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Emerging Economies' Supply Shocks and Japan's Price Deflation: International Transmissions in a Three-Country DSGE Model

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Abstract

This paper examines the international transmission effects that a positive supply shock in emerging economies may have on inflation in developed economies. We construct a dynamic stochastic general equilibrium (DSGE) model for three countries and analyze the impact of a supply shock in an emerging economy, the People's Republic of China (PRC), on inflation rates in two developed economies, the United States (US) and Japan. We demonstrate that the assumed asymmetric trade structures among the three countries and the PRC's choice of exchange rate regime influence the international transmission of a supply shock in the PRC. Specifically, Japan is under a greater deflationary pressure than the US because of its vertical trade specialization vis-à-vis the PRC and the PRC's US-dollar-pegged regime. This outcome suggests that, even though Japan and the US may face common positive supply shocks from emerging economies, the deflationary impact of the shock is greater for Japan.

JEL Classification: F32, F41, F44, F47

Contents

1. INTRODUCTION

Over the past 20 years, the People's Republic of China (PRC) and other emerging economies have strengthened their supply capacities, leading to an expansion in their share of global production and exports. Developed economies' imports from emerging economies have sharply increased in recent years. Rapid productivity increases in emerging economies have led them to experience high inflation, while causing low inflation in developed economies such as the United States (US), European countries, and Japan. Among the developed economies, Japan has faced lowest inflation and even deflation. Imports of cheap goods from emerging economies whose wages are lower than those in developed economies may have partially contributed to low inflation in developed economies, particularly Japan.

Recent empirical analyses by Auer and Fischer (2010) and Auer, Degen, and Fischer (2011) reported that rising imports from emerging to developed economies—due to the former's positive supply shocks—as a share of the latter's total imports had reduced the inflation rates in the US and European countries. Extending these empirical studies to Japan, we investigate whether positive supply shocks in emerging economies have also significantly reduced the inflation rate in Japan, as in the US and Europe. Further, we examine whether the downward impact of these emerging economy supply shocks on the inflation rate in Japan has been greater than those in the US and Europe.

Then, we attempt to analyze the international transmission mechanisms through which emerging economies' positive supply shocks may affect inflation rates in both emerging and developed economies. Our goal is to explain why different developed economies—such as the US and Europe on the one hand and Japan on the other—may respond differently to emerging economy supply shocks, even though these shocks are common to the global economy.

This paper is organized as follows. In Section 2, we summarize the specific features of the model used in the paper and argue that the model is new in the literature. In Section 3, we perform an empirical analysis of the impact of emerging economy supply shocks on Japan's inflation rate, using the methodology developed by Auer and Fischer (2010). In Section 4, we explain the details of the three-country dynamic stochastic general equilibrium (DSGE) model that incorporates short-term price rigidity, vertical specialization of trade, and exchange rate regimes to analyze the international transmission effects of an emerging economy supply shock. In Section 5, we calibrate model parameters and present results of impulse responses of macroeconomic variables in the three countries, particularly Japan's inflation rate, to a positive supply shock in an emerging economy. In Section 6, we conclude the paper.

2. FEATURES OF THE MODEL AND THE LITERATURE

2.1 Features of the Three-Country DSGE Model

We construct a DSGE model for three countries—two developed (Japan and the US) and an emerging economy (the PRC)—and simulate the international transmission effects of a positive supply shock in the emerging economy (the PRC) on macroeconomic variables, especially inflation rates, in both the developed and emerging economies. The three-country DSGE model used for our analysis includes three main features: (i) the presence of tradable and nontradable goods industries; (ii) international vertical specialization of trade (supply chains) where one sector in the tradable goods industry produces parts and components and the other sector uses these parts and components to assemble final products; and (iii) the emerging economy's adoption of a US-dollar-pegged exchange rate regime.

The first feature of the model—the presence of tradable and nontradable goods—suggests the possible Balassa–Samuelson mechanism that produces inflation differences between emerging and developed economies. In the emerging economy, the inflation rate of general prices rises because of higher productivity in the tradable goods industry, which leads to an increase in nominal wages and then nontradable goods prices. In developed economies, the decline in the price of tradable goods imported from emerging economies reduces the inflation rate of general prices. These issues have been discussed in Rabanal (2009) and Berka and Devereux (2010), for example, who used general equilibrium models with tradable and nontradable goods to analyze the differences in inflation rates and real exchange rate movements among European countries.

The second feature of the model—international vertical specialization of trade—is incorporated in the analysis for two reasons. First, vertical specialization in global and regional supply chains has contributed greatly to the recent expansion of international trade.[1] Second, the trade structure, especially vertical specialization, is an important element in determining the extent of international business cycles.[2] For example, using a model of international business cycles for two countries with vertical specialization, Burstein, Kurz, and Tesar (2008) demonstrated that the stronger the degree of vertical specialization, the stronger the correlation between the business cycles of the two countries. Such studies suggest that both vertical specialization and trade in intermediate goods are crucial factors when considering the international transmission of shocks. In analyzing the impact of emerging economy productivity shocks on inflation rates in emerging and other economies, it is important to distinguish between vertical specialization involving trade in parts and components and horizontal specialization involving reciprocal trade in final products. Under horizontal specialization, supply shocks in an emerging economy stimulate its production and exports and reduce production in other competing countries, while under vertical specialization they can stimulate the production of intermediate goods in both the emerging economy and its trading partners. We will show that this difference has significant implications for exchange rates and inflation in different developed countries.

We introduce two assumptions about the trade structures of the three countries. First, trade between Japan and the PRC can be characterized as vertical specialization, where Japan exports parts and components to the PRC and imports final products

[1] Hummels, Ishii, and Yi (2001) calculated the impact of the trade volume derived from vertical specialization on overall trade at the industry level for Organisation for Economic Co-operation and Development (OECD) countries and emerging economies. They reported that about 40% of total global exports result from vertical specialization. Koopman, Wang, and Wei (2008) further improved on the vertical specialization computation methodology and reported that the average proportion of PRC export goods made up of foreign parts and components was 50%, and in the case of electronic equipment this exceeded 80%. Yi (2003) also highlighted the importance of vertical specialization in describing the dramatic expansion of trade volumes that occurred following World War II. Tariff reductions expanded the volume of trade, involving vertical specialization in a nonlinear manner. Thus, about 50% of the increase in trade volume in the post-World War II period can be explained by these tariff reductions.

[2] Empirical studies such as those conducted by Clark and van Wincoop (2001) and Baxter and Kouparitsas (2003, 2005) have reported a positive relationship between trade volumes and business cycle synchronization for two countries. However, in the standard international business cycle model where countries trade final products with each other, the correlation of business cycles between two countries does not rise even with increases in the trade volumes.

assembled in the PRC. However, trade between the US and the PRC or between the US and Japan does not involve significant vertical specialization. Second, the parts and components produced by Japan are not highly substitutable with those from other countries, while final products are highly substitutable regardless of where they are produced. We demonstrate that these asymmetric trade structures among the three countries create a larger trade deficit in the US than in Japan when there is a positive supply shock in the PRC, causing the yen to appreciate against the US dollar, thus aggravating the deflationary impact on Japan.

The third feature of the model—the PRC's US-dollar-pegged exchange rate regime and Japan's freely floating exchange rate regime—approximates the reality and may play a key role under the assumption of short-term price rigidity. With this feature, a positive supply shock to the PRC's final product assembly sector allows the country to run a sizable trade surplus without nominal currency appreciation against the dollar. In contrast, the Japanese yen is affected during the adjustment period. If the PRC currency, the renminbi (RMB), were free-floating, the PRC's positive supply shock would likely lead to a nominal appreciation of the RMB against the dollar to restore a steady state trade balance. However, with the RMB pegged to the dollar, the restoration of the steady state trade balance would require the yen to appreciate against the US dollar because of a smaller trade deficit in Japan than in the US. These results, therefore, suggest that although Japan and the US may face common supply shocks originating in the PRC, the asymmetric trade structures among the three countries and the PRC's dollar-peg policy can create greater deflationary pressures for Japan.

2.2 Existing Literature

The three-country DSGE model with price rigidity, vertical specialization, and exchange rate regimes is new in the literature. Corsetti et al. (2000) used a three-country model of the US (central country) and two emerging economies (neighboring countries) to examine the international spillover effects of monetary easing (currency devaluation) by one of the emerging economies. Their analysis assumed that the goods produced by the two neighboring countries (textiles such as sweaters and shirts) had a high degree of substitutability with each other while goods produced by the central country (machinery products such as computers) had a low degree of substitutability.[3] Markovic and Povoledo (2007) used a three-country model of the US, Europe, and Asian emerging economies and analyzed the issues of the PRC exchange rate regime. These analyses, however, assumed horizontal specialization where only final goods were exchanged between countries and did not include vertical specialization of trade in final products that require intermediate goods from other countries.

Huang and Liu (2006) developed a multistage production model for vertical specialization to examine the international transmission effects of monetary policy shocks. However, their model was limited to two countries. Yi (2003) noted the importance of trade in intermediate goods and showed that vertical specialization and trade in intermediate goods played a significant role in the expansion of global trade. But he did not focus on nominal variables such as price inflation. Ambler, Cardia, and Zimmermann (2002) and Burstein, Kurz, and Tesar (2008) used a multisector model including vertical specialization and international business cycles and demonstrated

[3] In their analysis, the elasticity of substitution was important in determining the impact of one country's currency devaluation on the other neighboring country in terms of welfare.

that vertical specialization was able to explain cross-country correlations of business cycles. However, they did not develop a three-country model. Zimmermann (1997) and Kose and Yi (2006) explained the extent of international business cycles in a three-country business cycle model, but did not consider vertical specialization.

We extend and integrate these various models, by incorporating short-term price rigidity, vertical specialization, and a mix of pegged and floating exchange rate regimes for three countries. Such a model allows us to examine the international transmission mechanisms of an emerging economy supply shock on macroeconomic variables of developed economies—particularly the inflation rate in Japan—in a way that has not been analyzed in previous studies.

3. EMPIRICAL TESTS: SUPPLY SHOCKS IN EMERGING ECONOMIES AND INFLATION IN JAPAN

Before analyzing the three-country DSGE model, we carry out an empirical analysis of the impact of supply shocks in emerging economies on Japan's inflation rate. We follow the methodology adopted by Auer and Fisher (2010) who analyzed such an impact on inflation rates in the US and Europe. We apply their methodology to Japanese data and compare our empirical results with those of the US and Europe. We can then examine whether or not emerging economy supply shocks have affected inflation rates in Japan as they did in the US and Europe.

3.1 Previous Studies on the United States and Europe

The empirical study by Auer and Fischer (2010), from which we borrow the methodology, is typical of recent studies on the relationship between emerging economies' growth and developed countries' inflation rates. The authors introduced a new methodology for identifying emerging economies' supply shocks that stimulate their exports to, and affect inflation rates in, developed economies such as the US and Europe.

In previous studies, developed economies' imports from emerging economies as a share of the former's total imports were used as a proxy variable for emerging economies' supply shocks from the perspective of developed economies. However, regressing inflation rates on the share of imports from emerging economies can create an endogeneity bias, making it difficult to obtain consistent estimates. The endogeneity bias arises because a domestic demand shock in a developed economy, which affects its inflation rate, will also likely affect its share of imports from emerging economies. This suggests that the import share—i.e., the share of imports from emerging economies in total imports of developed economies—cannot be considered as exogenous in the equation to estimate the rate of inflation in developed economies. In fact, in studies by Kamin, Marazzi, and Schindler (2006) and Auer and Fischer (2010), the results of ordinary least squares (OLS) estimation using the import share on the right-hand side of the equation showed neither significant coefficients nor the correct signs for the import share. The novelty of the work by Auer and Fischer (2010) was that they developed an instrumental variable method that used US industry data and adopted the following identification strategy. Assuming that emerging economies with low wages have a comparative advantage in labor-intensive industries, their positive supply shocks can squeeze the profitability of labor-intensive industries in developed economies. So, by using the US cross-industry data of labor intensities and emerging economy growth rates as instrumental variables for the import share at the industry level, it was expected that the endogeneity bias of the import share would be minimized.

Auer and Fischer's estimation results based on US data showed that emerging economies' positive supply shocks that would increase US imports from these economies indeed significantly reduced the inflation rate of producer prices in the US. Specifically, an increase in the US import share by 1 percentage point was reported to reduce the inflation rate, measured by the producer price index (PPI), by 2.3%. According to Auer, Degen, and Fischer (2011), who used European industry data to estimate the impact of emerging economy supply shocks on European inflation rates, an increase in the European import share (from emerging economies) by 1 percentage point reduced the European PPI inflation rate by 3.5%.

3.2 Extension of the Estimation Model to Japan

We apply the same methodology to Japanese industry data to estimate the impact of emerging economy supply shocks on Japan's inflation rate.[4] Although the number of industry groups is smaller in Japan than in the US or Europe, we have been able to obtain meaningful results. As summarized in Table 1, the estimation results for Japan demonstrate that both the instrumental variable—the product of labor intensities and emerging economy growth rates—in the first stage of estimation and the import share in the second stage of estimation have correct signs of the coefficients and are also statistically significant. The size of the estimated coefficient in the second-stage estimation shows that an increase in Japan's import share (from emerging economies) by 1 percentage point reduces Japan's PPI inflation rate by 4%–5%. Comparing the size of this estimate value for the import share in the inflation rate equation with those of the estimates for the US and Europe, we find that Japan's estimate of −4.9 was larger in absolute value than those for the US (−2.3) and Europe (−3.5). The issue remains as to whether these differences between Japan and the US/Europe are statistically significant, but they do suggest that positive supply shocks in emerging economies have had a more deflationary impact on Japan.

