveness of Chinese computers.

We also find the above conclusion holds even if the RMB/US exchange rate is flexible and China's export become invoiced in RMB rather than in the US dollar. As long as China's import prices in RMB terms do not change much in response to changes in the RMB exchange rates, such exchange rate shocks do not affect the competitiveness of Chinese exports through the cost-cutting channel.

The above findings are important for the discussion on global imbalance. The appreciation of RMB has been advocated by many as a solution to the global imbalance, but how much appreciation is needed to stabilize the trade balance in China? As the import contents in China's exports are high, even a large appreciation of RMB would not affect exports by much. But will a collective appreciation of RMB and other Asian currencies be more effective in restoring global imbalance? The finding in this paper shows the answer depends on to what extent prices for intermediate inputs China imports are flexible. If these prices are flexible, China's exports will indeed become less competitive if other Asian currencies appreciate. Note that price flexibility is not the same as currency invoicing - even if all intermediate goods are priced in the US dollar, their values could still change quickly as exchange rate moves.

How much do we know about the degree of exchange rate pass-through for intermediate good prices? There is limited research on this issue, but anecdotal evidence suggests that prices could be quite flexible for intermediate goods in Asia. Prices for many computer parts are available on a daily basis in major technology parks in China,[1] but it is not clear how much they change when exchange rate shocks take place. Empirical research on this issue warrants more attention.

This paper is related to some previous research on trade in Asia or China. Cook and Devereux (2006) argues that the practice of setting export goods prices in dollars led to a powerful internal propagation effect of the Asian crisis within the region, contributing greatly to the decline in regional trade flows. Their model does not capture the vertical trade structure in East Asia, which is the focus of our paper. Ahmed (2009) studies the effect of East Asian currency exchange rates on China's exports and found some mixed evidence for linkage between the two. Our paper is a theoretical work that shows the linkage could depend on the price flexibility for intermediate goods.

Our paper is also closely related to some work on intermediate goods trade and monetary policy. For example, Devereux and Engel (2005), Shi and Xu (2007), Huang and Liu (2006). These papers, however, focus on the the impact of intermediate goods trade on monetary policy, whereas our paper concentrates on the export dynamic in a small open economy with intermediate goods trade.

The paper is arranged as follows. Section 2 shows some stylized facts about vertically integrated trade in East Asia. Section 3 lays out the model. Section 4 discusses the dynamics of the model in response to an exchange rate shock. Section 5 concludes

2 Vertically Integrated Trade in East Asia

A large portion of trade in East Asia is vertically integrated, as China imports intermediate inputs from other economies in the region, assembles them into final goods, and exports them to overseas markets. One way to quantify the importance of the vertical trade is to

[1]Some prices are available at www.zol.com.cn.

look at the share of processing exports in China's total exports.[2] In 2008, 47 percent of China's exports are classified as processing exports - that is, they use imported intermediate inputs (Figure 1). The share was above 50 percent in previous years.

How much imported inputs are embedded in the processing exports? The answer is about 56 percent in 2008. The import contents in processing have been declining in recent years as more parts and components are made in China. Nonetheless, vertical trade is still an important part of China's exports, as imported intermediate goods account for 26 percent of China's exports.

Imported intermediate inputs for processing trade are mostly from East Asia. The Chinese authorities do not report how much imports from each country are used as inputs for processing trade. To find out the sources of processing imports, we rely on a firm level database that covers all import and export transactions for every firm that operates in China from 2003 to 2005. The details of the database are discussed in Manova and Zhang (2008). Figure 3 illustrates the breakdown by source countries for imported inputs in 2005. Japan, Korea, Taiwan, Hong Kong, and ASEAN economies provided 67 percent of imported inputs, while the US and Euro area only account for 11 percent.[3]

The imported inputs for processing trade concentrates in the sector of electronics and machinery, which accounts for 57 total of the total. This is consistent with anecdotal

[2] Processing exports are defined as exports that use imported intermediate inputs. The Customs in China classify every import and export transaction into processing and non-processing categories. Imported intermediate inputs for processing trade purpose are eligible for import tax rebates.

[3] Two issues about Figure 3 warrant some explanation. First, 13 percent of imported inputs are from China herself. This is (at least partly) because some firms sell their intermediate products to Hong Kong, and these products were imported into China as inputs for processing trade. Second, the inputs from the US and Euro area could be underestimated. For instance, computer CPUs from the US could be exported to Taiwan and assembled into a motherboard, which could be exported to China and assembled into a computer. In our database, the CPUs would be counted as imports from Taiwan instead of the US. But the size of this estimation bias may not be large.

evidence that the East Asian supply chain in electronics business is highly fragmented across countries. It is also consistent with Koopman, Wang, and Wei (2008) who find that the domestic value added in China's exports of electronic products is low. According to their estimates, only 8.2 percent of China's exports of electronic computers are actually made in China.

There is a clear production network in East Asia with China as the assembly point, and inputs coming mostly from other economies in the region. Intuitively, this type of trade structure indicates that exchange rate shocks that occur in other East Asian economies could have implications for costs of China's exports. The next section employs a theoretical model to study this issue.

3 Basic Model

We construct a small open economy two-sector model. Two types of goods are produced: non-traded goods and traded goods. Domestic agents consume non-traded goods and import foreign goods. Nominal rigidities, in the form of costs of price adjustment for non-traded goods and export goods firms are considered in the model. Our model also exhibits the following three features: a) intermediate goods trade, where export firms have to import intermediate goods to produce export goods; b) foreign currency pricing of export goods, i.e., export goods are priced in foreign currency (we will simply call it dollars in the later discussion); and c) restricted capital flow, in terms of international bond adjustment cost.

There are three types of domestic agents in the model: consumers, firms, and the monetary authority. Domestic households determined their consumption, labor supply and how much to borrow or lend on domestic and international financial markets. Production firms in two sectors hire labor from households, and sell goods to domestic residents and foreign markets. The monetary policy (or the exchange rate regime) is represented by a domestic interest rate targeting rule set by the monetary authority.

There will three regions, the domestic economy (A or China), other Asia economy (B or Korea), and the world market (C or the US). For simplicity, we will not model country B and world market C as we will focus on the domestic economy instead. We assume the Chinese exchange rate is S^A, which is the RMB price of US dollar, the Korea exchange rate is S^B, which is Korean Won price of US dollar. Therefore, we have $S^A = S^{AB}S^B$, where S^{AB} is the RMB price of Korean Won. In the model, we will consider S^B is an external exchange rate shock. The detailed structure of the economy is described below. Where appropriate, foreign currency C (dollar) prices are indicated with an asterisk.

3.1 Households

The preference of the representative household is given by:

$$EU = E_t \sum_{s=t}^{\infty} \beta^{s-t} [\frac{C_s^{1-\rho}}{1-\rho} - \eta \frac{L_s^{1+\psi}}{1+\psi}] \tag{3.1}$$

where C_t is an aggregate consumption index defined across domestic non-traded goods and foreign goods; E_t is the expectation operator conditional on information at time t; β is the discount factor; ρ is the inverse of the elasticity of intertemporal substitution; η is a scale parameter for the disutility of the labor supply.

The consumption index, C, is defined as $C_t = \frac{1}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} C_{Nt}^{1-\alpha} C_{Ft}^{\alpha}$, where C_N is the aggregate non-traded goods, C_F is the consumption of foreign goods,[4] and α is the share of imported foreign goods in the total consumption expenditure of domestic households. The Cobb-Douglas form of equation (3.1) implies a unit elasticity of substitution between domestic goods and foreign goods in consumption. Given the consumption index, the consumer price index for domestic households can be derived as

$$P_t = P_{Nt}^{1-\alpha} P_{Ft}^{\alpha}, \tag{3.2}$$

[4] For simplicity, the foreign consumption goods are imported from the US market.

where P_N and P_F are the prices of domestic non-traded goods and imported foreign goods, respectively.

Households may borrow or lend in domestic or international non state-contingent bonds. Trade in international bonds is subject to portfolio adjustment costs. If the household borrows an amount, D_{t+1}, then the adjustment cost will be $\frac{\psi_D}{2}(D_{t+1} - \bar{D})^2$ (denominated in the composite good), where $\bar{D}$ is an exogenous steady state level of net foreign debt. In our model, a large ψ_D represents tighten government restriction on capital flow across border. The household can borrow in international bonds(denominated in US dollar) at a given interest rate i_t^* , or in domestic currency bonds at an interest rate i_t.

Households own all domestic firms and therefore receive the profits on non-traded and traded firms. A consumer's revenue flow in any period then comes from the wage income, $W_t L_t$, transfers T_t, from the government, profits from both the non-traded sector and the traded sector, Π_t, less debt repayments from the last period, $(1 + i_t^*)S_t D_t + (1 + i_t)B_t$, as well as portfolio adjustment costs. The household then obtains new loans from the domestic and/or international capital market, and uses all the revenue to finance consumption. The budget constraint is thus

$$P_t C_t = W_t L_t + T_t + \Pi_t + S_t D_{t+1} + B_{t+1} - P_t \frac{\psi_D}{2}(D_{t+1} - \bar{D})^2 - (1 + i_t^*)S_t D_t - (1 + i_t)B_t. \quad (3.3)$$

The household chooses how much non-traded and imported consumption goods to consume to minimize expenditure conditional on total composite demand. Demand for non-traded and imported goods is then

$$C_{Nt} = (1 - \alpha)\frac{P_t C_t}{P_{Nt}}, \qquad C_{Ft} = \alpha \frac{P_t C_t}{P_{Ft}}. \quad (3.4)$$

The household optimality conditions can be characterized by the following conditions:

$$\frac{1}{1 + i_{t+1}^*}\left[1 - \frac{\psi_D P_t}{S_t}(D_{t+1} - \bar{D})\right] = \beta E_t \left[\frac{C_t^\rho P_t}{C_{t+1}^\rho P_{t+1}} \frac{S_{t+1}}{S_t}\right] \quad (3.5)$$

$$\frac{1}{1 + i_{t+1}} = \beta E_t \left(\frac{C_t^\rho P_t}{C_{t+1}^\rho P_{t+1}}\right) \quad (3.6)$$

$$W_t = \eta L_t^{\psi} P_t C_t^{\rho}. \tag{3.7}$$

Equations (3.5) and (3.6) represent the Euler equation for the foreign and domestic bond holdings. Equation (3.7) is the labor supply equation. Combining (3.5) and (3.6) gives interest rate parity condition for this economy.

