Tailwinds and Headwinds: How Does Growth in the BRICs Affect Inflation in the G-7?*

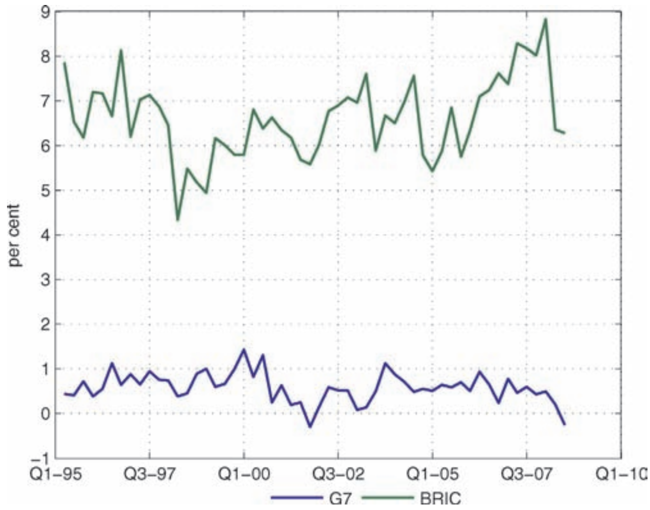
Anna Lipińska[a] and Stephen Millard[b]
[a]Federal Reserve Board
[b]Bank of England and Durham Business School

In this paper, we analyze the impact of a persistent productivity increase in a set of countries—which we think of as the economies of Brazil, Russia, India, and China (BRIC)—on inflation in their trading partners, the Group of Seven (G-7). In particular, we want to understand the conditions under which this shock can lead to tailwinds or headwinds in the economies of trading partners. We build a three-country dynamic stochastic general equilibrium (DSGE) model in which there are two oil-importing countries (home and foreign) and one oil-exporting country. In our benchmark calibration, we find that the tailwind effect, lowering inflation in the home economy, dominates the headwind effect. However, if the oil demand elasticity is low (equal to the empirical short-run estimate) or the labor market is flexible, inflation at home rises in the subsequent periods as a result of the foreign productivity shock.

JEL Codes: E12, F41, E31.

 We thank Carl Walsh (editor), Paul Beaudry, James Hamilton, Andrew Levin, John Williams, and the participants of the IJCB conference on Monetary Policy Issues in Open Economies for valuable comments. The views expressed in this paper are those of the authors and not necessarily those of the Bank of England or the Board of Governors of the Federal Reserve System. Most of the work on the paper was done while Anna Lipińska was employed at the Bank of England. Author contact: Lipińska: Board of Governors of the Federal Reserve System, Division of Monetary Affairs, 20th Street and Constitution Avenue NW, Washington, DC 20551, USA; e-mail: anna.lipinska@frb.gov. Millard: Bank of England, Monetary Analysis, Structural Economic Analysis Division, Threadneedle Street, London, EC2R 8AH, United Kingdom; e-mail: stephen.millard@bankofengland.co.uk.

Figure 1. Quarterly Real GDP Growth in 1995–2008



Data Source: Datastream.

1. Introduction

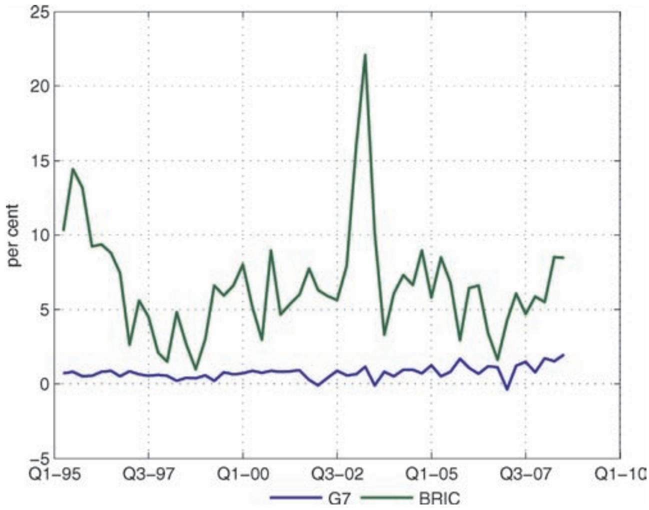
Recently, much has been written about the impact of globalization on the economy.[1] It is clear that the pace of globalization has increased since the early 1990s, in both advanced and emerging economies, and we might expect this development to have a major impact on the world economy. An important part of this has been the emergence of the so-called BRIC economies—Brazil, Russia, India, and, perhaps most important, China—which have been experiencing rapid rises in productivity and gross domestic product (GDP) over this period (see figure 1).

Many authors have argued that increased trade with the BRIC economies has helped keep inflation low in the developed world—so-called tailwind—by depressing import prices and increasing the share of imports in domestic demand.[2] Furthermore, more intense global competition can reduce the markups of domestic producers

[1]See, e.g., Bean (2006), International Monetary Fund (2006), Borio and Filardo (2007), and Lomax (2007).

[2]See, e.g., Nickell (2005), Bean (2006), and European Central Bank (2006).