Figure 1 depicts the estimated impact of emerging economies' supply shocks on the Japanese and US PPIs based on the above results. According to these estimates, positive supply shocks in emerging economies likely reduced the Japanese PPI inflation rate by an average of 2.3% per year between 1989 and 2007. However, they reduced the average US PPI inflation rate by slightly less than 1% per year between 1998 and 2006.[5] Without emerging economies' supply shocks, Japanese PPI inflation rates would have recorded positive numbers throughout the sample period except for a few years (1997–1998 and 2000).

These results suggest that the negative impact of positive supply shocks in emerging economies on price inflation in the developed world was likely greater for Japan than for the US and Europe.

[4] Most of the data are from the Japan Industrial Productivity (JIP) database 2010 compiled by the Research Institute of Economy, Trade and Industry.

[5] Performing the same estimations to European inflation rates was difficult because of data limitations.

Table 1: Instrumental Variable Estimation Results for Producer Price Inflation

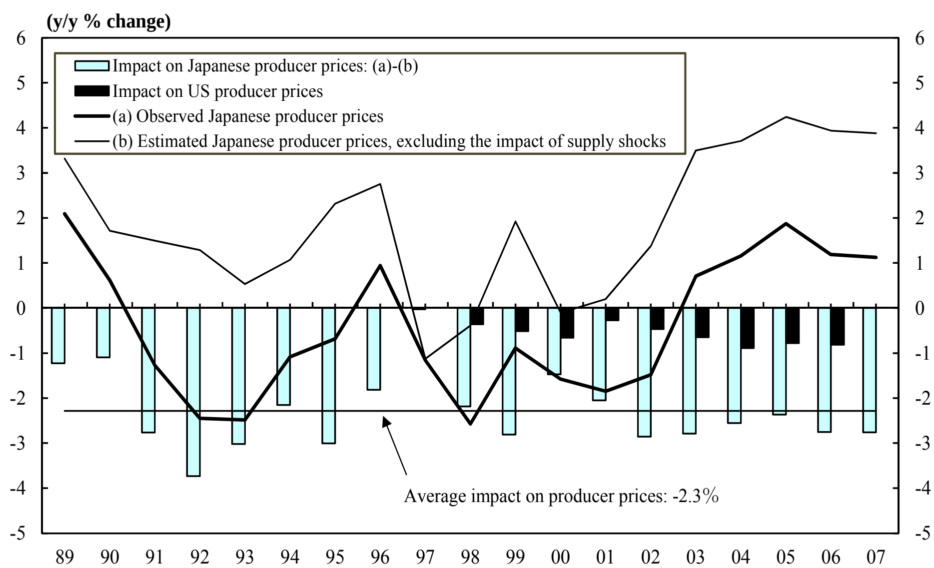
	Japan		United States		Europe	
Sample period	1989–2007		1997–2006		1995–2008	
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	No	Yes	No	Yes	No
IV First stage estimation: dependent variable is year-on-year change in the import share (value of imports from emerging economies / industry size)						
Manufacturing output	--	-0.025 [0.0232]*	--	0.0707 [0.0276]*	--	0.002 [0.012]
Labor intensity * output	0.0694 [0.0395]*	0.0694 [0.0391]*	0.0300 [0.0038]**	0.0300 [0.0039]**	0.01 [0.002]**	0.009 [0.002]**
R-squared (within)	0.024	0.024	0.14	0.11	0.02	0.05
IV Second stage estimation: dependent variable is year-on-year rate of change in producer prices						
Manufacturing output	--	0.0206 [0.0645]	--	1.225 [0.144]**	--	0.342 [0.069]***
Import share	-4.869 [2.524]*	-4.869 [2.502]*	-2.352 [0.515]**	-2.356 [0.526]**	-3.531 [0.964]***	-3.575 [0.805]***
Number of observations	988	988	2702	2702	7010	7010
Number of groups	52	52	325	325	618	618

IV = instrumental variable.

Notes: (1) Industry size in Japan is defined as domestic production plus imports. Data from Japan are from the Japan Industrial Productivity (JIP) database 2010 compiled by the Research Institute of Economy, Trade, and Industry.
(2) Standard errors reported in brackets; * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: Authors' compilation (from Auer and Fischer [2010] on the US and from Auer, Degen, and Fischer [2011] on Europe) and estimation (on Japan).

Figure 1: Impact of Emerging Economies' Supply Shocks on Japan's Inflation



Source: Authors' compilation (from Auer and Fischer [2011]) on United States data and estimation on Japan's data (estimation for Japan are based on data from the Japan Industrial Productivity (JIP) database 2010 compiled by the Research Institute of Economy, Trade and Industry).

4. THE THREE-COUNTRY DSGE MODEL

The empirical results in the previous section have suggested that emerging economies' supply shocks reduced inflation rates in Japan, the US, and Europe in a significant manner. The deflationary impact was likely greater for Japan than for the US and European countries. On the basis of this empirical evidence, we now construct an open-economy DSGE model consisting of three countries to examine international transmission mechanisms of emerging economies' supply shocks.

4.1 Overall Structure of the Three-Country World Economy

The world economy in the model consists of three countries, called Japan, the US, and the PRC, designated by *J, U,* and *C,* respectively. The sizes of these countries are given by s^J, s^U, and s^C, respectively. Each country has both tradable and nontradable goods industries, and the tradable goods industry in each country comprises a parts and components production sector and a final goods production (or product assembly) sector that uses parts and components to manufacture tradable final goods.

Each of the nontradable goods industry, the parts and components production sector, and the final goods production (or product assembly) sector contains an infinite number of firms. Each firm operates under monopolistic competition; that is, the goods produced by individual firms have brand power and are differentiated from each other. The index for firms in the nontradable goods industry is given by $n^k \in [0, s^k], k = J, U, C$, that for firms in the parts and components production sector is given by $h_1^k \in [0, s^k], k = J, U, C$, and that for firms in the product assembly sector is given by $h_2^k \in [0, s^k], k = J, U, C$.

Nominal prices are rigid in the short run as a firm incurs adjustment costs to alter its price, while they are fully flexible in the long run. For simplicity, labor is the only fundamental factor of production, and capital accumulation is not considered.[6] Firms in the nontradable goods industry and those in the parts and components production sector use only labor for production. However, the production of tradable final goods requires parts and components in addition to labor; the produced parts and components are first shipped to domestic and foreign aggregators, who aggregate the domestic and imported parts and components into aggregate parts and components, T_1, in each country; and then these aggregate parts and components, T_1, are shipped to firms in the product assembly sector.[7] Firms in the product assembly sector thus use labor and T_1 to produce tradable final goods. In this sense, there is vertical specialization between the two sectors in the tradable goods industry. The tradable final goods are shipped to domestic and foreign aggregators who aggregate them into a bundle of tradable final goods, T_2. The aggregate of nontradable goods manufactured by all firms is a bundle of nontradable goods, *N,* which are all consumed in their country of production. The aggregate of nontradable goods *N* and tradable final goods T_2 is a bundle of final consumer goods, *C,* to be consumed by households.

[6] For simplicity, capital stock and capital investment are omitted in the model. Considering international business cycles, however, the international spillover of shocks due to trade in capital goods could in reality be significant. In fact, as Figure 2 illustrates, capital goods exports from the PRC to the United States have been rising in recent years. This suggests that for future analysis, it may be necessary to formulate capital accumulation and investment. Nevertheless, our simple model can still deliver many rich results that are largely consistent with the observed data.

[7] The costs of aggregation and shipment are assumed to be zero in the model.

In the financial market, there are internationally tradable bonds. As international lending and borrowing are allowed between countries, there is no need for each country to achieve a balanced current account (which is the same as a balanced trade account in the absence of net external assets or liabilities) in each period, but it must achieve a balance in the long term.

In the next section, we describe the model in greater detail. It assumes the three countries of Japan, the US, and the PRC, but for simplicity, equations will all be described using Japan (*J*).

4.2 Final Goods Consumption

The function $C_t(j^J)$ denotes the level of consumption of final goods in Japan, and η^J is a constant elasticity of substitution between aggregate tradable final goods ($T_{2,t}(j^J)$) and aggregate nontradable goods ($N_t(j^J)$). The term j^J is the index for a household in Japan, and the subscript 2 indicates that firms are in the second production stage, i.e., product assembly. The aggregation function $C_t(j^J)$ is defined by

$$C_{\mathrm{t}}(j^J) = \left[(\nu^J)^{\frac{1}{\eta^J}} T_{2,t}(j^J)^{1-\frac{1}{\eta^J}} + (1-\nu^J)^{\frac{1}{\eta^J}} N_t(j^J)^{1-\frac{1}{\eta^J}}\right]^{\frac{\eta^J}{\eta^J-1}}, \quad (1)$$

where ν^J is the share of tradable final goods in the consumption basket in Japan.

4.2.1 Tradable Final Goods

The aggregate of tradable final goods $T_{2,t}(j^J)$ is defined by the following aggregate function of domestically produced tradable final goods, $Q_{2,t}^J(j^J)$, and imported final goods from the US, $M_{2,t}^U(j^J)$, and from the PRC, $M_{2,t}^C(j^J)$:

$$T_{2,t}(j^J) = \left[\left(\nu_J^J\right)^{\frac{1}{\varphi_2^J}} Q_{2,t}^J(j^J)^{1-\frac{1}{\varphi_2^J}} + \left(\nu_U^J\right)^{\frac{1}{\varphi_2^J}} M_{2,t}^U(j^J)^{1-\frac{1}{\varphi_2^J}} + \left(\nu_C^J\right)^{\frac{1}{\varphi_2^J}} M_{2,t}^C(j^J)^{1-\frac{1}{\varphi_2^J}}\right]^{\frac{\varphi_2^J}{\varphi_2^J-1}}, \quad (2)$$

where $\nu_J^J, \nu_U^J, \text{and } \nu_C^J$ are the shares of tradable final goods produced, respectively, by Japanese, US, and PRC firms in Japan's aggregate consumption basket of tradable final goods. The term φ_2^J is the elasticity of substitution between tradable final goods produced in different countries, and $Q_{2,t}^J(j^J), M_{2,t}^U(j^J), \text{and } M_{2,t}^C(j^J)$ are respectively given by

$$Q_{2,t}^J(j^J) \equiv \left[\left(\frac{1}{s^J}\right)^{\frac{1}{\theta}} \int_0^{s^J} Q_{2,t}\left(h_2^J, j^J\right)^{1-\frac{1}{\theta}} dh_2^J\right]^{\frac{\theta}{\theta-1}},$$

$$M_{2,t}^U(j^J) \equiv \left[\left(\frac{1}{s^U}\right)^{\frac{1}{\theta}} \int_0^{s^U} M_{2,t}(h_2^U, j^J)^{1-\frac{1}{\theta}} dh_2^U\right]^{\frac{\theta}{\theta-1}},$$

$$M_{2,t}^C(j^J) \equiv \left[\left(\frac{1}{s^C}\right)^{\frac{1}{\theta}} \int_0^{s^C} M_{2,t}\left(h_2^C, j^J\right)^{1-\frac{1}{\theta}} dh_2^C\right]^{\frac{\theta}{\theta-1}},$$

where $Q_{2,t}\left(h_2^J,\ j^J\right), M_{2,t}(h_2^U,\ j^J), \text{and } M_{2,t}\left(h_2^C,\ j^J\right)$ respectively denote Japanese household demand for tradable final goods produced by Japanese firms (h_2^J), US firms (h_2^U), and PRC firms (h_2^C).

4.2.2 Nontradable Goods

The aggregate of nontradable goods $N_t(j^J)$ is defined by

$$N_t(j^J) \equiv \left[\left(\frac{1}{s^J}\right)^{\frac{1}{\theta}} \int_0^{s^J} N_t(n^J, j^J)^{1-\frac{1}{\theta}} dn^J\right]^{\frac{\theta}{\theta-1}}, \quad (3)$$

where $n^j \in [0, s^J]$ is an index for Japanese firms in the nontradable industry. The term $N_t(n^J, j^J)$ denotes Japanese household demand for nontradable goods produced by Japanese firms (n^j). Note that there are no intermediate goods in the nontradable goods industry.

4.2.3 Price Index

The consumer price index that corresponds to the overall consumption bundle is given by

$$P_t^J = \left[\nu^J \, {P_{2,t}^J}^{1-\eta^J} + (1-\nu^J) {P_{N,t}^J}^{1-\eta^J}\right]^{\frac{1}{1-\eta^J}}.$$

The price of tradable final goods, $P_{2,t}^J$, is given by

$$P_{2,t}^J = \left[\nu_J^J {P_{2,t}^{JJ}}^{1-\varphi_2^J} + \nu_U^J {P_{2,t}^{UJ}}^{1-\varphi_2^J} + \nu_C^J {P_{2,t}^{CJ}}^{1-\varphi_2^J}\right]^{\frac{1}{1-\varphi_2^J}}.$$

The prices of domestically produced tradable final goods and imported final goods from the PRC and from the US are, respectively, given by

$$P_{2,t}^{kJ} \equiv \left[\left(\frac{1}{s^k}\right) \int_0^{s^k} p_{2,t}^J\left(h_2^k\right)^{1-\theta} dh_2^k\right]^{\frac{\theta}{1-\theta}}, k = J, U, C,$$

where $p_{2,t}^J\left(h_2^k\right), k = J, U, C$ respectively, denote the yen-denominated prices which firms in the three countries (Japan, the US, and the PRC) set in the Japanese market.

As for nontradable goods, the aggregate price index is given by

$$P_{N,t}^J \equiv \left[\left(\frac{1}{s^J}\right) \int_0^{s^J} p_{N,t}(n^J)^{1-\theta} dn^J\right]^{\frac{\theta}{1-\theta}},$$

where $p_{N,t}(n^J)$ denotes the price which a firm in the nontradable industry (n^J) sets.