3.2 Firms

There are two sectors in this small open economy: the non-traded goods sector and the traded goods sector. Firms in these two sectors produce differentiated goods and therefore have monopolistic power. Also, all firms face costs of price adjustments. The two sectors differ in their production technologies. Non-traded firms produce output using only labor, while export goods are produced by combining labor and import intermediates.

3.2.1 The Non-traded Goods Sector

The non-traded sector is monopolistic competitive and contains a unit interval [0,1] of firms indexed by j. Each firm j produces a differentiated non-traded good, which is imperfect substitute for each other in the production of composite goods, Y_N, produced by a representative competitive firm. Aggregate non-traded output is defined using the Dixit and Stiglitz function

$$Y_{Nt} = (\int_0^1 Y_{Nt}(j)^{\frac{\lambda-1}{\lambda}} dj)^{\frac{\lambda}{\lambda-1}}, \tag{3.8}$$

where λ is the elasticity of substitution between differentiated non-traded goods. Given the above aggregation, the demand for each individual non-traded good, j can be derived as

$$Y_{Nt}(j) = (\frac{P_{Nt}(j)}{P_{Nt}})^{-\lambda} Y_{Nt}, \tag{3.9}$$

where the price index for composite non-traded goods, P_{Nt}, is given by

$$P_{Nt} = (\int_0^1 P_{Nt}(j)^{1-\lambda})^{\frac{1}{1-\lambda}}. \tag{3.10}$$

Each monopolistically competitive firm has a linear production technology:

$$Y_{Nt}(j) = L_{Nt}(j) \tag{3.11}$$

We follow Rotemberg (1982) in assuming that each firm bears a small direct cost of price adjustments. As a result, firms will only adjust prices gradually in response to changes of demand or marginal cost. Non-traded firms are owned by domestic households. Thus, a firm will maximize its expected profit stream, using the household's marginal utility as the discount factor. We may define the objective function of the non-traded firm, j, as:

$$E_t \sum_{l=0}^{\infty} \beta^l \Gamma_{t+l} \left[P_{Nt+l}(j) Y_{Nt+l}(j) - MC_{Nt+l} Y_{Nt+l}(j) - \frac{\psi_{P_N}}{2} P_{t+l} \left(\frac{P_{Nt+l}(j) - P_{Nt+l-1}(j)}{P_{Nt+l-1}(j)} \right)^2 \right], \tag{3.12}$$

where $\Gamma_{t+l} = \frac{1}{P_{t+l} C_{t+l}^{\sigma}}$ is the marginal utility of wealth for a representative household, and $MC_{Nt} = W_t$ represents the marginal cost for non-traded firm j, and the third term inside parentheses describes the cost of price adjustment incurred by firm j.

Since all non-traded goods firms face the same downward-sloping demand function and price adjustment cost and they have the same production technology, we may write the optimal price-setting equation in a symmetric manner as:[5]

$$\begin{aligned} P_{Nt} \;=\;& \frac{\lambda}{\lambda - 1} MC_{Nt} - \frac{\psi_{P_N}}{\lambda - 1} \frac{P_t}{Y_{Nt}} \frac{P_{Nt}}{P_{Nt-1}} \left(\frac{P_{Nt}}{P_{Nt-1}} - 1 \right) + \\ & \frac{\psi_{P_N}}{\lambda - 1} E_t \left[\beta \frac{\Gamma_{t+1}}{\Gamma_t} \frac{P_{t+1}}{Y_{Nt}} \frac{P_{Nt+1}}{P_{Nt}} \left(\frac{P_{Nt+1}}{P_{Nt}} - 1 \right) \right]. \end{aligned} \tag{3.13}$$

When the parameter ψ_{P_N} is zero, firms simply set prices as a markup over the marginal cost. In general, however, the non-traded goods price follows a dynamic adjustment process.

3.2.2 The Traded Goods Sector

It is assumed that there is a unit interval [0,1] of firms indexed by i in the traded goods sector. They solve a similar maximization problem as firms in the non-traded goods sector

[5] This Rotemberg-type pricing is equivalent to the standard Calvo-type pricing, as we can choose the value of ψ_{P_N} to match the dynamic of price under Calvo pricing.

do. Each firm, i, in this sector sells a differentiated export good and the aggregate traded good is given by

$$Y_{Tt} = (\int_0^1 Y_{Tt}(i)^{\frac{\lambda-1}{\lambda}} di)^{\frac{\lambda}{\lambda-1}}. \tag{3.14}$$

Export firms, however, face the world market and use different production technologies. Each monopolistically competitive firm i imports intermediate goods to produce differentiated good, and re-exports their output to the world market. Thus, there exists the so-called "vertical trade" in this small open economy. The production function of the export firm, i is given as follows

$$Y_{Tt}(i) = [\alpha_T^{\frac{1}{\theta}} L_{Tt}(i)^{\frac{\theta-1}{\theta}} + (1-\alpha_T)^{\frac{1}{\theta}} IM_t(i)^{\frac{\theta-1}{\theta}}]^{\frac{\theta}{\theta-1}} \tag{3.15}$$

where α_T is the share of labor in the traded goods firms' production, $\theta \geq 0$ is the elasticity of substitution between local labor and import intermediate. When $\theta = 0$, the imported intermediate goods are complementary to local labor in the production of traded goods. In the general case where $\theta > 0$, the marginal cost, MC_{Tt}, is given by

$$MC_{Tt} = [\alpha_T W_t^{1-\theta} + (1-\alpha_T)(P_m)^{1-\theta}]^{\frac{1}{1-\theta}}, \tag{3.16}$$

where P_m is the domestic price of intermediate goods and will be set by intermediate goods firms from country B.

Since the traded goods sector is monopolistically competitive, each traded firm, i, sets prices in a way similar to the non-traded goods firms, but the export prices are set in terms of the US dollar.

Therefore, if firm i chooses its price in the US dollar, then its profit maximization problem is given by:

$$E_t \sum_{l=0}^{\infty} \beta^l \Gamma_{t+l} \left[S_t P^*_{TFt+l}(i) Y_{TFt+l}(i) - MC_{Tt+l} Y_{TFt+l}(i) - \frac{\psi_{P_T}}{2} P_{t+l} (\frac{P^*_{TFt+l}(i) - P^*_{TFt+l-1}(i)}{P^*_{TFt+l-1}(i)})^2 \right], \tag{3.17}$$

subject to

$$Y_{TFt}(i) = (\frac{P^*_{TFt}(i)}{P^*_{Tt}})^{-\lambda} Y_{Tt}, \tag{3.18}$$

where $P^*_{TFt+l}(i)$ and $Y_{TFt+l}(i)$ represent the dollar price and the output of traded goods firm, i, which sets its price in dollar. Y_{Tt} represents the aggregate output of domestically produced traded goods, which is give by

$$Y_{Tt} = {P^*_{Tt}}^{-\mu_a} P^{\mu_b}_{asiat} X_t \tag{3.19}$$

For simplicity, we assume $P_{asiat} = (S_{bt})^{-\omega}$, where $\omega < 1$ measures the sensitivity of aggregate Asia export to the change of currency B.

The demand structure implies that the elasticity of demand for export firms is λ, where $\lambda > 1$. The price elasticity of Chinese goods in the world market is $\mu_a > 0$, while the elasticity of substitution between Chinese traded goods and other Asian goods is $\mu_b > 0$. Finally, X_t is the foreign demand shock. [6]

Imposing symmetry, we may get the optimal price setting equation for P^*_{TFt} as:

$$\begin{aligned} P^*_{TFt} &= \frac{\lambda}{\lambda-1}\frac{MC_{Tt}}{S_t} - \frac{\psi_{P_T}}{\lambda-1}\frac{1}{S_t}\frac{P_t}{Y_{TFt}}\frac{P_{TFt}}{P_{TFt-1}}\left(\frac{P_{TFt}}{P_{TFt-1}}-1\right)+ \\ &\quad \frac{\psi_{P_T}}{\lambda-1}E_t\left[\beta\frac{1}{S_t}\frac{C_t^{\rho}P_t}{C_{t+1}^{\rho}P_{t+1}}\frac{P_{t+1}}{Y_{TFt}}\frac{P_{TFt+1}}{P_{TFt}}\left(\frac{P_{TFt+1}}{P_{TFt}}-1\right)\right]. \end{aligned} \tag{3.20}$$

where $Y_{TFt} = (\frac{P^*_{TFt}}{P^*_{Tt}})^{-\lambda} Y_{Tt}$. and P^*_{Tt} represents the price index of these goods, which is given by$P^*_{T_t} = [\int_0^1 {P^*_{TFt}}^{1-\lambda}(i)]^{\frac{1}{1-\lambda}}$.

3.3 Prices of Imported Consumption Goods and Intermediates

To determine the domestic prices of imported consumption and intermediate goods, we will allow for the possibility that there is some delay between movements in the exchange rate and the adjustment of imported consumption and intermediate goods prices. Without

[6] Without loss of generality, let P^*_{Tt} and P^* be denominated in dollars.

loss of generality, we assume that the domestic prices are adjusted in the same manner as prices in the non-traded goods sector. That is, in the face of exchange rates changes, foreign export firms which adjust the local currency (RMB) price of their goods, are subject to a price adjustment cost of a similar form to that of the domestic non-traded goods firms. Therefore, these price adjustment costs will determine the degree of exchange rate pass-through to imported consumption prices and intermediate inputs prices. Finally, it is assumed that the intermediate goods are also differentiated with elasticity of substitution, λ, across varieties.

Thus, the problem of a Korean intermediate goods firm that sets intermediate goods prices may be described as follows

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ (\frac{P_{Mt}(i)}{S_t^{AB}} - W_t^*) I_{Mt}(i) - \frac{\psi_{P_M}}{2} [\frac{P_{Mt}(i) - P_{Mt-1}(i)}{P_{Mt-1}(i)}]^2 \right\},$$

where W_t^* can be considered as the marginal cost of imported inputs in terms of foreign currency, $I_{Mt}(i) = (\frac{P_{Mt}(i)}{P_{Mt}})^{-\lambda} I_{Mt}$ is the demand for import intermediate goods, i, and I_{Mt} is the total demand for import intermediates of the domestic country. For simplicity, we assume that the foreign currency price of inputs is $P_{Mt}^* = \frac{\lambda}{\lambda-1} W_t^*$. Thus, the imported input price faced by domestic traded firms is given by

$$\begin{aligned} P_{Mt} &= S_t^{AB} P_{Mt}^* - \frac{\psi_{P_M}}{\lambda - 1} \frac{P_t}{I_{Mt}} \frac{P_{Mt}}{P_{Mt-1}} \left(\frac{P_{Mt}}{P_{Mt-1}} - 1 \right) + \\ & \quad \frac{\psi_{P_M}}{\lambda - 1} E_t \left[\beta \frac{P_{t+1}}{I_{Mt}} \frac{P_{Mt+1}}{P_{Mt}} \left(\frac{P_{Mt+1}}{P_{Mt}} - 1 \right) \right]. \end{aligned} \tag{3.21}$$

The interpretation of (3.21) is that the foreign firm wishes to achieve an identical price in the domestic market as in the Chinese market. But it incurs quadratic price adjustment costs, and unless $\psi_{P_M} = 0$, it will move its price only gradually towards the desired price. The higher these adjustment costs, the lower the degree of exchange rate pass-through into domestic imported intermediate goods prices.

Given the assumption that the consumption of import goods is also differentiated with elasticity of substitution, λ, across varieties, we can derive the domestic price of imported consumption goods similarly:

$$
\begin{aligned}
P_{Ft} \quad &= \quad SP^*_{Ft} - \frac{\psi_{P_F}}{\lambda - 1}\frac{P_t}{T_{Mt}}\frac{P_{Ft}}{P_{Ft-1}}\left(\frac{P_{Ft}}{P_{Ft-1}} - 1\right) + \\
&\frac{\psi_{P_F}}{\lambda - 1}E_t\left[\beta\frac{P_{t+1}}{T_{Mt}}\frac{P_{Ft+1}}{P_{Ft}}\left(\frac{P_{Ft+1}}{P_{Ft}} - 1\right)\right], \qquad (3.22)
\end{aligned}
$$

where P^*_{Ft} is the world price of foreign consumption goods, and T_{Mt} is the demand for the foreign consumption goods. Similarly, the parameter ψ_{P_F} determines the degree of exchange rate pass-through to imported consumption goods prices.

In our model, for simplicity, we assume that P^*_{Mt} and P^*_{Ft} are constant over time and are normalized as unity.

3.4 Monetary Policy Rules

The monetary authority uses a short-term domestic interest rate as its monetary instrument. The general form of the interest rate rule may be written as

$$1 + i_{t+1} = \left(\frac{P_{Nt}}{P_{Nt-1}}\frac{1}{\bar{\pi}_n}\right)^{\mu_{\pi_n}}\left(\frac{S_t}{\bar{S}}\right)^{\mu_S}(1 + \bar{i}). \qquad (3.23)$$

The parameter μ_{π_n} allows the monetary authority to control the inflation rate in the non-traded goods sector around a target rate of $\bar{\pi}_n$. μ_S controls the degree to which the monetary authority attempts to control variations in the exchange rate, around a target level of $\bar{S}$. The general form of the interest rule (3.23) allows for two types of monetary policy stances. The first rule is one whereby the monetary authority targets the inflation rate of non-traded goods (NTP rule), so that $\mu_{\pi_N} \to \infty$. This is analogous to a domestic inflation targeting rule. The exchange rate is flexible under such a rule, so this rule implies a flexible exchange rate regime. The second rule we analyze is a simple fixed exchange rate rule (FER rule) by setting $\mu_s \to \infty$, whereby the monetary authority adjusts interest rates to keep the nominal exchange rate fixed at the target level of $\bar{S}$. [7]

[7] In a numerical exercise, we set $\mu_{\pi_N} = 900$ and $\mu_s = 900$ for the NTP rule and the FER rule, respectively.

3.5 External Exchange Rate Shocks

In the economy, the only uncertainty the small open economy faces is the exchange rate changes of currency B, which follows

$$log(S_{bt+1}) = \rho_s log(S_{bt}) + \epsilon_t \tag{3.24}$$

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3.6 Equilibrium

In equilibrium, besides the optimality conditions for firms and households, we have the following labor market, goods market, and bonds market clearing conditions:[8]

$$L_{Nt} + L_{Tt} = L_t, \tag{3.25}$$

where $L_{Tt} = \alpha_T(\frac{W_t}{MC_{Tt}})^{-\theta} Y_{Tt}$. The non-traded goods market clearing condition is given by

$$Y_{Nt} = (1-\alpha)\frac{P_t Z_t}{P_{Nt}}, \tag{3.26}$$

where Z_t is the aggregate expenditure, which includes consumption, the international bond adjustment cost, and the price adjustment cost for traded and non-traded firms.

$$Z_t = C_t + \frac{1}{2}\psi_{p_N}(\frac{P_{Nt}}{P_{Nt-1}} - 1)^2 + \frac{1}{2}\psi_{p_T}(\frac{P^*_{TFt}}{P^*_{TFt-1}} - 1)^2 + \frac{1}{2}\psi_D(D_{t+1} - \bar{D})^2 \tag{3.27}$$

In the traded goods market, we have $Y_{Tt} = {P^*_{Tt}}^{-\mu_a} P^{\mu_b}_{asia} X_t$, which implies that the aggregate output in the traded goods sector is determined by the foreign demand, X_t, and both prices of the Chinese export goods and other Asian goods.

In a symmetric equilibrium, the representative household's domestic bond holding is $B_t = 0$. Therefore, using equation (3.27), we can rewrite the household's budget constraint as

$$S_t P^*_{Tt} Y_{T_t} - \alpha P_t Z_t - P_m IM_t + S_t D_{t+1} - (1 + i^*_t) S_t D_t = 0. \tag{3.28}$$

In each case, we set the policy so that the equilibrium is determinate.

[8]The details of the equilibrium conditions are given in the technical appendix.

Table 1: Calibration Parameters

Parameters	value	Parameters	value	Parameters	value
ρ	2	β	0.99	α	0.4
λ	11	α_T	0.3	μ_a	1
ψ	1	ϕ_D	0.1	μ_b	1
σ_ϵ	10%	θ	0.99	ω	0.15
ϕ_{P_N}	4	ϕ_{P_T}	4	ρ_s	0.5

This is a balance of payment condition, where trade surplus will be affected by imports for both consumption goods, $\alpha P_t Z_t$, and intermediate inputs, $S_t P_m IM_t$.

4 The Dynamics of the Model

4.1 Calibration

The parameters that need to be calibrated in our model are listed in Table 1. The coefficient of risk aversion, ρ, is set to 2 as is commonly assumed in the literature. The discount factor, β, is calibrated at 0.99, so that the steady state annual real interest rate is 4%. The elasticity of labor supply, $\frac{1}{\psi}$, is set to unity. The elasticity of substitution across individual export goods λ is chosen to be 11, which implies a steady state markup of 10%. This is equal to the common value found by Basu and Fernald (1997). We set $\mu_a = \mu_b = 1$ so that the elasticity of export to own export price and Asian aggregate price are both unitary. ω is set to 0.15, which approximately equals to the market share of country B in the total Asian market. We set α_T=0.3, so that the share of labor in the production of trade goods is close to the estimation cited in the literature. α is set to 0.4, which implies that the share of non-traded goods in the consumer price index equals 0.6.

Ortega and Rebei (2006) show that price rigidity differs in different sectors in small open economies. Prices are more rigid in the non-traded goods sector than in the traded goods sector. Therefore, to determine the degree of nominal rigidity in the model, we set the parameters governing the cost of price adjustment in the non-traded goods sector and the traded goods sector as $\phi_{P_N} = 4$ and $\phi_{P_T} = 4$, respectively, which give us an implied Calvo price adjustment probability of approximately 0.80[9] and 0.70, respectively. This is consistent with the standard estimates used in the literature that prices usually adjust on average after four quarters. Regarding the parameter related to the bond adjustment cost, we set $\phi_D = 0.1$, this is much larger than the value ($\phi_D = 0.0007$) used by Schmitt-Grohe and Uribe (2003), as we want to use the parameter to model the capital immobility in China.

The elasticity of substitution between local labor and imported intermediate inputs in the traded goods sector (θ) is set to 0.99, which is close to a unitary input substitution.

For the stochastic process of external exchange rate, we assume $\rho_s = 0.5$ and $\sigma_\epsilon = 10\%$, which implies that the shock is 10% percentage change and last for about one year.

4.2 Dynamic

In this subsection, we analyze the response of the economy to a foreign exchange rate shocks S_{bt} under both fixed exchange rate and flexible exchange rates. The discussion focuses on consumption, employment, sectoral output, and some nominal variables such as prices of export goods and imported intermediate goods, and nominal exchange rates.

The effect of the depreciation of Korean Won on China is very much different depending on the degree of vertical trade integration between China and Korea. The more import contents are in China's exports, the more the exporters benefit from depreciation of the Korean Won, if prices for intermediate goods are flexible. To illustrate this point, we report

[9] That is, if the model is interpreted as being governed by the dynamics of the standard Calvo price adjustment process, firms in the non-traded sector will adjust prices on average after five quarters.

the impulse response of various economic variables to an exchange rate shock under three scenarios. Under all three scenarios, we assume that the Korean Won depreciates against the US dollar and RMB by 10%, and the RMB/US exchange rate remains constant. We also assumes the prices for intermediate goods are not very sticky, which means the exchange rate pass-through from an exchange rate shock to intermediate good prices is large. In the first scenario, we assume that imported intermediate goods account for 20% of China's total exports. In the second scenario, the ratio rises to 70%. In the third scenario, the ratio rises further to 100%. The results are shown in Figures 5, 6, and 7.