4.3 Nontradable Goods Production

Firms in the nontradable goods industry ($n^J \in [0, s^J]$) use only labor for production:

$$Y_t(n^J) = Z_{N,t}^J l_t(n^J), \quad (4)$$

where $Z_{N,t}^J$ denotes productivity, which is assumed to follow a first order autoregressive process, AR(1).

Each firm in the nontradable goods industry maximizes the discounted sum of profits under monopolistic competition and the price setting behavior of a Rotemberg-type price restriction:

$$\max_{p_{N,\tau}(n^J)} E_t \sum_{\tau=t}^{\infty} D_{t,\tau}(j) \, \Pi_\tau(n^J), \quad (5)$$

where $D_{t,\tau}(j)$ is a stochastic discount factor. The profit function ($\Pi_t(n^J)$) is given by

$$\Pi_t(n^J) \equiv \left[p_{N,t}(n^J) - MC_t(n^J)\right] \int_0^{s^J} N_t(n^J, j^J) dj^J \left[1 - \Gamma^J_{N,t}(n^J)\right].$$

Here, $MC_t(n^J)$ is the marginal cost, which can be written as

$$MC_t(n^J) = \frac{W_t^J}{Z_{N,t}^J},$$

where W_t^J denotes the nominal wage which is identical across industries and sectors, and $\Gamma^J_{N,t}(n^J)$ is Rotemberg's (1982) price adjustment cost, which is defined by

$$\Gamma^J_{N,t}(n^J) \equiv \frac{\phi_N^J}{2}\left[\pi_t \frac{p_{N,t}(n^J)/p_{N,t-1}(n^J)}{\pi_t^{\alpha}\left(P_{N,t-1}/P_{N,t-2}\right)^{1-\alpha}} - 1\right]^2,$$

where ϕ_N^J is the price adjustment cost coefficient and α indicates the degree of price indexation.

The first order condition for (5) can be written as:

$$0 = \left[1 - \Gamma^J_{N,t}(n^J)\right]\left[p_{N,t}(n^J)(1-\theta) + \theta MC_t(n^J)\right] - \left[p_{N,t}(n^J) - MC_t(n^J)\right]\frac{\partial \Gamma^J_{N,t}(n^J)}{\partial p_{N,t}(n^J)}$$
$$+ E_t D_{t,t+1}\left[p_{N,t+1}(n^J) - MC_{t+1}(n^J)\right]\frac{\int_0^{s^J} N_{t+1}(n^J, j^J) dj^J}{\int_0^{s^J} N_t(n^J, j^J) dj^J}\frac{\partial \Gamma^J_{N,t+1}(n^J)}{\partial p_t(n^J)}.$$

In steady state, $p_{N,t}(n^J)$ is set by mark-up pricing:

$$p_{N,t}(n^J) = \frac{\theta}{1-\theta} MC_t(n^J).$$

4.4 Tradable Goods Production

There are two types of firms in the tradable goods industry. One type produces parts and components, and the other assembles them to manufacture final products.

4.4.1 Parts and Components Production Sector

Firms in the parts and components production sector h_1^J use only labor ($l_t(h_1^J)$) for production:

$$Y_{1,t}(h_1^J) = Z_{1,t}^J l_t(h_1^J), \tag{6}$$

where $Z_{1,t}^J$ denotes productivity, which follows an AR(1) process.

We assume that each firm sets its price under the producer currency pricing (PCP) scheme. In this case, the profit maximization problem for the representative Japanese firm in the parts and components production sector is as follows:

$$\max_{p_{1,\tau}^J(h_1^J)} E_t \sum_{\tau=t}^{\infty} D_{t,\tau}(j)\, \Pi_\tau(h_1^J), \tag{7}$$

where $D_{t,\tau}(j)$ is a stochastic discount factor. The profit function ($\Pi_t(h_1^J)$) is given by

$$\Pi_t(h_1^J) \equiv \left[p_{1,t}^J(h_1^J) - MC_t(h_1^J)\right] \times \left[\int_0^{s^J} Q_{1,t}^J(h_1^J,h_2^J)dh_2^J + \int_0^{s^U} M_{1,t}^U(h_1^J,h_2^U)dh_2^U + \int_0^{s^C} M_{1,t}^C(h_1^J,h_2^C)dh_2^C\right] \times \left[1-\Gamma_{1,t}^J(h_1^J)\right],$$

where $MC_t(h_1^J)$ is the marginal cost given by

$$MC_t(h_1^J) = \frac{W_t^J}{Z_{1,t}^J}.$$

The price adjustment cost $\Gamma_{1,t}^J(h_1^J)$ is given by

$$\Gamma_{1,t}^J(h_1^J) \equiv \frac{\phi_1^J}{2}\left[\pi_t \frac{p_{1,t}^J(h_1^J)/p_{1,t-1}^J(h_1^J)}{\pi_t^{\alpha}\left(P_{1,t-1}^J/P_{1,t-2}^J\right)^{1-\alpha}} - 1\right]^2,$$

where ϕ_1^J is the price adjustment cost coefficient; and $Q_{1,t}^J(h_1^J,h_2^J), M_{1,t}^U(h_1^J,h_2^U)$, and $M_{1,t}^C(h_1^J,h_2^C)$ denote the respective countries' household demand for tradable final goods produced by Japanese firms (h_2^J).

Letting $p_{1,t}^U(h_1^J)$ and $p_{1,t}^C(h_1^J)$ denote, respectively, the export price of Japanese parts and components to the US and the PRC in the importer's local currency, the law of one price holds:

$$p_{1,t}^J(h_1^J) = \varepsilon_t^{JU} p_{1,t}^U(h_1^J) = \varepsilon_t^{JC} p_{1,t}^C(h_1^J),$$

where ε_t^{JU} and ε_t^{JC} respectively denote the nominal yen–US dollar exchange rate and the yen–RMB exchange rate.

The first order condition for (7) can be written as

$$0 = \left[1-\Gamma_{1,t}^J(h_1^J)\right]\left[p_{1,t}^J(h_1^J)(1-\theta) + \theta MC_t(h_1^J)\right] - \left[p_{1,t}^J(h_1^J) - MC_t(h_1^J)\right]\frac{\partial \Gamma_{1,t}^J(h_1^J)}{\partial p_{1,t}^J(h_1^J)} + E_t D_{t,t+1}\left[p_{1,t+1}^J(h_1^J) - MC_{t+1}(h_1^J)\right] \times \left[\frac{\int_0^{s^J} Q_{1,t+1}(h_1^J,h_2^J)dh_2^J}{\int_0^{s^J} Q_{1,t}(h_1^J,h_2^J)dh_2^J} + \frac{\int_0^{s^U} M_{1,t+1}^U(h_1^J,h_2^U)dh_2^U}{\int_0^{s^U} M_{1,t}^U(h_1^J,h_2^U)dh_2^U} + \frac{\int_0^{s^U} M_{1,t+1}^C(h_1^J,h_2^U)dh_2^C}{\int_0^{s^U} M_{1,t}^C(h_1^J,h_2^C)dh_2^C}\right] \times \frac{\partial \Gamma_{1,t+1}^J(h_1^J)}{\partial p_{1,t}^J(h_1^J)}.$$

Then, as in the case of the nontradable goods industry, the Phillips curve for the tradable goods industry can be obtained by log-linearizing this equation.

4.4.2 Aggregator of Parts and Components

The produced parts and components are shipped to domestic and foreign aggregators, who aggregate them into parts and components T_1 in each country:

$$T_{1,t}(h_2^J) = \left[(\mu_J^J)^{\frac{1}{\varphi_1^J}} Q_{1,t}^J(h_2^J)^{1-\frac{1}{\varphi_1^J}} + (\mu_U^J)^{\frac{1}{\varphi_1^J}} M_{1,t}^U(h_2^J)^{1-\frac{1}{\varphi_1^J}} + (\mu_C^J)^{\frac{1}{\varphi_1^J}} M_{1,t}^C(h_2^J)^{1-\frac{1}{\varphi_1^J}}\right]^{\frac{\varphi_1^J}{\varphi_1^J-1}}, \quad (8)$$

where $\mu_J^J, \mu_U^J,$ and μ_C^J are the shares of parts and components produced, respectively, by Japanese, US, and PRC firms in Japan's aggregate bundle of parts and components that are needed for the production of tradable final goods in Japan. The term φ_1^J is the elasticity of substitution between parts and components produced in different countries. Additionally,

$$Q_{1,t}^J(h_2^J) \equiv \left[\left(\frac{1}{s^J}\right)^{\frac{1}{\theta}} \int_0^{s^J} Q_{1,t}^J(h_1^J, h_2^J)^{1-\frac{1}{\theta}} dh_1^J\right]^{\frac{\theta}{\theta-1}},$$

$$M_{1,t}^U(h_2^J) \equiv \left[\left(\frac{1}{s^U}\right)^{\frac{1}{\theta}} \int_0^{s^U} M_{1,t}^U(h_1^U, h_2^J)^{1-\frac{1}{\theta}} dh_1^U\right]^{\frac{\theta}{\theta-1}},$$

$$M_{1,t}^C(h_2^J) \equiv \left[\left(\frac{1}{s^C}\right)^{\frac{1}{\theta}} \int_0^{s^C} M_{1,t}^C(h_1^C, h_2^J)^{1-\frac{1}{\theta}} dh_1^C\right]^{\frac{\theta}{\theta-1}}.$$

The price index for aggregated parts and components, $P_{1,t}^J$, is defined by

$$P_{1,t}^J = \left[\mu_J^J P_{1,t}^{JJ\,1-\varphi_2^J} + \mu_U^J P_{1,t}^{UJ\,1-\varphi_2^J} + \mu_C^J P_{1,t}^{CJ\,1-\varphi_2^J}\right]^{\frac{1}{1-\varphi^J}},$$

where $P_{1,t}^{kJ}$ denotes the yen-denominated price of parts and components produced in country *k* (= *J, U, C*):

$$P_{1,t}^{kJ} \equiv \left[\left(\frac{1}{s^k}\right)\int_0^{s^k} p_{1,t}^J(h_1^k)^{1-\theta} dh_1^k\right]^{\frac{\theta}{1-\theta}}, k = J, U, C.$$

4.4.3 Tradable Final Goods (or Product Assembly) Sector

Product assembly firms use both labor and aggregated parts and components, $T_{1,t}(h_2^J)$, to manufacture tradable final goods. The production function is given by

$$Y_{2,t}(h_2^J) = Z_{2,t}^J \left\{\alpha^{\frac{1}{\eta_2}} l_{2,t}(h_2^J)^{\frac{\eta_2-1}{\eta_2}} + (1-\alpha)^{\frac{1}{\eta_2}} T_{1,t}(h_2^J)^{\frac{\eta_2-1}{\eta_2}}\right\}^{\frac{\eta_2-1}{\eta_2}}, \quad (9)$$

where $Z_{2,t}^J$ denotes productivity, which follows an AR(1) process.

A firm is assumed to set its price under the PCP scheme as did firms in the parts and components production sector. The profit maximization problem can be formulated as follows:

$$\max_{p_{2,\tau}^J(h_2^J)} E_t \sum_{\tau=t}^{\infty} D_{t,\tau}(j)\,\Pi_\tau(h_2^J), \quad (10)$$

where $D_{t,\tau}(j)$ is a stochastic discount factor.The profit function $\Pi_t(h_2^J)$ is given by

$$\Pi_t(h_2^J) \equiv \left[p_{2,t}^J(h_2^J) - MC_t(h_2^J)\right] \times \left[\int_0^{s^J} Q_{2,t}^J(h_2^J, j^J)dj^J + \int_0^{s^U} M_{2,t}^U(h_2^J, j^U)dj^U + \int_0^{s^C} M_{1,t}^C(h_1^J, j^C)dj^C\right] \times \left[1 - \Gamma_{2,t}^J(h_2^J)\right],$$

where $MC_t(h_2^J)$ is the marginal cost given by

$$MC_t(h_2^J) = \frac{1}{Z_{2,t}^J}\left\{\alpha\left(W_t^J\right)^{1-\eta_2} + (1-\alpha)(P_{1,t}^J)^{1-\eta_2}\right\}^{\frac{1}{1-\eta_2}},$$

and $\Gamma_{2,t}^J(h_2^J)$ denotes the price adjustment cost, defined by

$$\Gamma_{2,t}^J(h_2^J) \equiv \frac{\phi_2^J}{2}\left[\pi_t \frac{p_{2,t}^J(h_2^J)/p_{2,t-1}^J(h_2^J)}{\pi_t^{\alpha}\left(P_{2,t-1}^J/P_{2,t-2}^J\right)^{1-\alpha}} - 1\right]^2,$$

where ϕ_2^J is the price adjustment cost coefficient.

Letting $p_{2,t}^U(h_2^J)$ and $p_{2,t}^C(h_2^J)$ denote, respectively, the export price of Japanese tradable final goods to the US and the PRC in the importer's local currency, the law of one price means that

$$p_{2,t}^J(h_2^J) = \varepsilon_t^{JU} p_{2,t}^U(h_2^J) = \varepsilon_t^{JC} p_{2,t}^C(h_2^J).$$

4.5 Household Behavior

The representative household maximizes the following lifetime utility function:

$$E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t}\{U_\tau[C_\tau(j^J)] - V_\tau[l_\tau(j^J)]\}, \qquad (11)$$

where $U_\tau[C_\tau(j^J)]$ denotes utility from aggregate consumption and $V_\tau[l_\tau(j^J)]$ denotes disutility from labor supply; and $U_\tau[C_\tau(j^J)]$ and $V_\tau[l_\tau(j^J)]$ are given by

$$U_\tau[C_\tau(j^J)] = \frac{(1-b_C)^{\sigma}[C_t(j^J) - b_C C_{t-1}(j^J)]^{1-\sigma} - 1}{1-\sigma},$$

$$V_\tau[l_\tau(j^J)] = \frac{l_\tau(j^J)^{1+\zeta}}{1+\zeta},$$

where b_C denotes the importance of habit stock, and σ and ζ respectively are the elasticity of intertemporal substitution in consumption and the Frisch labor supply elasticity.

The budget constraint of the household is given by

$$\begin{aligned}
&\varepsilon_t^{JU} B_{F,t+1}(j^J) + B_{J,t+1}(j^J) \\
&\quad \leq (1+i_t^U)\left[1 - \Gamma_{B,t}(j^J)\right]\varepsilon_t^{JU} B_{F,t}(j^J) + \left(1+i_t^J\right)B_{J,t}(j^J) + W_t^J l_t(j^J) \\
&\quad + \int_0^{s^J} \Pi(n^J)dn^J + \int_0^{s^J} \Pi\left(h_1^J\right)dh_1^J + \int_0^{s^J} \Pi\left(h_2^J\right)dh_2^J - P_t C_t(j^J),
\end{aligned}$$

where

$$\Gamma_{B,t}(j^J) = \phi_{B1} \frac{exp\left[\phi_{B2}\frac{\varepsilon_t^{JU} B_{F,t}(j^J)}{P_t}\right] - 1}{exp\left[\phi_{B2}\frac{\varepsilon_t^{JU} B_{F,t}(j^J)}{P_t}\right] + 1}.$$

4.5.1 Euler Equations and Labor Supply Decisions

The consumption Euler equation and the bond Euler equation are given, respectively, by

$$1 = E_t\left(1 + i_{t+1}^{J}\right)D_{t,t+1}(j^J), \tag{12}$$

$$1 = E_t(1 + i_{t+1}^{U})\left[1 - \Gamma_{B,t+1}(j^J)\right]\left[D_{t,t+1}(j^J)\frac{\varepsilon_{t+1}^{JU}}{\varepsilon_t^{JU}}\right], \tag{13}$$

where $\mathrm{D}_{t,\tau}(j^J)$ is a stochastic discount factor defined by

$$\mathrm{D}_{t,\tau}(j^J) \equiv \beta^{\tau-t}E_t\frac{P_t U'\ [C_\tau(j^J)]}{P_\tau U'\ [C_t(j^J)]}.$$

Equations (12) and (13) demonstrate that risk-adjusted uncovered interest parity holds. In other words, a rise in external debt leads to an increase in financing costs and risk premiums.

The first order condition for labor supply is given by

$$\frac{V_t'\ (j^J)}{U_t'\ (j^J)} = \frac{W_t^J}{P_t}.$$

Additionally,

$$V_t'\ (j^J) = l_t(j^J)^\zeta\ .$$

4.5.2 Foreign Assets

Foreign assets held by Japanese households are given by

$$F_t(j^J) = (1 + i_t^U)\left[1 - \Gamma_{B,t}(j^J)\right]\varepsilon_t^{JU}B_{F,t}(j^J).$$

The foreign assets dynamic equation is dictated by

$$E_t D_{t,t+1}s^J F_{t+1}(j^J) = s^J F_t(j^J) + (1 + i_t^U)\,\Gamma_{B,t}(j)\varepsilon_t^{JU}s^J B_{F,t}(j) + TBAL_t^J\ ,$$

where $TBAL_t^J$ denotes the Japanese trade balance, defined by

$$TBAL_t^J = TBAL_{1,t}^{JU} + TBAL_{1,t}^{JC} + TBAL_{2,t}^{JU} + TBAL_{2,t}^{JC}\ ,$$

where $TBAL_{1,t}^{JU}$ and $TBAL_{1,t}^{JC}$ are respectively Japan's trade balance in parts and components against the US and the PRC, and $TBAL_{2,t}^{JU}$ and $TBAL_{2,t}^{JC}$ are Japan's trade balance in tradable final goods with the US and the PRC. These variables are given by

$$TBAL_{1,t}^{JU} = \varepsilon_t^{JU}P_{1,t}^{JU}s^U M_{1,t}^J(j^U) - P_{1,t}^{UJ}s^J M_{1,t}^U(j^J)\ ,$$

$$TBAL_{1,t}^{JC} = \varepsilon_t^{JC}P_{1,t}^{JC}s^C M_{1,t}^J(j^C) - P_{1,t}^{CJ}s^J M_{1,t}^C(j^J)\ ,$$

$$TBAL_{2,t}^{JU} = \varepsilon_t^{JU}P_{2,t}^{JU}s^U M_{2,t}^J(j^U) - P_{2,t}^{UJ}s^J M_{2,t}^U(j^J)\ ,$$

$$TBAL_{2,t}^{JC} = \varepsilon_t^{JC}P_{2,t}^{JC}s^C M_{2,t}^J(j^C) - P_{2,t}^{CJ}s^J M_{2,t}^C(j^J)\ .$$

In steady state, each country's trade balance is assumed to be zero. That is, the following equation holds in steady state:

$$\overline{\mathrm{TBAL}_1^{JU}} + \overline{\mathrm{TBAL}_1^{JC}} + \overline{\mathrm{TBAL}_2^{JU}} + \overline{\mathrm{TBAL}_2^{JC}} = 0\ .$$

4.6 Monetary Policy and the Exchange Rate

Monetary policy in Japan and the US is pursued with a standard Taylor rule that targets the consumer price index (CPI) inflation and the gross domestic product (GDP) gap:

$$(1+i_t^J)^4 - 1 = \omega_i\left[\left(1+i_{t-1}^J\right)^4 - 1\right] + \omega_\pi\left(\left(\pi_t^J\right)^4 - \overline{\pi^J}\right) + \omega_y\left(\frac{GDP_t^J}{\overline{GDP^J}} - 1\right), \tag{14}$$

where $\overline{\pi^J}$ is a target inflation rate, and $\overline{GDP^J}$ denotes a steady-state value, or the level of potential GDP.

We assume that the PRC adopts a US-dollar-pegged exchange rate regime, so its monetary policy is constrained by the dollar peg. The PRC's nominal interest rate is determined endogenously to keep the RMB–US dollar rate, ε_t^{CU}, fixed. That is, its change is zero:

$$\Delta\ \varepsilon_t^{CU} = 0.$$

4.7 Market Clearing

The market clearing conditions for each market are given in the following way.

In the labor market, labor supply equals labor demand:

$$l_t(j^J) = l_{1,t}\left(h_1^J, j^J\right) + l_{2,t}\left(h_2^J, j^J\right) + l_t(n^J, j^J)\ .$$

In the parts and components market, the production of parts and components equals domestic demand and exports to the US and the PRC:

$$Y_{1,t}\left(h_1^J\right) = s^J Q_{1,t}^J\left(h_1^J, h_2^J\right) + s^U M_{1,t}^U\left(h_1^J, h_2^J\right) + s^C M_{1,t}^C\left(h_1^J, h_2^C\right)\ .$$

In the tradable final goods market, the production of these goods equals domestic demand and exports to the US and the PRC:

$$Y_{2,t}\left(h_2^J\right) = s^J Q_{2,t}^J\left(h_2^J, j^J\right) + s^U M_{2,t}^U\left(h_2^J, j^U\right) + s^C M_{2,t}^C\left(h_2^J, j^C\right)\ .$$

In the nontradable goods market, these good are domestically produced and consumed:

$$Y_t(n^J) = s^J N_t(n^J, j^J)\ .$$

In the bond market, the market clearing condition is

$$B_{F,t+1}(j^U) = -\frac{s^C}{s^U} B_{F,t+1}(j^C) - \frac{s^J}{s^U} B_{F,t+1}(j^J)\ .$$

5. SIMULATION ANALYSIS OF A POSITIVE SUPPLY SHOCK IN AN EMERGING ECONOMY

Using the three-country DSGE model, we next examine the mechanism where emerging economies' supply shocks affect macroeconomic variables in developed economies, particularly their inflation rates. The supply shock analyzed here is a positive productivity shock in the tradable final goods (or product assembly) sector in an emerging economy (the PRC). This is tantamount to a positive shock, $Z_{2,t}^{C}$, in the PRC version of equation (9).[8] The reason for considering this type of productivity shock is the observation that economic growth in emerging economies in recent years has been the result mainly of supply capacity expansion in the low-value-added final goods assembly sector, rather than in the high-value-added intermediate goods production sector requiring advanced technologies.

We can provide further explanations of factors behind positive productivity shocks in product assembly sectors in emerging economies. Our model assumes that labor is the only fundamental factor of production. As a result, increases in labor productivity—due to the reallocation of labor from rural to urban areas, capital investment, or technology transfer from foreign multinational firms—are not explicitly modeled, but they can be considered to be the effects of such domestic labor migration, capital accumulation including foreign direct investment, and transfers of production technology and managerial expertise from foreign sources.

To understand the basic international transmission mechanism of this model, we present the results of simulation analysis under a set of baseline parameters. We then consider the effects of altering these baseline parameters and model settings to highlight the importance of certain features of the model in driving the specific results. More specifically, we examine the effects of trade structures, exchange rate regimes, and price-setting behavior to clarify the model's international transmission mechanism.

5.1 Baseline Parameters

We first describe the setting of baseline parameters in the three-country model. Figure 2 illustrates the actual trade structure between these three countries. Figure 2A compares the trade volume (exports plus imports) of Japan and the US, as ratios of the respective GDPs, with the PRC. The figure confirms that Japan has a deeper trade relationship with the PRC than does the US. Figure 2B shows the PRC's trade balance by goods with Japan and the US. It is clear that the PRC runs significant trade surpluses in final goods (i.e., consumption goods and capital goods) with both Japan and the US. Further, it runs a large trade deficit in parts and components and processed goods with Japan, but not with the US. These observations support the presence of vertical specialization in trade between the PRC and Japan, but not between the PRC and the US.

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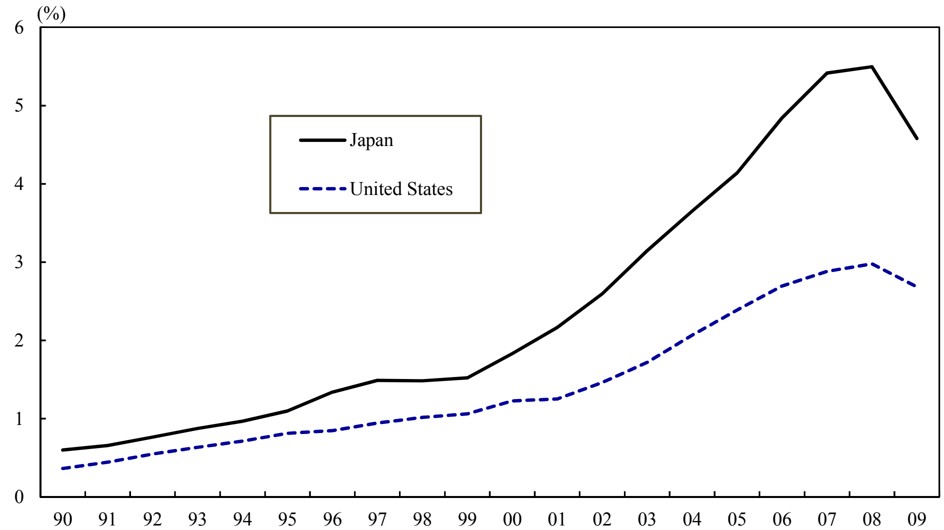
[8] Here, it is assumed that the logarithm of the productivity shock $Z_{2,t}^{C}$ follows an AR(1) process, that is,

$$\ln Z_{2,t}^{C} = (1-\lambda_2^C)\ln\overline{Z_2^C} + \lambda_2^C \ln Z_{2,t-1}^{C} + e_{2,t}^{C} ,$$

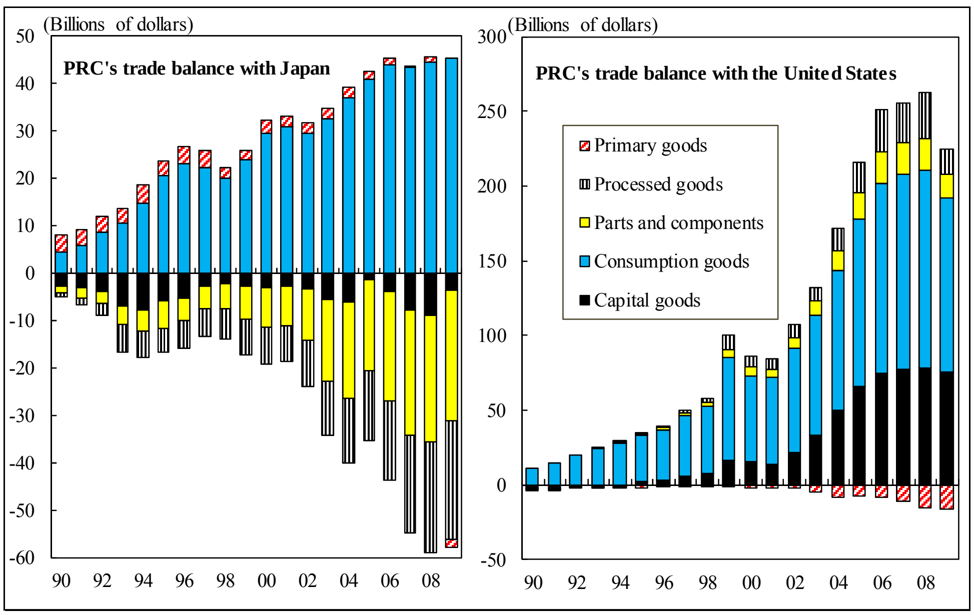
where $\overline{Z_2^C}$ is the steady-state value of the shock. In our model, we apply a shock to $e_{2,t}^{C}$ under the assumption that $\lambda_2^C = 0.9$.