The impulse response functions show that the share of intermediate goods in the final goods production is crucial in determining how the final goods exports responds to an external exchange rate shock. When imported intermediate goods account for 20 percent of exports (figure 5), China's exports dropped slightly following the exchange rate shock. As the share of imported intermediate goods in China's exports rises, the effect of the exchange rate shock on China's exports changes direction. In the extreme case that $\alpha_T = 0$, thus the intermediate goods share is 100%, China's exports can climb up to nearly 4% initially when the other currency depreciates 10%, as shown in Figure 7.

The above findings hold when the home country is under the flexible exchange regime, though the effect of the exchange rate shock on China's exports becomes smaller. We estimate the three scenarios again with a flexible exchange rate regime in China. The results are shown in Figures 8, 9, and 10. Take the extreme case (the intermediate goods share in the final goods production is 100%) as an example, when China follows a fixed exchange rate regime, China's exports rise by 4% following the Korean Won depreciation (Figure 7). When China follows a flexible exchange rate regime, China's exports rise by less than 3% (Figure 10). The reason behind the difference is intuitive. As the RMB exchange rate becomes flexible, RMB depreciates against the US dollar which partly offset the competitive gains from the depreciation of Korean Won (Figure 10).

The findings so far depends on a critical assumption – prices for intermediate goods are not very sticky so that exchange rate pass through is large. What happens if prices for intermediate goods are sticky? We also report impulse response functions for the extreme case scenario (the intermediate goods share in the final goods production is 100%), and introduce price stickiness to intermediate goods. The value of parameter ψ_{p_M} shows how fast the intermediate goods price is adjusted to the exchange rate shock. Higher value of ψ_{P_M} implies slower price adjustment. We set $\psi_{P_M} = 50$ instead of 4 in this case. The results are shown in Figure 11. Comparing Figure 7 and Figure 11, the only difference in assumption is intermediate good flexibility, and the responses of exports to Korean Won depreciation are quite different. When prices are more sticky, China's exports dropped initially after the exchange rate shock. The impulse responses in Figure 11 look very much similar to those in Figure 5 when trade is not vertically integrated. This finding is intuitive as price stickiness essentially shut down the price transmission channel through intermediate goods. Therefore China's exports can not benefit from a depreciation of Korean Won.

4.3 Effects of RMB Internationalization

The Chinese authorities have been actively promoting RMB internationalization and RMB trade invoicing. What happens if China's trade is priced in RMB instead of the US dollar? We find that our findings in the previous section does not change when exports are priced in RMB and China follows a fixed exchange rate regime. To illustrate this point, we estimate the impulse responses under the extreme scenario in the previous section, and change the currency invoicing of China's exports from the US dollar to RMB. Under fixed exchange rate regime, the currency invoicing does not matter for our exercise. This is not surprising because effectively RMB pricing and US dollar pricing would be equivalent in terms of transmission of shocks in this model if the two are pegged.

Does the exchange rate regime make a difference in our exercise? From Figure 12, 13, 14, we find the difference to be marginal. Under the extreme case scenario where China relies fully on imported intermediate goods to produce the final goods, when the RMB/US exchange rate is flexible, the depreciation of Korean Won will cause China's export to increase by 4% when all the goods are priced in RMB, which is slightly higher than the 3% increment when priced in US Dollar, as shown in Figure 10. The consumption drops less than it does in the case of US dollar pricing (0.7% v.s. 1% in Figure 10).

5 Conclusion

This paper studies how China's exports respond to exchange rate shocks from its intermediate goods suppliers' currencies. We find a depreciation of suppliers' currencies could improve the competitiveness in China's exports by reducing input costs when prices for intermediate goods are flexible. The more imported contents are in China's total exports, the stronger this channel becomes. The choices of exchange rate regimes and currency invoicing do not change this finding.

The findings in this paper indicate that future research on how flexible intermediate good prices are would be promising. Without understanding this issue, we can not make conclusive statements on how exchange rates affect trade in East Asia, and how the global imbalance can be resolved by exchange rate adjustments. It will also shed light on how the RMB internationalization affects the trade dynamics in East Asia.

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Technical Appendix

Not to be Published

A Equilibrium Condition

Household

$$P_t = P_{Nt}^{1-\alpha} {P_{Ft}}^{\alpha} \tag{A.1}$$

$$C_{Nt} = (1-\alpha)\frac{P_t C_t}{P_{Nt}} \tag{A.2}$$

$$C_{Ft} = \alpha \frac{P_t C_t}{P_{Ft}} \tag{A.3}$$

$$\frac{1}{1+i^*_{t+1}}\left[1 - \frac{\psi_D P_t}{S_t}(D_{t+1} - \bar{D})\right] = \beta E_t \left[\frac{C_t^{\rho} P_t}{C_{t+1}^{\rho} P_{t+1}} \frac{S_{t+1}}{S_t}\right] \tag{A.4}$$

$$\frac{1}{1+i_{t+1}} = \beta E_t \left(\frac{C_t^{\rho} P_t}{C_{t+1}^{\rho} P_{t+1}}\right) \tag{A.5}$$

$$W_t = \eta L_t^{\psi} P_t C_t^{\rho}. \tag{A.6}$$

Non-traded Sector

$$Y_{Nt} = L_{Nt} \tag{A.7}$$

$$\begin{aligned} P_{Nt} \quad = \quad & \frac{\lambda}{\lambda - 1} W_t - \frac{\psi_{P_N}}{\lambda - 1} \frac{P_t}{Y_{Nt}} \frac{P_{Nt}}{P_{Nt-1}} \left(\frac{P_{Nt}}{P_{Nt-1}} - 1\right) + \\ & \frac{\psi_{P_N}}{\lambda - 1} E_t \left[\beta \frac{C_t^{\rho} P_t}{C_{t+1}^{\rho} P_{t+1}} \frac{P_{t+1}}{Y_{Nt}} \frac{P_{Nt+1}}{P_{Nt}} \left(\frac{P_{Nt+1}}{P_{Nt}} - 1\right)\right]. \end{aligned} \tag{A.8}$$

Traded Sector

$$MC_{Tt} = [\alpha_T W_t^{1-\theta} + (1-\alpha_T)(P_m)^{1-\theta}]^{\frac{1}{1-\theta}} \tag{A.9}$$

$$P_{T_t}^* = [\kappa {P_{TFt}^*}^{1-\lambda} + (1-\kappa)(\frac{P_{TDt}}{S_t})^{1-\lambda}]^{\frac{1}{1-\lambda}} \tag{A.10}$$

[10]

$$L_{Tt} = \alpha_T (\frac{W_t}{MC_{Tt}})^{-\theta} Y_{Tt} \tag{A.11}$$

$$IM_t = (1 - \alpha_T)(\frac{P_m}{MC_{Tt}})^{-\theta} Y_{Tt} \tag{A.12}$$

$$Y_{TFt} = (\frac{P_{TFt}}{P^*_{Tt}})^{-\lambda} Y_{Tt} \tag{A.13}$$

$$Y_{TDt} = (\frac{P_{TDt}}{S_t P^*_{Tt}})^{-\lambda} Y_{Tt} \tag{A.14}$$

$$\begin{aligned} P^*_{TFt} \quad = \quad & \frac{\lambda}{\lambda-1}\frac{MC_{Tt}}{S_t} - \frac{\psi_{P_T}}{\lambda-1}\frac{1}{S_t}\frac{P_t}{Y_{TFt}}\frac{P_{TFt}}{P_{TFt-1}}\left(\frac{P_{TFt}}{P_{TFt-1}} - 1\right) + \\ & \frac{\psi_{P_T}}{\lambda-1} E_t \left[\beta \frac{1}{S_t}\frac{C_t^{\rho} P_t}{C_{t+1}^{\rho} P_{t+1}}\frac{P_{t+1}}{Y_{TFt}}\frac{P_{TFt+1}}{P_{TFt}}\left(\frac{P_{TFt+1}}{P_{TFt}} - 1\right)\right]. \end{aligned} \tag{A.15}$$

$$\begin{aligned} P_{TDt} \quad = \quad & \frac{\lambda}{\lambda-1} MC_{Tt} - \frac{\psi_{P_T}}{\lambda-1}\frac{P_t}{Y_{TDt}}\frac{P_{TDt}}{P_{TDt-1}}\left(\frac{P_{TDt}}{P_{Tt-1}} - 1\right) \\ & + \frac{\psi_{P_T}}{\lambda-1} E_t \left[\beta \frac{C_t^{\rho} P_t}{C_{t+1}^{\rho} P_{t+1}}\frac{P_{t+1}}{Y_{TDt}}\frac{P_{TDt+1}}{P_{TDt}}\left(\frac{P_{TDt+1}}{P_{TDt}} - 1\right)\right] \end{aligned} \tag{A.16}$$

Import goods price and intermediate goods price

$$\begin{aligned} P_{Mt} \quad = \quad & S_t^{AB} P^*_{Mt} - \frac{\psi_{P_M}}{\lambda-1}\frac{P_t}{I_{Mt}}\frac{P_{Mt}}{P_{Mt-1}}\left(\frac{P_{Mt}}{P_{Mt-1}} - 1\right) + \\ & \frac{\psi_{P_M}}{\lambda-1} E_t \left[\beta \frac{P_{t+1}}{I_{Mt}}\frac{P_{Mt+1}}{P_{Mt}}\left(\frac{P_{Mt+1}}{P_{Mt}} - 1\right)\right]. \end{aligned} \tag{A.17}$$

[10] In our benchmark model, we set $\kappa = 1$, which represents a dollar currency pricing. When export goods price are set in RMB, then $\kappa = 0$.

$$P_{Ft} = SP^*_{Ft} - \frac{\psi_{P_F}}{\lambda - 1}\frac{P_t}{T_{Mt}}\frac{P_{Ft}}{P_{Ft-1}}\left(\frac{P_{Ft}}{P_{Ft-1}} - 1\right) + \frac{\psi_{P_F}}{\lambda - 1}E_t\left[\beta\frac{P_{t+1}}{T_{Mt}}\frac{P_{Ft+1}}{P_{Ft}}\left(\frac{P_{Ft+1}}{P_{Ft}} - 1\right)\right],. \quad \text{(A.18)}$$