Figure 2: Trade Structures of Japan, the PRC, and the United States

2A. Trade with the PRC as a Ratio of GDP of Japan and the United States [(exports to the PRC + imports from the PRC) / country's GDP]



2B. Trade Balance of the PRC with Japan and the United States



PRC = People's Republic of China.

Sources: International Monetary Fund (IMF), *Direction of Trade Statistics*; Research Institute of Economy, Trade and Industry (RIETI), *RIETI-TID2010*; IMF, *World Economic Outlook* database.

Table 2 presents calibrated trade balances in steady state for the three countries as well as baseline parameter values used in the model. In Table 2A, in steady state, the overall trade balance for each country is assumed to be zero, while bilateral trade balances are not necessarily zero. The values of these calibrated bilateral trade balances are close to the actual observed data except the Japan–US and PRC–US bilateral trade balances in final goods. Observed data for 2005 show that Japan has trade surpluses both in parts and components and in final goods with the US, and that it has a trade surplus in parts and components and a trade deficit in final goods with the

PRC. The PRC has a trade deficit in parts and components and a trade surplus in final goods with Japan, while it has trade surpluses both in parts and components and in final goods with the US. In model calibration, Japan and the PRC are assumed to have small trade deficits in final goods with the US, though in reality they have trade surpluses. The reason for this discrepancy is that we assume that the overall trade balance of each country is zero in steady state, even though Japan and the PRC had large overall trade surpluses and the US had a sizable overall trade deficit in 2005.[9] Notwithstanding this problem, our simulation still yields a set of rich and revealing results that are consistent with the observed data on macroeconomic variables, particularly inflation rates and exchange rates.

Table 2B summarizes baseline parameter values for the model, particularly elasticities of substitution between goods. These elasticities play a vital role in international transmissions of productivity shocks. Here, the elasticity assumptions are based on the following considerations regarding parts and components and tradable final goods. First, for tradable final goods, the country of production is not considered an important factor in determining the goods' characteristics. Considering that many firms have transferred their product assembly operations to emerging economies such as the PRC, in search of cheap labor, the tradable final goods are largely homogeneous no matter where they are produced. In addition, as described in the empirical section, the rising share of imports from emerging economies with low wages has reduced domestic prices in developed economies. Therefore, the elasticity of substitution between tradable final goods produced in different countries is assumed to be high. On the other hand, parts and components are not homogeneous across countries and a country with a high technology sector—such as Japan—can produce high-quality parts and components needed for product assembly in the PRC. Thus, parts and components are not highly substitutable internationally and the elasticity of substitution between those produced in different countries is assumed to be low. Specifically, in the baseline simulation analysis, equation (2) assigns the value 15 for $\varphi_2^J, \varphi_2^U, \text{and } \varphi_2^C$, while equation (8) assigns the value 0.5 for $\varphi_1^J, \varphi_1^U, \text{and } \varphi_1^C$. Other parameters are basically set on the basis of Laxton and Pesenti (2003).

Table 2: Calibrated Parameters

2A. Trade Balance as a Ratio of GDP in Steady State (%)

		Against	Calibration	Data at 2005
Japan	Final goods	United States	-0.7	0.7
		PRC	-1.8	-0.9
	Parts and components	United States	0.5	0.6
		PRC	2.1	0.7
PRC	Final goods	Japan	1.8	1.8
		United States	-0.4	4.9
	Parts and components	Japan	-2.1	-1.5
		United States	0.7	1.7
United States	Final goods	Japan	0.8	-0.3
		PRC	0.4	-0.9
	Parts and components	Japan	-0.5	-0.2
		PRC	-0.7	-0.3

GDP = gross domestic product, PRC = People's Republic of China.

[9] In this regard, assuming a semi-permanent trade deficit for the US might be more appropriate. The following simulation sets a high degree of vertical specialization between the PRC and Japan to analyze the different international transmission mechanism of the PRC's supply shock on Japan and the US. A different characterization of steady-state trade balances may be an issue for future study.

2B. Baseline Parameter Values

Parameter	Value	Description
η	1.5	Elasticity of substitution between tradable and nontradable goods
φ_1	0.5	Elasticity of substitution between home and foreign parts and components
φ_2	15	Elasticity of substitution between home and foreign final goods
ζ	3	Inverse of the Frisch elasticity
θ	6	Mark up ($\theta/(\theta-1)$)
Φ_N	400	Price adjustment cost coefficient for nontradable goods
Φ_1	400	Price adjustment cost coefficient for parts and components
Φ_2	400	Price adjustment cost coefficient for final goods
β	$1.03^{-0.25}$	Subjective discount factor
v	0.4	Share of final goods in total consumption
b_c	0.83	Habit persistence
$1/\sigma$	0.8	Inverse of elasticity of intertemporal substitution
ω_i	0.8	Persistence of the nominal interest rate in the Taylor rule
ω_I	1.5	Coefficient on inflation in the Taylor rule
ω_y	0.5	Coefficient on the gross domestic product gap in the Taylor rule

Calibrated parameters for aggregator of parts and components, equation (8)

ν_J^J	0.39	ν_J^C	0.45	ν_J^U	0.33
ν_U^J	0.33	ν_U^C	0.3	ν_C^U	0.38
ν_C^J	0.283	ν_C^C	0.25	ν_U^U	0.29

Calibrated parameters for aggregator of final goods, equation (2)

μ_J^J	0.1	μ_J^C	0.35	μ_J^U	0.38
μ_U^J	0.1	μ_U^C	0.10	μ_C^U	0.58
μ_C^J	0.8	μ_C^C	0.55	μ_U^U	0.08

Sources: Research Institute of Economy, Trade and Industry (RIETI), *RIETI-TID2010*; and authors' assumptions.

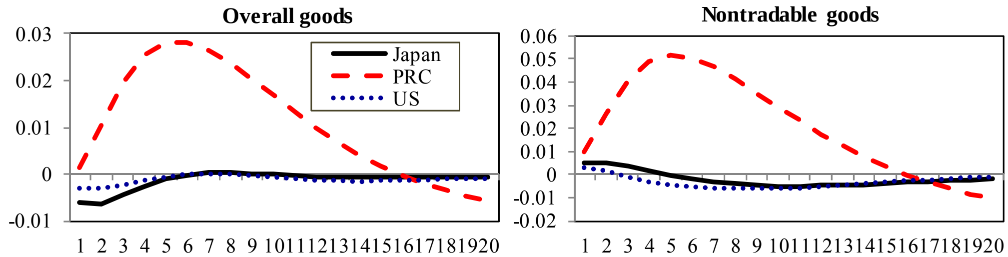
5.2 Baseline Simulation Analysis

Figure 3 summarizes the impulse responses of key macroeconomic variables under the baseline assumptions. A positive supply shock in the PRC's tradable final goods (or product assembly) sector affects not only the PRC's macroeconomic variables but also those in Japan and the US and the yen–US dollar exchange rate through international spillover effects. In particular, a productivity shock in the PRC creates deflationary pressures in both Japan and the US, with a greater deflationary impact on Japan than on the US at least in the first five periods. This result obtains because of the asymmetric trade structures for the three countries and the PRC's dollar-pegged exchange rate regime.

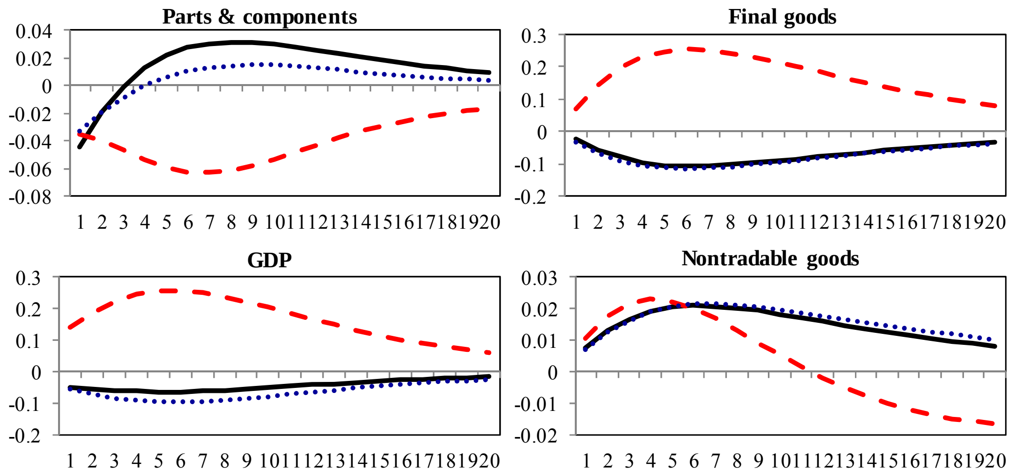
The international transmission of a positive supply shock in the PRC's product assembly sector works in the following way. First, it expands the production of tradable final goods in the PRC (Figure 3B, top right), which stimulates demand for parts and components required for final goods production. Due to the low elasticity of substitution for parts and components and the vertical specialization trade structure between the PRC and Japan, the PRC's rising demand for parts and components is met by the greater supply of these intermediate goods by Japanese firms (Figure 3B, top left). The trade structure between the PRC and the US is largely one of horizontal specialization, so US firms do not expand production nor export of parts and components, as much as do Japanese firms. Thus, the PRC's productivity shock alters the international allocation of production among the three countries.

Figure 3: Impulse Responses to a Positive Supply Shock to the PRC's Final Assembly Sector

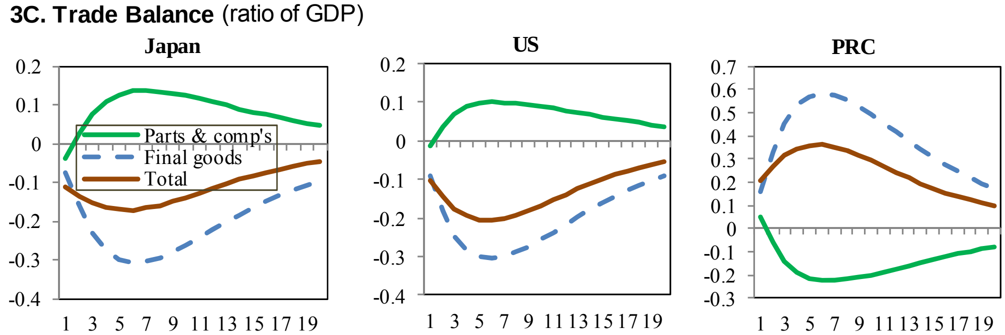
3A. Inflation Rate



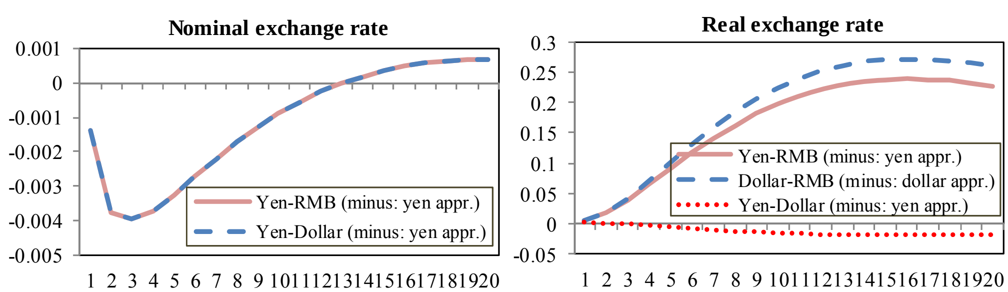
3B. Production Activity



3C. Trade Balance (ratio of GDP)



3D. Exchange Rate (negative sign means yen appreciation)



GDP = gross domestic product, PRC = People's Republic of China, RMB = renminbi, US = United States.

Source: Authors' computation.

Second, the production expansion of tradable final goods in the PRC exerts downward pressure on prices of these goods in the global market. Because of the high elasticity of substitution for these final goods, the PRC's export of these goods expands while production of these goods declines and imports rise in both Japan and the US. This leads to a trade surplus in the PRC and trade deficits in both Japan and the US. However, the size of the trade deficit in Japan is smaller than in the US (Figure 3C, left and center) because Japan exports parts and components to the PRC while the US does not.

Third, the PRC's positive supply shock creates inflation in the PRC and reduces inflation in Japan and the US (Figure 3A). The rise in the PRC's inflation results from rapid increases in nontradable goods prices. That is, a positive productivity shock in the PRC's tradable final goods sector expands its supply and thus lowers their prices. However, a positive productivity shock allows nominal wages to rise, which pushes up the price of nontradable goods, more than offsetting a decline in tradable final goods prices, and thus leads to higher general-price inflation. This result is consistent with the Balassa–Samuelson hypothesis, which asserts that a country's general inflation rate is high—thereby causing real exchange rate appreciation over time—when productivity growth is higher in the tradable goods industry than in the nontradable goods industry.[10]

The inflation rates in both Japan and the US decline moderately mainly because the expansion of supply of the PRC-made tradable final goods exerts downward pressure on the price of these goods globally. The induced expansion of demand for parts and components can create upward pressure on the price of these intermediate goods globally, but this impact is secondary and more than offset by the initial global decline in tradable final goods prices. In addition, the downward pressure on inflation rates is greater in Japan than in the US (Figure 3A). The reason for this difference is that the import share of tradable final goods is higher in Japan than in the US, which creates a greater downward pressure on Japan's inflation rate.

Fourth, the differential international spillover impacts of the PRC's supply shock on the trade balance in Japan and the US can have consequences for the yen–US dollar exchange rate and inflation rates in the two countries. Because Japan has a smaller overall trade deficit than does the US, the Japanese yen appreciates against the US dollar (Figure 3D). The yen appreciates—or the US dollar depreciates—because the model assumes the presence of transactions costs requiring an additional return in international financial markets as a country accumulates external debt. With a greater rise in the trade deficit—and the consequent accumulation of external debt—in the US, the real returns on US-issued bonds must rise, adjusted for transactions costs, causing US dollar depreciation. As the RMB is assumed to be pegged to the US dollar, it cannot appreciate against the dollar and as a result the yen is forced to appreciate. The yen's appreciation creates further downward pressure on import prices, aggravating the

[10] See Rabanal (2009), Rabanal and Tuesta (2010), and Berka and Devereux (2010) for discussions of the Balassa–Samuelson effect and the real exchange rate. In a multi-country general equilibrium model, whether an increase in productivity in the tradable goods industry leads to the country's real exchange rate appreciation depends on assumptions made. One factor affecting the result is the size of the elasticity of substitution between domestically produced goods and imported goods. When the elasticity of substitution is low, the real exchange rate tends to depreciate because the low elasticity means that the relative price elasticity is also low and, therefore, the expansion of supply due to higher productivity leads to substantial price declines. The impact of this price decline can be greater than increases in nontradable goods prices, leading to general price declines and real exchange rate depreciation.

deflationary pressure in Japan.[11] The more competitive the Japanese parts and components production sector is in comparison to that of the US, the more significant the yen appreciation and price deflation pressure is.

Finally, in the PRC, GDP rises because a supply shock augments the supply capacity of the economy (Figure 3B, bottom left). The production of both tradable final goods and nontradable goods rises as labor shifts away from the parts and components production sector toward the nontradable industry. In Japan and the US, GDP declines as households find it attractive to reduce labor supply, as in the case of the usual real business cycle model. But Japanese GDP declines less than US GDP because the parts and components production sector expands more in Japan than in the US.[12]

5.3 Role of the Trade Structure

The asymmetric trade structures assumed for the PRC, Japan, and the US are an important feature of the model that creates greater deflationary pressures in Japan than in the US in response to a productivity shock in the PRC. Two key determinants of the trade structures for the three countries are the degree of vertical specialization between the PRC and Japan (represented by the share of Japan-made parts and components required for the production of tradable final goods in the PRC) and the elasticity of substitution between parts and components produced in different countries. To verify the importance of trade structures for the international transmission mechanism and, more specifically, impacts on Japan's inflation rates, we examine how changes in trade structures may alter the benchmark simulation results.

5.3.1 Vertical Specialization

First, we consider how the changing degree of vertical specialization between Japan and the PRC may affect the international spillovers of the PRC's supply shock. In the baseline scenario, we assume a relatively high degree of vertical specialization between Japan and the PRC; that is, the import share of Japan-made parts and components required for the production of final goods in the PRC is 0.45. This means that the shares of US-made and the PRC-made parts and components needed for the production of final goods in the PRC are relatively low.[13] This assumption leads to the specific patterns of bilateral trade balances in the steady state: the PRC runs trade surpluses in final goods with Japan and in parts and components with the US and a trade deficit in parts and components with Japan; Japan runs trade surpluses in parts and components with the PRC and the US and a trade deficit in tradable final goods with the PRC.

To analyze the impact of the changing degree of vertical specialization between the PRC and Japan, we consider alternative values for the import share of Japan-made parts and components required for product assembly in the PRC. Specifically, we change the values of μ_J^C in equation (8) from the baseline parameter of 0.45 to lower values (0.35, 0.25, 0.15, and 0.05). Table 3 illustrates how changing the baseline

[11] The extent to which the nominal exchange rate affects the price depends on the price-setting behavior or the extent of exchange rate pass-through. In our model, PCP is assumed, where the pass-through is large. We discuss the impact of changing this assumption later in the paper.

[12] It is also important to note that, as observed in the inflation rates for tradable goods in Figure 3A, a positive supply shock in the PRC improves Japan's terms of trade and increases consumption levels.

[13] We assume that the shares of Japan-made parts and components required for the production of final goods are the same across countries.

values of μ_J^C affects steady-state bilateral trade balances among the three countries. One can clearly observe that reducing these values lowers the degree of vertical specialization between Japan and the PRC.

Table 3: Trade Balance as a Ratio of GDP for Alternative Import Shares (%)

		Import share	**0.45**	**0.35**	**0.25**	**0.15**	**0.05**
Japan	Parts and components	Total	2.6%	1.0%	-0.5%	-1.7%	-2.8%
		With PRC	2.1%	0.7%	-0.5%	-1.6%	-2.6%
		With US	0.5%	0.3%	0.1%	-0.1%	-0.3%
	Final goods	Total	-2.6%	-0.9%	0.5%	1.7%	2.8%
		With PRC	-1.8%	-0.7%	0.4%	1.3%	2.2%
		With US	-0.7%	-0.3%	0.1%	0.4%	0.7%
PRC	Parts and components	Total	-1.4%	0.2%	1.6%	2.8%	3.8%
		With Japan	-2.1%	-0.7%	0.5%	1.6%	2.5%
		With US	0.7%	0.9%	1.0%	1.2%	1.3%
	Final goods	Total	1.4%	-0.2%	-1.6%	-2.8%	-3.8%
		With Japan	1.8%	0.6%	-0.4%	-1.3%	-2.1%
		With US	-0.4%	-0.8%	-1.2%	-1.5%	-1.7%
United States	Parts and components	Total	-1.2%	-1.2%	-1.2%	-1.2%	-1.1%
		With Japan	-0.5%	-0.3%	-0.1%	0.1%	0.3%
		With PRC	-0.7%	-0.9%	-1.1%	-1.3%	-1.4%
	Final goods	Total	1.2%	1.2%	1.2%	1.1%	1.1%
		With Japan	0.8%	0.3%	-0.1%	-0.4%	-0.7%
		With PRC	0.4%	0.9%	1.3%	1.6%	1.8%

GDP = gross domestic product, PRC = People's Republic of China, US = United States.

Note: The import share is the share of Japan-made parts and components required for the production of tradable final goods in the PRC, in absolute value (not in %). Its baseline value is 0.45.

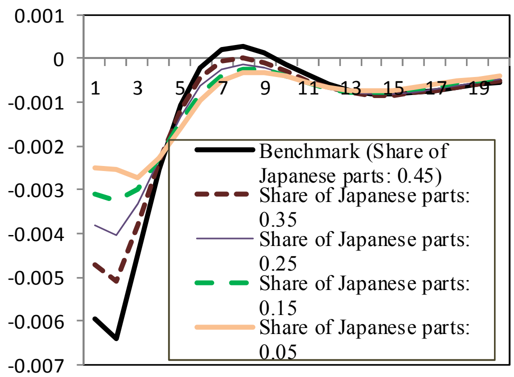
Source: Authors' computation.

Figure 4 summarizes the impulse responses under alternative degrees of vertical specialization. It shows that reducing the import share of Japanese parts and components required for final goods production in the PRC from the benchmark value reduces the downward pressure on Japan's inflation rate in response to a productivity shock in the PRC. Raising the import share of Japanese parts and components has the opposite effect. The responses of Japanese and US inflation rates to the PRC's productivity shock become similar as the degree of vertical specialization between Japan and the PRC declines (Figures 4A and 4B). Essentially, with a decline in the degree of vertical specialization between Japan and the PRC, a productivity shock in the PRC reduces exports of final goods from the PRC to the US, thus limiting the size of the US trade deficit more than that of Japan's trade deficit (Figure 4C). As a result, the yen appreciation pressure is mitigated (Figure 4D), thereby easing deflationary pressure in Japan.

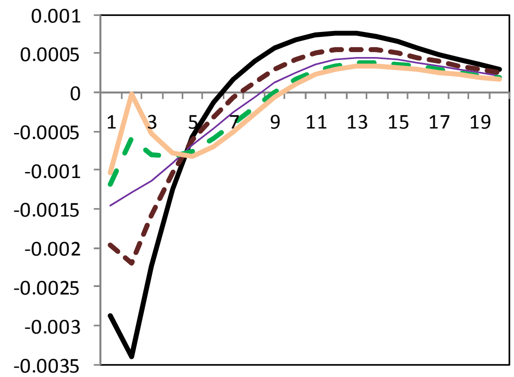
This verifies the important role of vertical specialization between Japan and the PRC in generating yen appreciation and deflationary pressures for Japan when there is a positive supply shock to the PRC's assembly production sector.

Figure 4: Impulse Responses under Alternative Shares of Japanese Parts and Components Used in the PRC

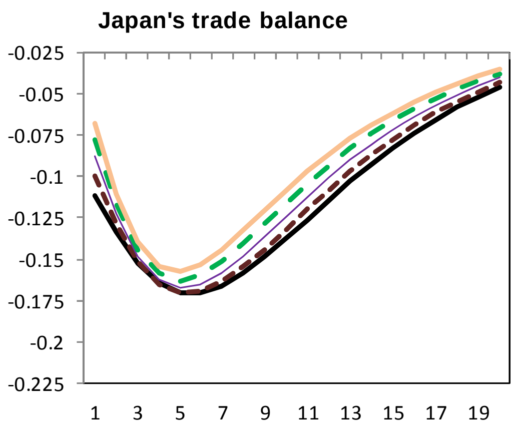
4A. Japan's Inflation Rate

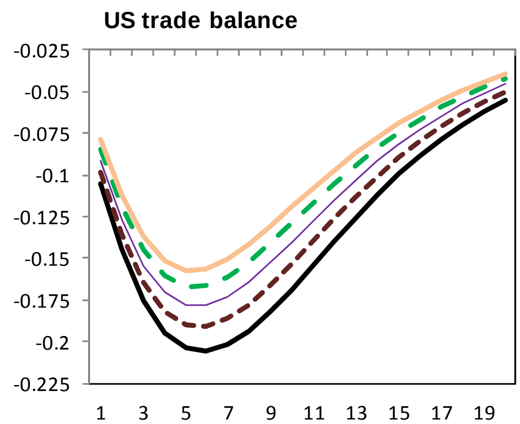


4B. Japan–US Inflation Rate Differential
(negative sign means Japan's relative deflation)

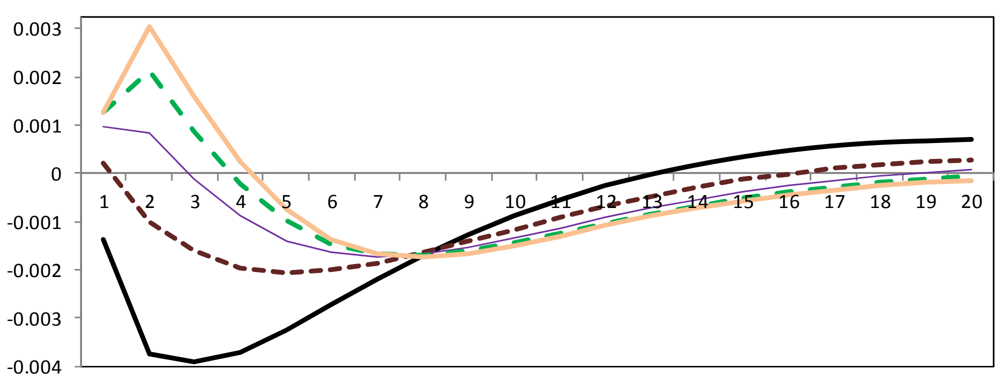


4C. Trade Balance (ratio of GDP)





4D. Yen–US Dollar Exchange Rate (negative sign means yen appreciation)



GDP = gross domestic product, PRC = People's Republic of China, US = United States.

Note: The share of Japanese parts and components in the PRC means the share of Japan-made parts and components that are required for the production of final goods in the PRC. With a decline in this value, competitiveness of Japanese parts and components production sector declines.

Source: Authors' computation.

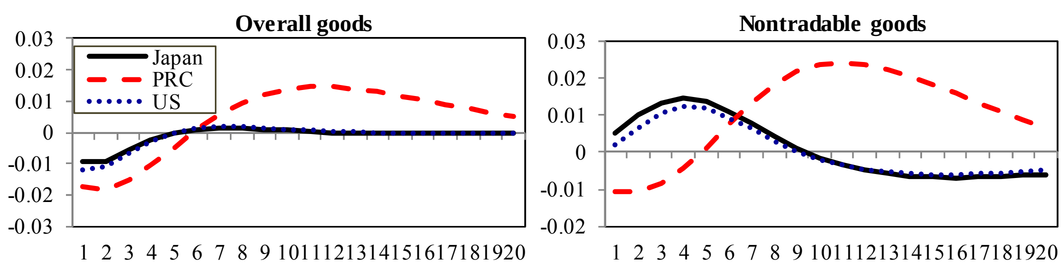
5.3.2 Elasticity of Substitution

The baseline model assumes a low elasticity of substitution between parts and components produced in different countries while the elasticity of substitution between tradable final goods produced in different countries is assumed to be high. This assumption is another factor determining the trade structures of the three countries studied and generating the different reactions of Japanese and US inflation rates to the PRC's productivity shock. To confirm this point, we conduct further simulation analysis by assuming a higher value for the elasticity of substitution for parts and components; that is, the parts and components produced in Japan, the US, and the PRC are more homogeneous. Specifically, in this simulation, we raise the values for $\varphi_1^J, \varphi_1^U,$ and φ_1^C in equation (8) from the baseline value of 0.5 to a higher value of 15, while maintaining the same baseline values for $\varphi_2^J, \varphi_2^U,$ and φ_2^C in equation (2) at 15.