Market Clearing Condition

$$L = L_{Nt} + L_{Tt} \quad \text{(A.19)}$$

$$Z_t = C_t + \frac{1}{2}\psi_{p_N}(\frac{P_{Nt}}{P_{Nt-1}} - 1)^2 + \frac{\kappa}{2}\psi_{p_T}(\frac{P^*_{TFt}}{P^*_{TFt-1}} - 1)^2 + \frac{1-\kappa}{2}\psi_{p_T}(\frac{P_{TDt}}{P_{TDt-1}} - 1)^2 + \frac{1}{2}\psi_D(D_{t+1} - \bar{D})^2 \quad \text{(A.20)}$$

$$Y_{Nt} = (1 - \alpha)\frac{P_t Z_t}{P_{Nt}} \quad \text{(A.21)}$$

$$Y_{Tt} = {P^*_{Tt}}^{-\mu_a} P^{\mu_b}_{asia} X_t \quad \text{(A.22)}$$

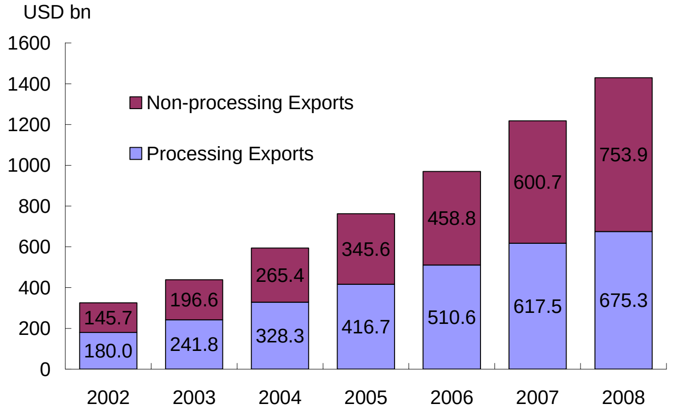
,

$$S_t P^*_T Y_{Tt} - \alpha P_t Z_t - P_m IM_t + S_t D_{t+1} - (1 + i^*_t) S_t D_t = 0. \quad \text{(A.23)}$$

$$1 + i_{t+1} = \left(\frac{P_{Nt}}{P_{Nt-1}}\frac{1}{\bar{\pi}_n}\right)^{\mu_{\pi_n}}\left(\frac{S_t}{\bar{S}}\right)^{\mu_S}(1 + \bar{i}). \quad \text{(A.24)}$$

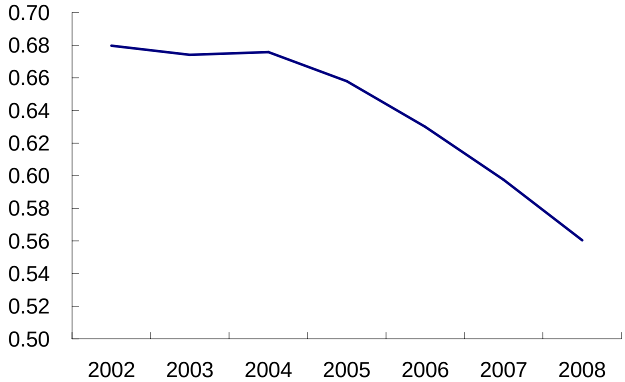
$$S = S^{AB} S^B \quad \text{(A.25)}$$

Figure 1: Processing and Non-processing Exports from China



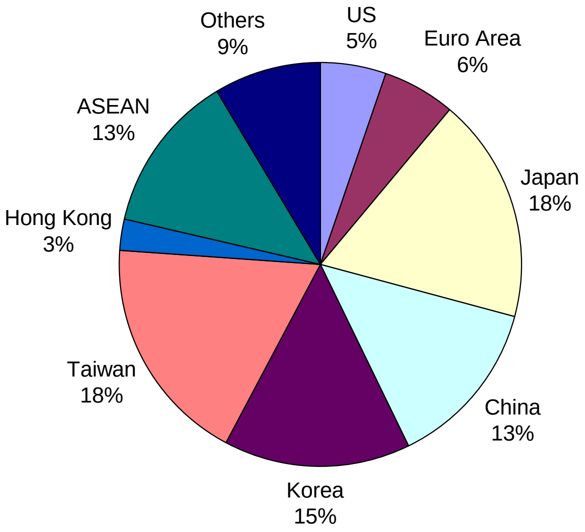
Source: CEIC.

Figure 2: Imported Contents in Processing Exports



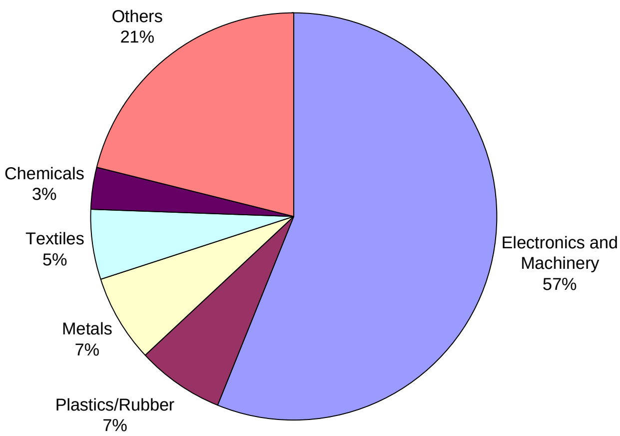
Source: CEIC.

Figure 3: Sources for Imported Inputs in China's Processing Trade, 2005



Source: Authors' estimates.

Figure 4: Imported Inputs by Products, 2005



Source: Authors' estimates

Figure 5: **The IRF with low intermediate goods share under fixed ex**

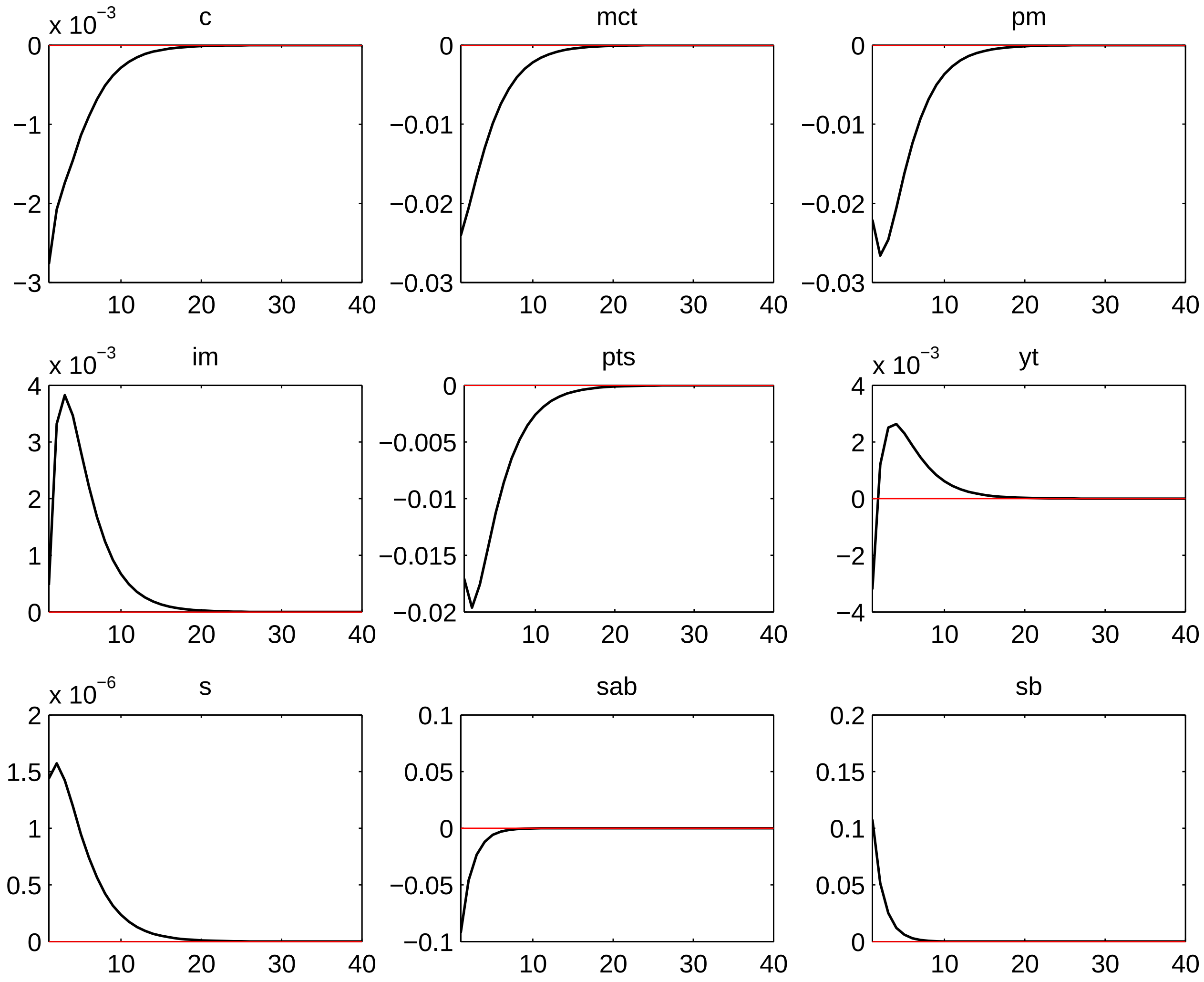


Figure 6: **The IRF with middle intermediate goods share under fixed ex**

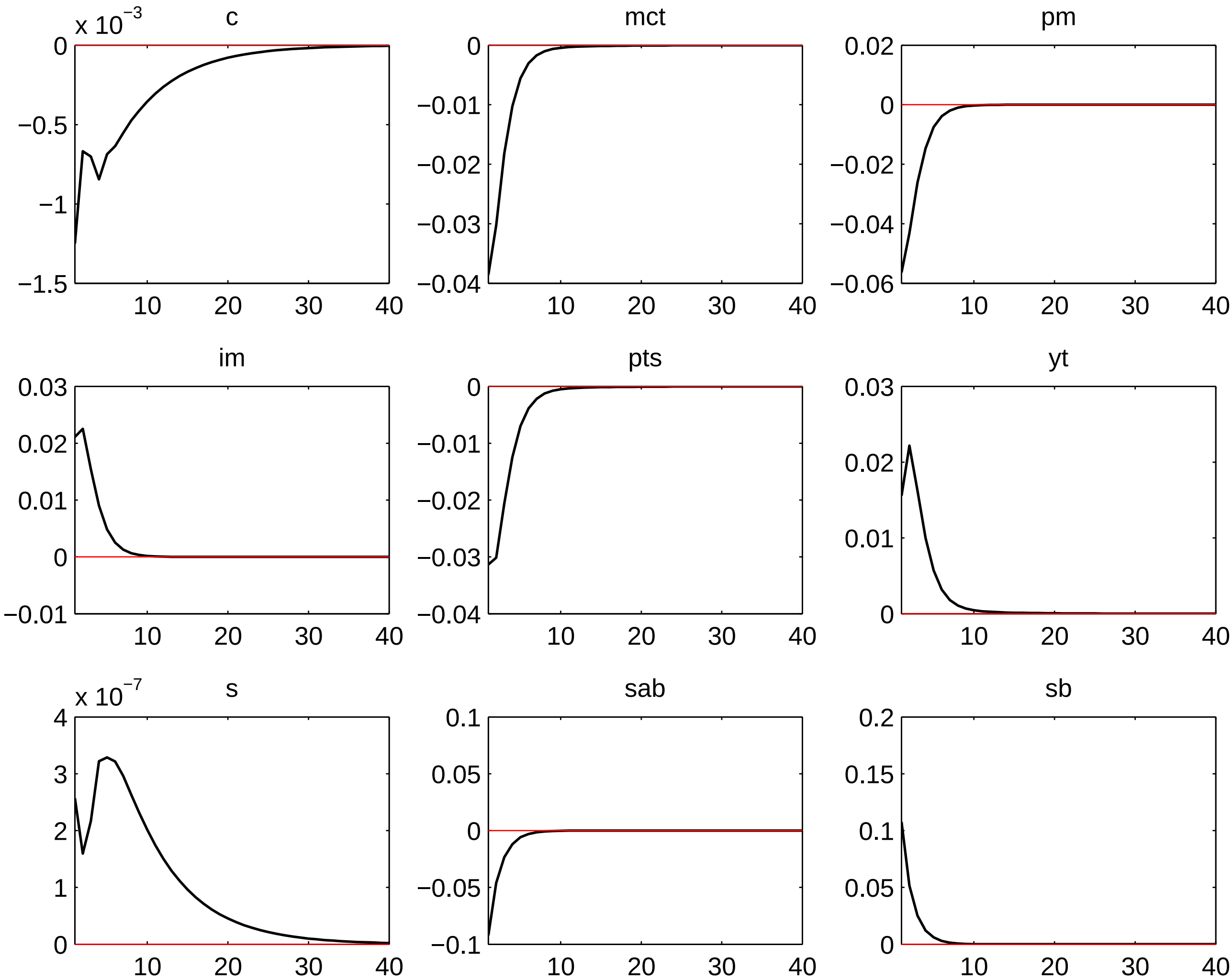


Figure 7: **The IRF with high intermediate goods share under fixed ex**

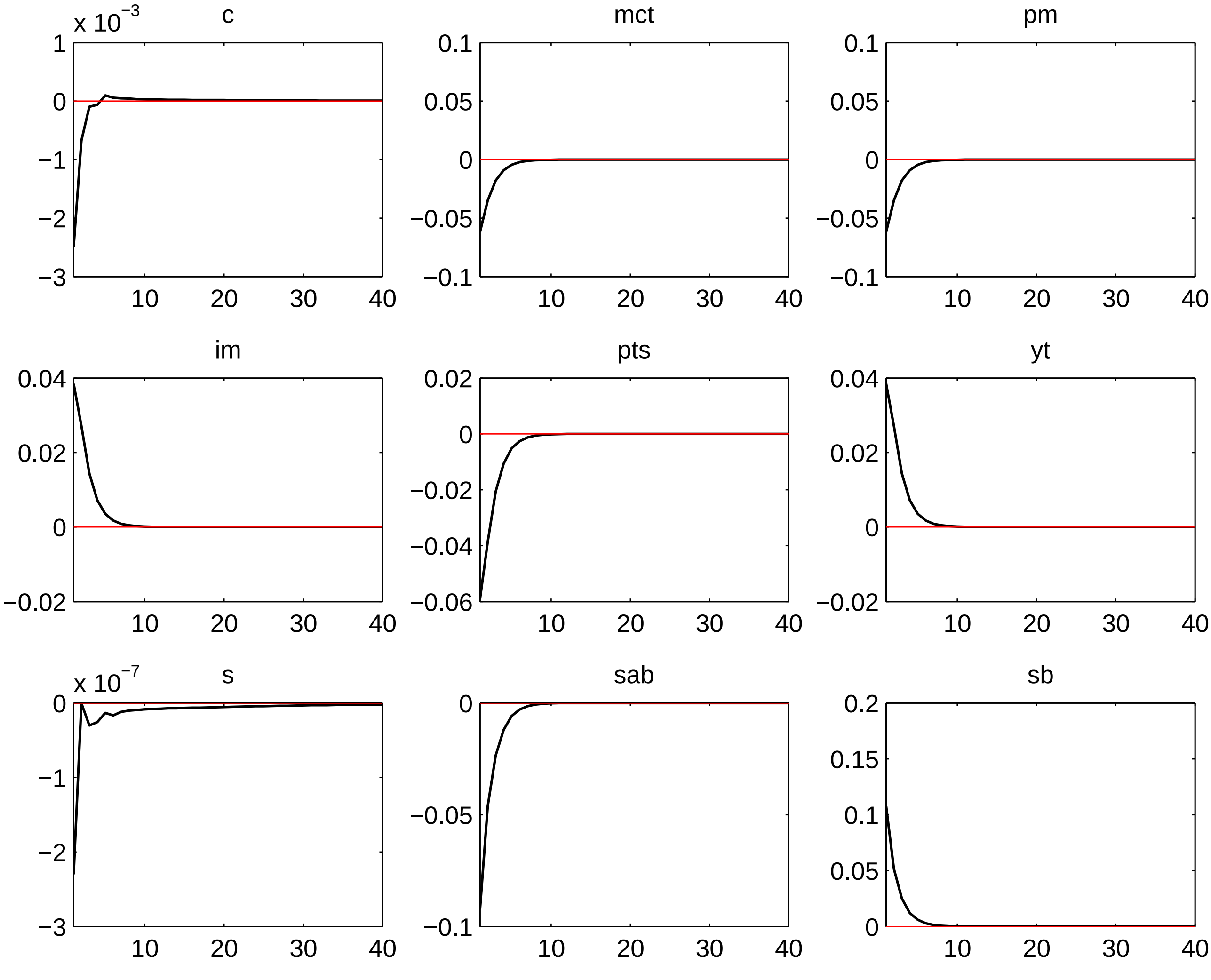