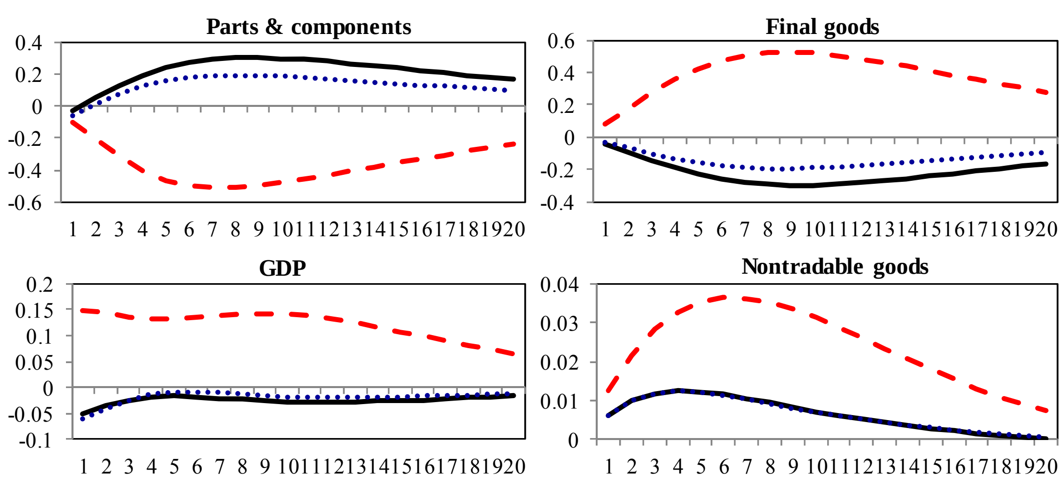
Figure 5 illustrates this simulation's results. With a higher value of the elasticity of substitution between parts and components produced in the three countries, a positive supply shock in the PRC's product assembly sector stimulates demand for parts and components which are now supplied by all firms irrespective of whether they are Japanese, US, or PRC firms. Therefore, Japan and the US respond virtually in the same manner in terms of parts and components production (Figure 5B, top left) and trade balances (Figure 5C). As a result, no significant differences are observed between Japanese and US inflation rates (Figure 5A).

Figure 5: Impulse Responses with a Higher Elasticity of Substitution in the Production of Parts and Components

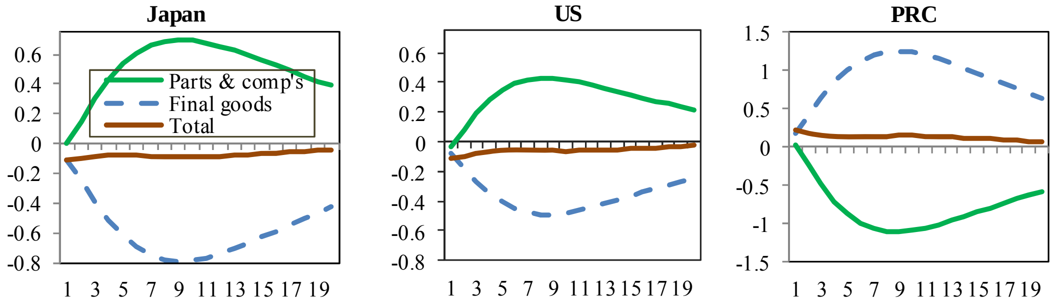
5A. Inflation Rate



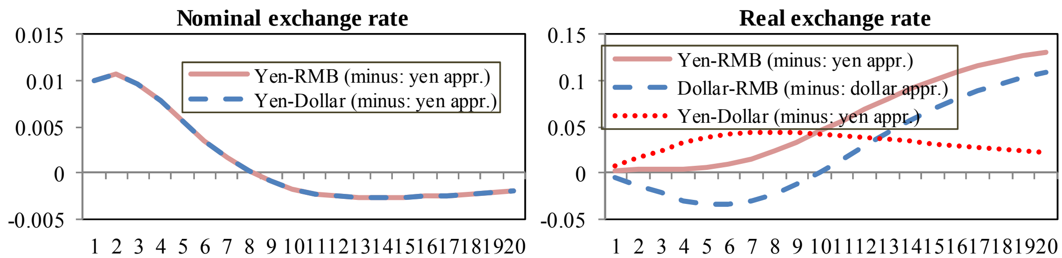
5B. Production Activity



5C. Trade Balance (ratio of GDP)



5D. Exchange Rate (negative sign means yen appreciation)



GDP = gross domestic product, PRC = People's Republic of China, RMB = renminbi, US = United States.

Note: With an increase in the elasticity of substitution from the baseline value of 0.5 to 15, Japan-made parts and components become more homogeneous to US- and PRC-made parts and components.

Source: Authors' computation.

Thus, this result reaffirms the major role played by Japanese firms in the production and export of highly sophisticated parts and components for which substitution is difficult, in explaining different patterns of Japanese and US inflation rates in the presence of a PRC positive productivity shock.

5.4 Role of the Exchange Rate Regime

In the baseline model, the RMB is fully pegged to the US dollar so the RMB–US dollar nominal exchange rate is constant. In reality, however, the RMB is not fully pegged (particularly since July 2005) and fluctuates moderately against the dollar. In recent years, the PRC monetary authorities have adopted a tight monetary policy to suppress high inflation and high real estate prices, resulting in a moderate appreciation of the RMB against the dollar. Nonetheless, the PRC authorities still tightly manage the RMB–US dollar exchange rate to avoid large rate fluctuations.

To highlight the importance of the PRC's exchange rate regime and monetary policies in affecting the international transmission of the PRC's supply shock, we next examine how the baseline simulations are affected by introducing alternative exchange rate and monetary policy regimes. We now consider different exchange rate and monetary policy regimes in the PRC; instead of a US-dollar-pegged regime, $\Delta\,\varepsilon^{CU} = 0$, where the nominal RMB–US dollar exchange rate, ε^{CU}, is constant, we assume a Taylor-rule-like monetary policy with a more flexible exchange rate regime:

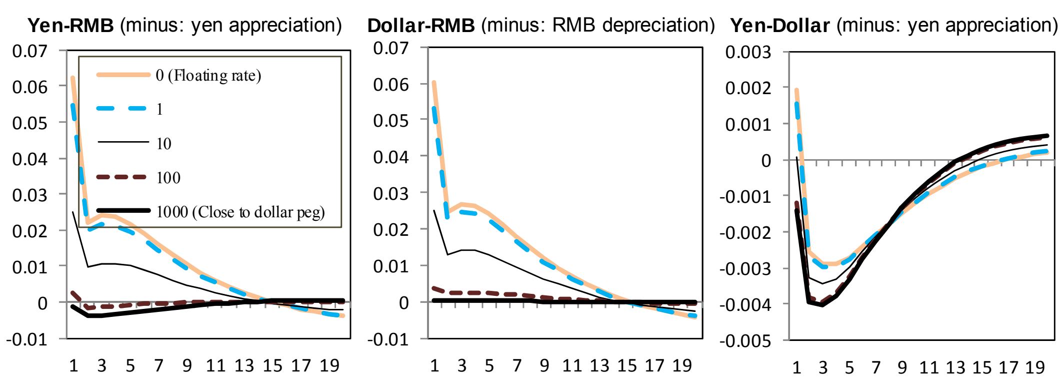
$$(1+i_t^C)^4 - 1 = \omega_i\left[\left(1+i_{t-1}^C\right)^4 - 1\right] + \omega_\pi\left((\pi_t^C)^4 - \overline{\pi^C}\right) + \omega_y\left(\frac{GDP_t^C}{\overline{GDP^C}} - 1\right) + \omega_e\,\Delta\,\varepsilon^{CU}\,.$$

Here, an increase in ε^{CU} means RMB depreciation. The parameter ω_e (≥ 0) measures the monetary authorities' reaction to exchange rate movements; when the RMB depreciates against the US dollar, the authorities attempt to raise the domestic interest rate and when it appreciates they lower it. The higher the value of ω_e, the closer they want to approach a pegged exchange rate regime, with a strong tendency toward reducing fluctuations in the exchange rate. The lower the value of ω_e, the more they allow the exchange rate to fluctuate. If ω_e is zero, the authorities maintain a pure floating exchange rate regime, with no goal of stabilizing the exchange rate.

Figure 6 illustrates the results of the simulation analysis. Several alternative values for ω_e are considered in the analysis, ranging from 0 (the case of a pure float) to 1,000 (close to a US dollar-peg, the baseline case).[14] When the parameter ω_e is set at high values, variations in the nominal RMB–US dollar exchange rate are small, and the results are virtually the same as the baseline scenario. When the parameter ω_e is set at low values, fluctuations in the nominal RMB–dollar exchange rate become larger and the RMB appreciates in response to the PRC's productivity shock (Figure 6A). In this case, the US trade deficit shrinks more than does Japan's trade deficit (Figure 6B). The reason for the greater shrinkage of the US deficit is that dollar depreciation reduces the US imports of final goods from the PRC and helps expand US exports. Japan's deficit shrinks to a lesser extent because the easing in the yen appreciation pressure helps expand net exports, while the reduced production of final assembly products in the PRC leads to smaller exports of parts and components from Japan to the PRC. With the PRC's exchange rate regime approaching a floating regime, pressure on the yen's appreciation against the US dollar is further eased because the US trade deficit shrinks.[15] As a result, downward pressures on the Japanese inflation rate become more limited (Figure 6C).

Figure 6: Impulse Responses under the PRC's Alternative Exchange Rate Regimes

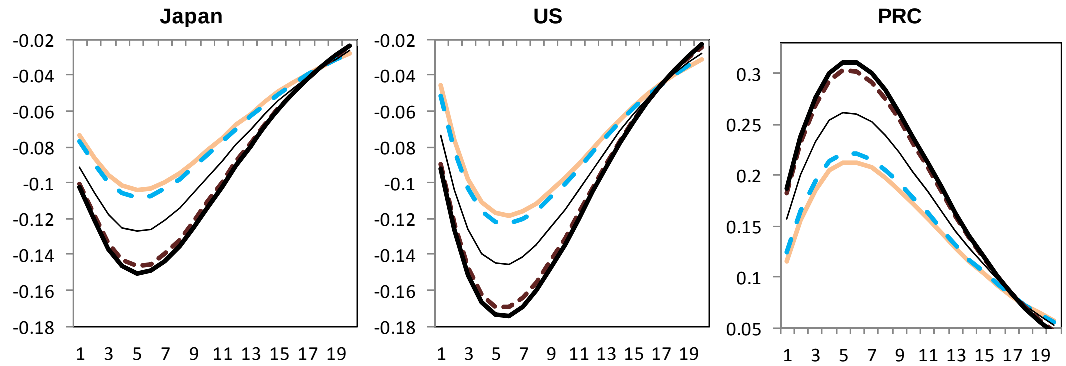
6A. Nominal Exchange Rate (negative sign means yen appreciation)



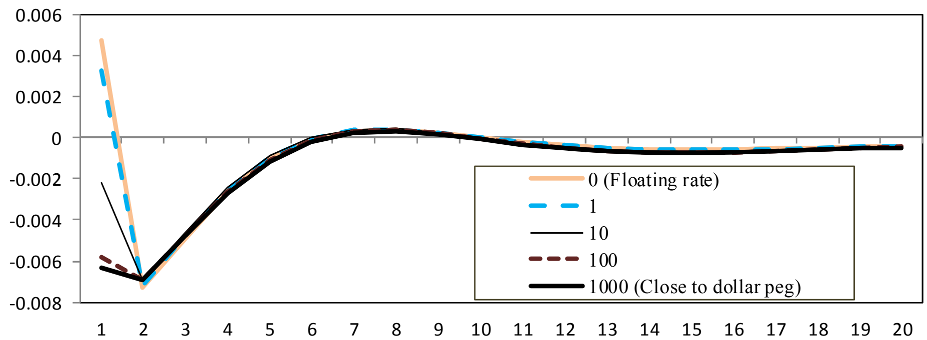
[14] However, even if ω_e is set at a large value, it does not exactly replicate the baseline case of $\Delta\varepsilon^{CU} = 0$. For more detailed discussions of the fixed exchange rate regime, see Benigno, Benigno, and Ghironi (2007).

[15] Even with a floating exchange rate system, however, the US trade deficit stays large, and yen appreciation pressures remain.

6B. Trade Balance (ratio of GDP)



6C. Japan's Inflation Rate



GDP = gross domestic product, PRC = People's Republic of China, RMB = renminbi, US = United States.

Note: The number (e.g., "0" or "1,000") indicates the value of ω_e in each simulation. With a decline in this value, the PRC's monetary policy tends toward greater exchange rate flexibility against the US dollar.

Source: Authors' computation.

This analysis confirms that the PRC's adoption of a US-dollar-pegged exchange rate regime is an important factor in generating Japan's deflationary response to a productivity shock in the PRC. This suggests that, as the PRC moves to greater exchange rate flexibility, the RMB appreciation could mitigate deflationary pressures in Japan.

5.5 Role of Price-Setting Behavior

Another factor causing the different inflation rate reactions in Japan and the US may be the large pass-through of the nominal exchange rate to prices, or the assumption of PCP. By contrast, in the case of local currency pricing (LCP), where domestic firms set prices in the importers' currency, pricing to the market reduces the short-term nominal exchange rate pass-through. Thus, if firms change their price setting behavior from PCP to LCP, one may observe different reactions in Japanese and US inflation rates, compared to the baseline.[16]

[16] Huang and Liu (2006) analyzed the differences in the impact of price-setting behavior using an international vertical specialization model.