Figure 8: **The IRF with low intermediate goods share under flexible ex**

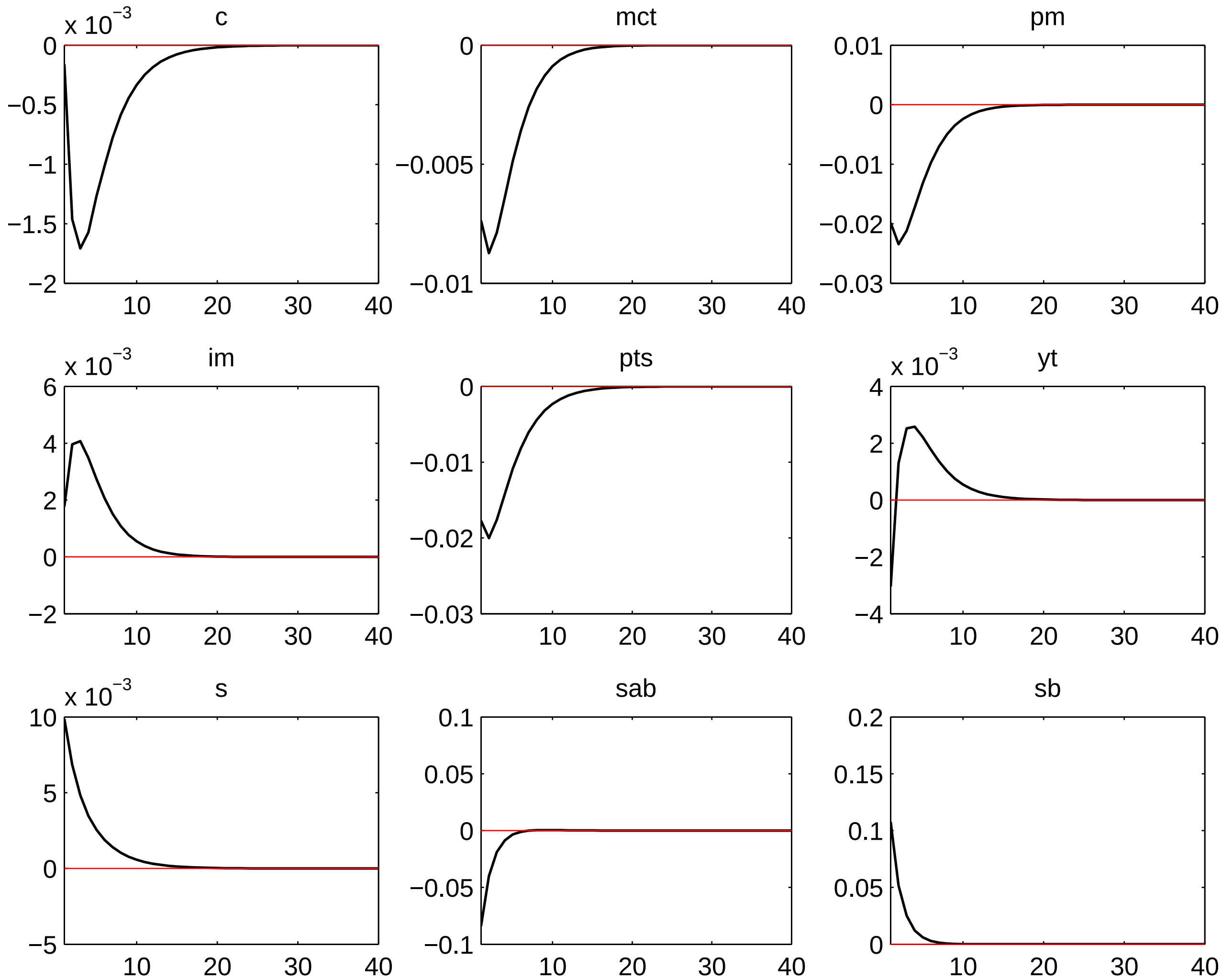


Figure 9: **The IRF with middle intermediate goods share under flexible ex**

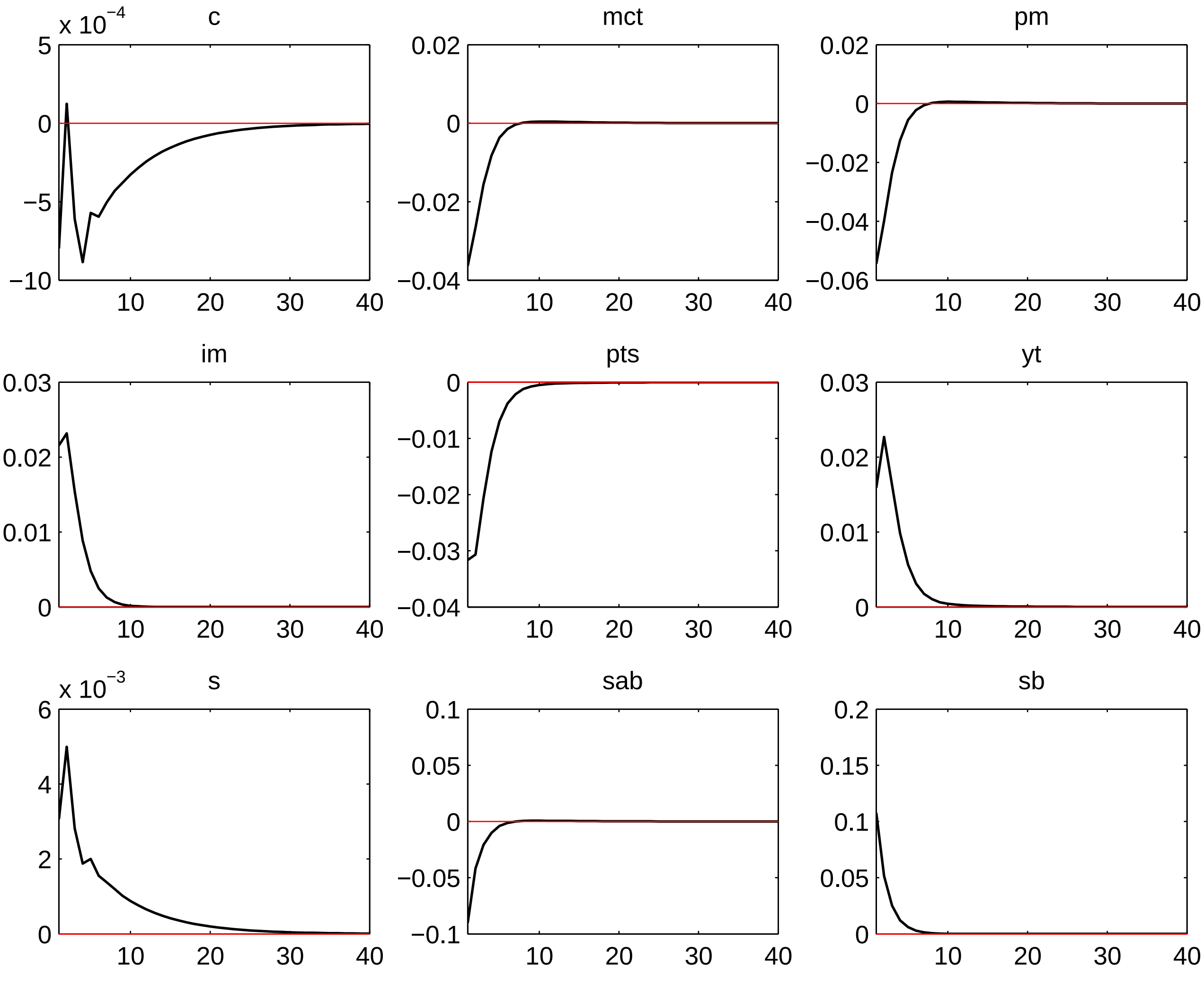


Figure 10: **The IRF with high intermediate goods share under flexible ex**

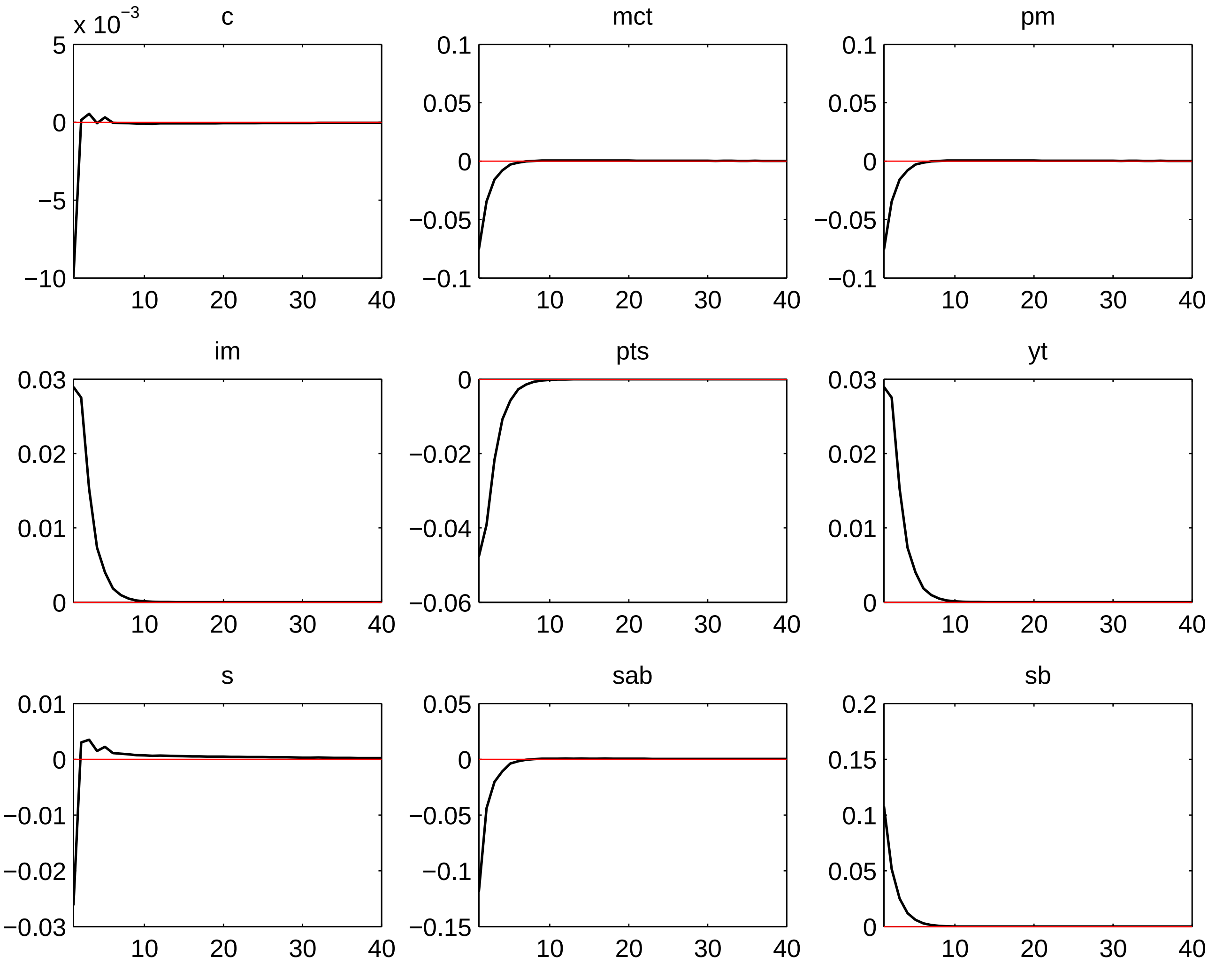


Figure 11: **The IRF with high intermediate goods share under fixed ex with more sticky intermediate goods price**