5.5.1 Formulation of Local Currency Pricing

Under LCP, the profit maximization problem of a representative Japanese firm in the parts and components production sector, h_1^J, is as follows:

$$\max_{p_{1,\tau}^J(h_1^J), p_{1,\tau}^U(h_1^J), p_{1,\tau}^C(h_1^J)} E_t \sum_{\tau=t}^{\infty} D_{t,\tau}(j)\, \Pi_\tau(h_1^J)\ ,$$

where

$$\Pi_t(h_1^J) \equiv \left[p_{1,t}^J(h_1^J) - MC_t(h_1^J)\right] \int_0^{s^J} Q_{1,t}(h_1^J, j^J)\, dj^J \left[1 - \Gamma_{1,t}^J(h_1^J)\right]$$
$$+ \left[\varepsilon^{JU} p_{1,t}^U(h_1^J) - MC_t(h_1^J)(1+\tau_t)\right] \int_0^{s^U} M_{2,t}^U(h_2^J, j^U)\, dj^U \left[1 - \Gamma_{1,t}^U(h_1^J)\right]$$
$$+ \left[\varepsilon^{JC} p_{1,t}^C(h_1^J) - MC_t(h_1^J)(1+\tau_t)\right] \int_0^{s^C} M_{1,t}^C(h_2^J, j^C)\, dj^C \left[1 - \Gamma_{1,t}^C(h_1^J)\right].$$

That is, under LCP, each firm sets its price for each country's market by denominating it in the currency of the partner country, which introduces price discrimination across markets so that products are not necessarily priced the same. In contrast, in the baseline case of PCP, there is no price discrimination as a firm in the tradable goods industry sets a single price for both their domestic and export markets. A similar maximization problem is solved by the representative firm in the tradable final goods sector.

5.5.2 Effects of Price Setting Behavior

Figure 7 illustrates the impulse responses of Japan's inflation rate and the yen–US dollar exchange rate. We consider two extreme cases of all firms in a country adopting either PCP or LCP.[17] So we conduct eight (2 × 2 × 2) simulations using PCP and LCP for the setting of export prices by firms in the three countries. Table 4 presents these eight patterns. Comparing the two extreme cases of the benchmark (PPP where firms in the three countries adopt PCP) and the complete opposite (LLL where firms in the three countries adopt LCP), Japan's inflation rate is lower under LLL than under PPP in the first three periods (Table 7A). It is known that the exchange rate pass-through is larger under PCP than under LCP. Thus, the case of LLL reduces Japan's inflation rate as the yen appreciation more than offsets the exchange rate pass-through effect (Figure 7B).[18]

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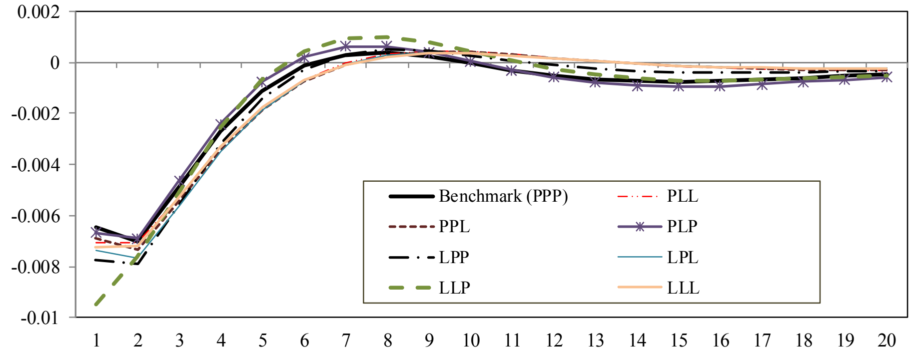
[17] In reality, however, US exporters and importers tend to denominate their goods traded in the US dollar (dollar pricing). Furthermore, when selecting a contract currency, the consideration of a firm's market share may lead to a specific price-setting behavior.

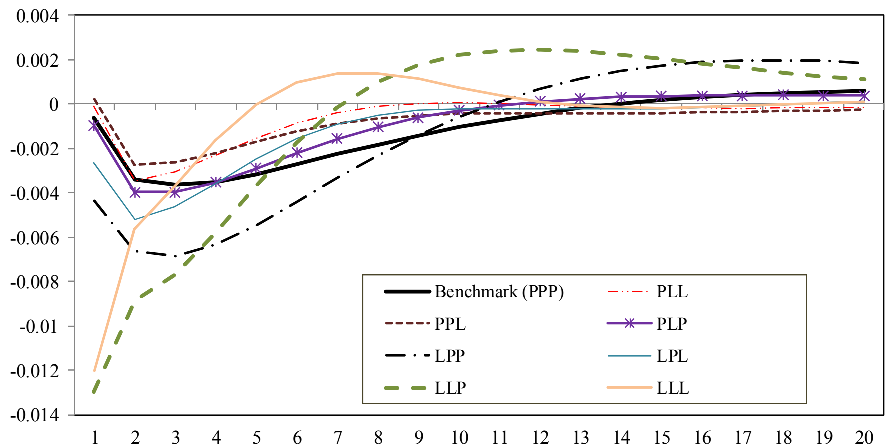
[18] In this case, it turns out that the variables for production activities, trade balances, and others differ little from the baseline. With LCP, the yen appreciates significantly against the US dollar compared to the baseline, but because the price pass-through of exchange rate changes is limited, the difference between Japanese and US inflation rates tends to be smaller. Betts and Devereux (2000) and others noted that in the case of LCP, fluctuations of the nominal exchange rate become large.

Figure 7: Impulse Responses under Alternative Price-Setting Behaviors

7A. Japan's Inflation Rate



7B. Yen–US Dollar Exchange Rate (negative sign means yen appreciation)



Note: Table 4 provides definitions of alternative combinations of price-setting behaviors.

Source: Authors' computation.

Table 4: Export Price Setting Behavior in Alternative Combinations

Combination	Japanese firms	US firms	PRC firms
PPP (baseline)	PCP	PCP	PCP
PPL	PCP	PCP	LCP
PLP	PCP	LCP	PCP
PLL	PCP	LCP	LCP
LPP	LCP	PCP	PCP
LPL	LCP	PCP	LCP
LLP	LCP	LCP	PCP
LLL	LCP	LCP	LCP

LCP = local currency pricing, PCP = producer currency pricing.

Source: Authors' assumptions.

This analysis demonstrates that a change in the export price-setting behavior of firms from PCP to LCP can further add deflationary pressures in Japan, but the difference is small.[19]

6. CONCLUSIONS

We have examined the possibility that positive supply shocks in emerging economies reduce inflation rates in developed economies. On the basis of previous empirical studies on the impact of emerging economy supply shocks on inflation rates in the US and Europe and our new empirical results on Japan, we conclude that these shocks likely expanded developed economies' imports of cheap goods from emerging economies and, thereby, reduced their inflation rates. We have also observed that the supply shocks in emerging economies likely had a greater impact on the inflation rate in Japan than in the US and Europe.

Then, we have constructed a three-country DSGE model for Japan, the US, and the PRC, incorporating price rigidity, asymmetric trade structures, and specific exchange rate regimes, to analyze the mechanism of international transmissions that a positive supply shock in the PRC can generate. The model has highlighted the important features of (i) deep vertical specialization between Japan and the PRC compared with that between the US and the PRC, and (ii) the PRC's US-dollar-pegged exchange rate regime while assuming full flexibility of the yen against the US dollar. The analysis has shown that these features play key roles in explaining the differential impacts of the PRC's productivity shock on the inflation rates in Japan and the US; that is, in creating greater deflationary impact on Japan than on the US.

The international transmission mechanism can be explained in the following way. When a positive productivity shock occurs in the PRC's product assembly sector, the PRC's production and export of final goods expand and Japanese and US imports of these goods expand. The PRC's production expansion stimulates the country's demand for parts and components as they are needed for the production of final goods. Being a competitive supplier of these parts and components in vertical specialization, Japan increases its exports of these intermediated goods to the PRC, while the US, which engages largely in horizontal specialization, does not. As a result, although both Japan and the US experience trade deficits with the PRC because of increases in imports of final goods, Japan's trade deficit with the PRC is smaller than that of the US.[20] A smaller trade deficit in Japan than in the US implies that the need to finance the deficit is greater in the US than in Japan, thereby leading to yen appreciation against

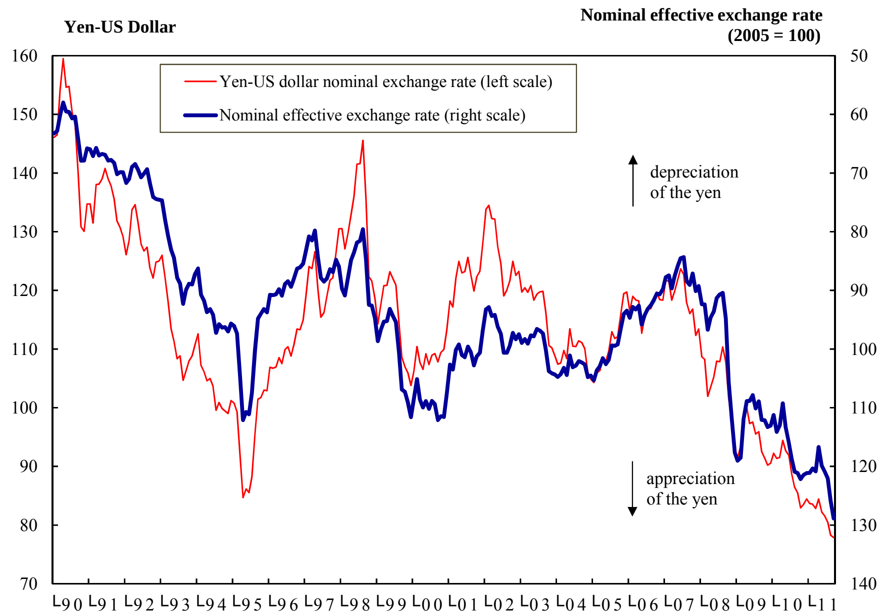
[19] One may ask which of the eight patterns is closest to reality. According to Gopinath and Rigobon (2008) and Gopinath, Itskhoki, and Rigobon (2010), among others, both exports and imports involving the US are mostly denominated in US dollars. In addition, even for Japan's trade with other Asian countries, about 50% of exports and 80% of imports are denominated in US dollars. PRC firms tend to set export prices in US dollars no matter where they export their products. As the RMB is pegged to the US dollar, dollar-denominated export pricing is de facto the same as RMB-denominated price setting, which is PCP. From these perspectives, with Japanese firms adopting LCP and US and PRC firms adopting PCP, the combination of LPP appears to be close to the actual practice. However, when the RMB begins to float against the US dollar in a more significant way, PRC firms can be expected to shift from PCP to LCP.

[20] In the simulation model, both Japan and the US experience trade deficits (though Japan's deficit is smaller than that of the US). This outcome occurs because in a dynamic model, a positive supply shock stimulates production in the country in which it occurs, while reducing production in other countries. Also, the shock creates an inflationary impact in the shock-originating country while exerting deflationary pressures on other countries.

the US dollar and a greater downward pressure on the inflation rate in Japan than in the US. This downward inflationary pressure is aggravated as the RMB is pegged to the US dollar and the yen is forced to appreciate more than would otherwise be the case. Thus, the vertical specialization trade structure between Japan and the PRC and the PRC's US-dollar-pegged exchange rate regime are important factors explaining deflationary impacts of the PRC's supply shocks on Japan.

This mechanism may have been in place during the period of Japan's low inflation (or deflation) in the 1990s and the 2000s. Since the 1990s, there have undoubtedly been significant increases in productivity—including supply capacity—in the tradable goods sector in emerging economies such as the PRC. During this period, Japanese multinational firms transferred their product assembly bases to emerging Asian economies, including the PRC. These firms have developed supply chains across emerging Asia and forged international vertical specialization where Japanese firms supply parts and components for product assembly in these emerging economies. Thus, supply shocks in emerging economies—due to transfers of production bases, technology, and management expertise by foreign, particularly, Japanese firms—have likely expanded both their product exports to Japan and imports of parts and components from Japan, without significantly worsening Japan's overall trade balance. In contrast, the US saw an expansion of product imports from the PRC, without concomitant increases in exports of parts and components, and, as a result, a large trade deficit with emerging economies, especially the PRC. The results of our simulation model are largely consistent with the trade structures and trade balance patterns observed in reality. They are also consistent with the observed trend of long-term yen appreciation. The nominal effective exchange rate of the yen depicted in Figure 8 demonstrates that, despite cyclical fluctuations with temporary depreciation episodes for the yen (as in 1996–1998 and 2005–2007), the medium- and long-term trends were of an overall appreciation at least until 2012.

Figure 8: Japanese Yen Exchange Rate, 1990–2011



Source: Bank of Japan.

In summary, there were persistent positive supply shocks in emerging economies, particularly in the PRC, throughout the 1990s and 2000s, as well as persistent nominal yen appreciation. If our model results are interpreted faithfully, continuous positive supply shocks in emerging economies caused sustained appreciations of the yen and deflationary pressures in Japan, largely due to the trade structure of vertical specialization between Japan and emerging Asian economies—represented by the PRC—and the latter's US-dollar-stabilization policies. However, other factors mitigated yen appreciation pressure from time to time. For example, the accommodating monetary policies pursued by the Bank of Japan from the late 1990s to the 2000s may have moderated these yen appreciation and deflationary pressures.[21] On the other hand, the yen continued to appreciate and price deflation was not eliminated despite these monetary policies. This suggests that, to end its price deflation, Japan could have taken two options: (i) adopt much more aggressive monetary easing policy to offset the deflationary pressure coming from persistent productivity shocks in emerging economies such as the PRC; and (ii) convince emerging Asia, particularly the PRC, to move to more flexible exchange rate regimes so as to mitigate yen appreciation pressure.

[21] The appreciation of the yen continued until the mid-1990s when zero interest rate and quantitative easing policies were adopted.

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