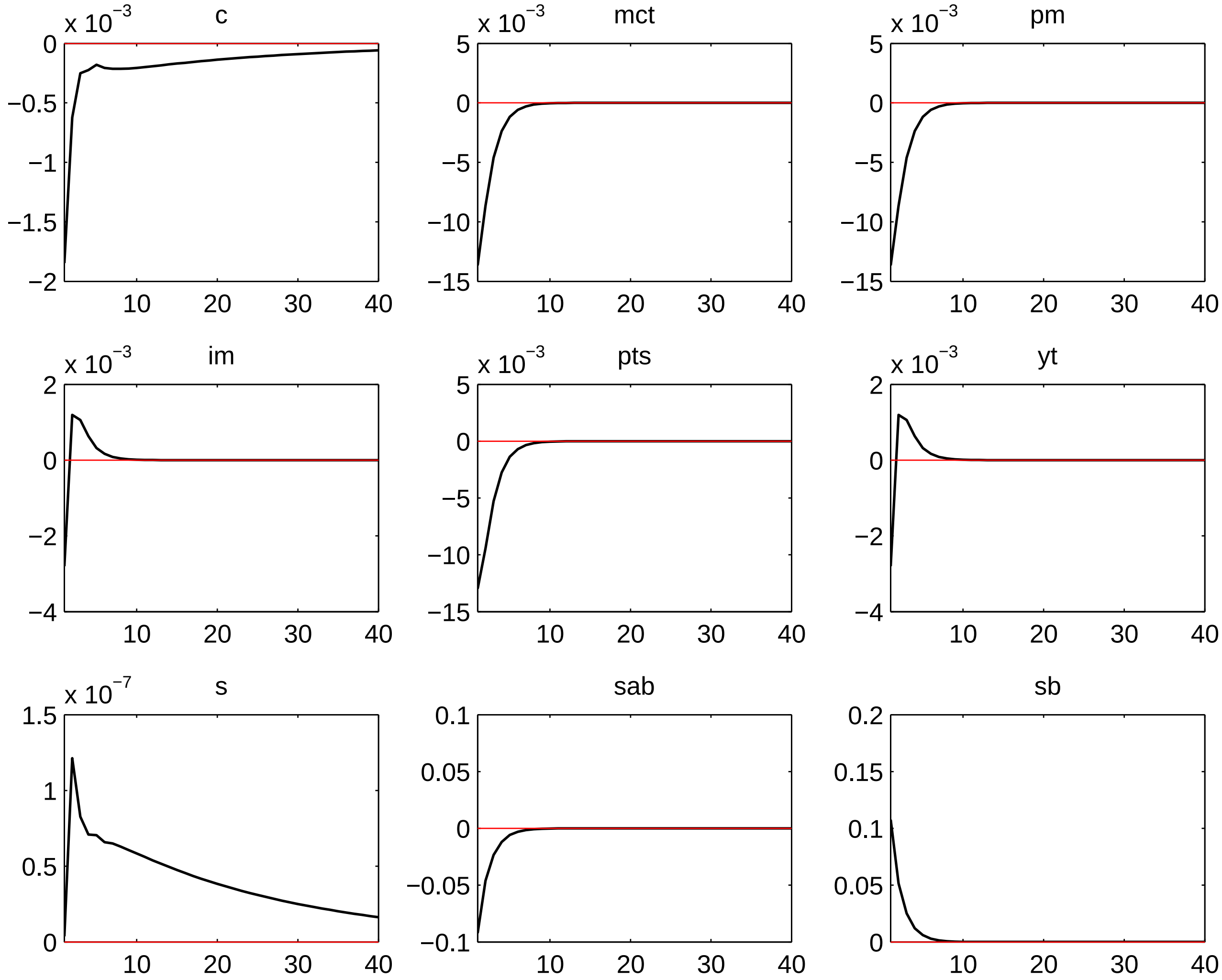


Figure 12: **The IRF with low intermediate goods share under flexible ex and RMB pricing**

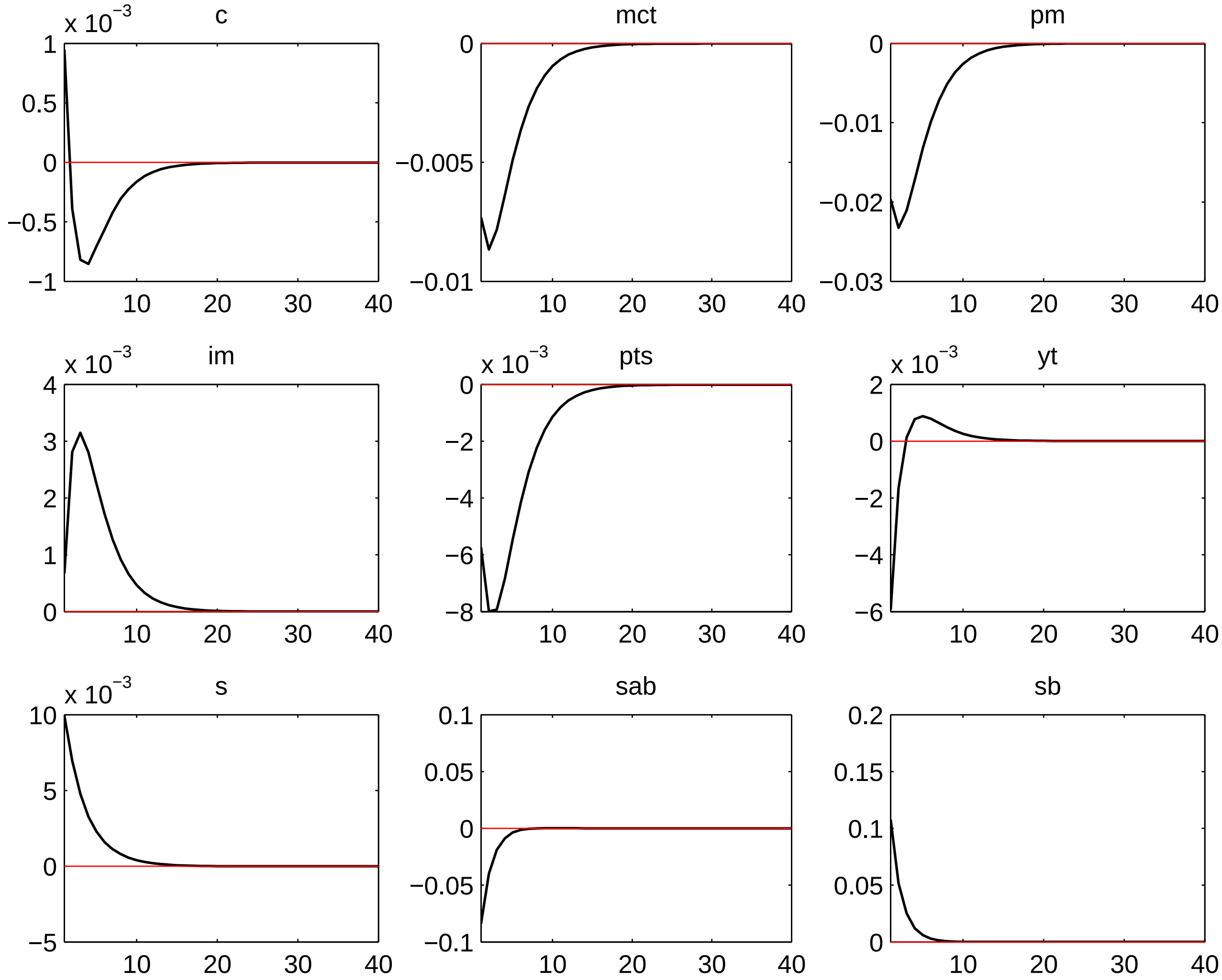


Figure 13: **The IRF with middle intermediate goods share under flexible ex and RMB pricing**

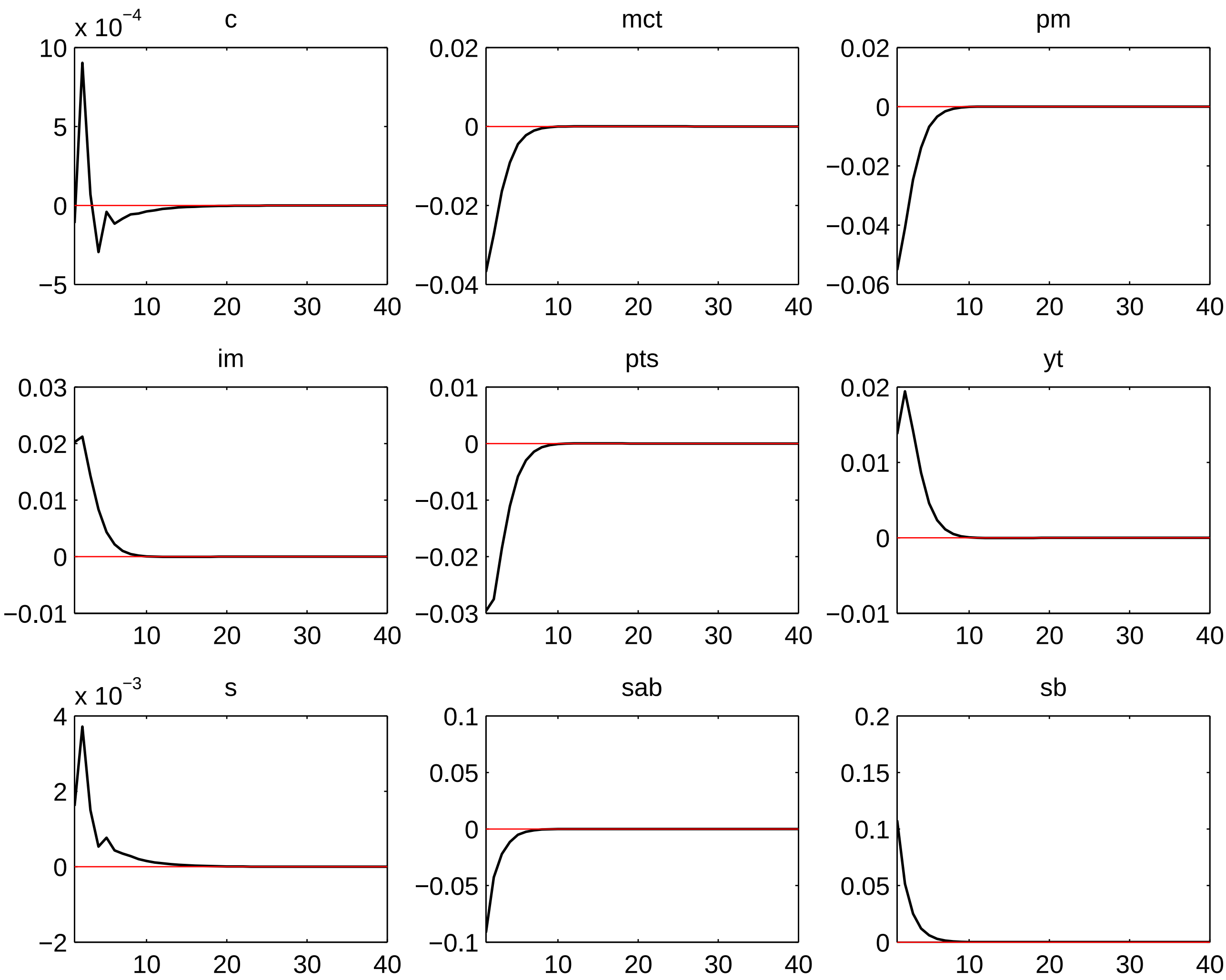


Figure 14: **The IRF with high intermediate goods share under flexible ex and RMB pricing**