Figure 2. Quarterly CPI Inflation in 1995–2008

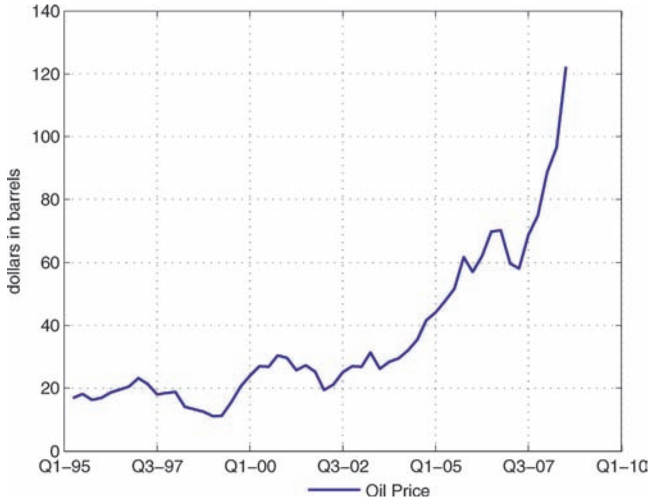


Data Source: Datastream.

and put downward pressure on wages, as well as raise productivity growth, as firms are put under increasing pressure to innovate. Production costs may also fall as firms increasingly find it easier to move activities offshore to low-cost countries and, through increased international mobility, to source low-cost labor from abroad rather than bidding up wages to attract workers from domestic firms. Aggregate production costs could also fall as inefficient firms exit the market. All of these factors could help explain why inflation has been so low in the developed world over the past decade (figure 2).

But there may be an inflationary headwind acting to counteract the tailwind. As shown by Campolmi (2008) and Hamilton (2009), among others, this headwind arises because rapid growth in emerging economies can push up the global price for commodities, such as oil and steel. Indeed, figure 3 shows that oil prices have increased dramatically over the past ten years—that is, at the same time as the rapid growth in the BRIC economies. Given such a rise in commodity prices, all countries importing these commodities will suffer an increase in their production costs and, potentially, their aggregate inflation rates.

Figure 3. Oil Price in 1995–2008



Data Source: Datastream.

The goal of this paper is to develop a calibrated structural model within which we can assess the quantitative impact of cheaper foreign goods and more expensive commodities on home inflation. This model will enable us to measure the quantitative impact of the persistent productivity increase in the BRIC economies on inflation in the G-7. We can then work out the key parameters determining how large the tailwind and headwind effects are and determine how robust our results are to reasonable changes to these parameter values. In particular, we study the importance of foreign monetary regime, degree of labor market flexibility, elasticity of oil, degree of financial integration, and trade elasticity. In doing so, we aim to increase our understanding of the links between growth in the BRIC economies, oil prices, and the G-7 inflation.

Our benchmark results indicate that the tailwind effect coming from cheaper foreign goods is stronger than the headwind effect. Moreover, the tailwind effect is immediate, while the headwind effect is delayed by one period due to a hump-shaped response of oil prices to an increased oil demand. However, our sensitivity analysis indicates that the headwind effect can actually outweigh the tailwind effect for the low oil demand elasticity (which reflects the short-run empirical estimate) or in the case of a flexible labor market.

Previous authors have looked at the question of why the rise in oil prices from 2003 to 2008 has had a much smaller effect on output and inflation in the G-7 than similar rises in the 1970s and early 1980s. Blanchard and Galí (2010) examine four different hypotheses: good luck, a smaller share of oil in production, more flexible labor markets, and improvements in monetary policy. They conclude that all four were important in lowering the impact of the oil shock. Kilian (2009) makes the point that it is the shock that caused oil prices to rise that matters. He uses a structural vector autoregression (SVAR) approach to decompose oil price movements into crude oil supply shocks, shocks to global demand for all industrial commodities, and shocks to global demand for oil specifically (capturing rises in precautionary demand associated with concerns about future supply shortfalls). He finds that the recent increase in oil prices resulted from a global demand shock and this is why it had smaller output and inflation effects than previous oil shocks.

Campolmi (2008) takes this finding further by demonstrating that it is exactly what a theoretical model would suggest. More specifically, she used a two-country model to show that a positive productivity shock in the foreign economy (she was thinking of China) led to a rise in the demand for, and hence the price of, oil with the sort of effects on the home economy that were seen in the United States in the 2000s.[3] Her paper is clearly similar to ours, though our emphasis is on the effects of the productivity shock specifically rather than on an explanation of the effects of oil price rises. In addition, we also consider the factors examined by Blanchard and Galí (2010) and ask to what extent they affect the response of the home economy to a foreign productivity shock.

The structure of the paper is as follows. In section 2, we develop the model we are going to use to analyze these issues before discussing its calibration in section 3. Section 4 considers the effects of globalization on the responses of variables to monetary policy

[3]Unalmis, Unalmis, and Unsal (2008) carry out a similar exercise using a small open-economy model in which the "oil demand shock" results from an exogenous increase in output in the rest of the world.

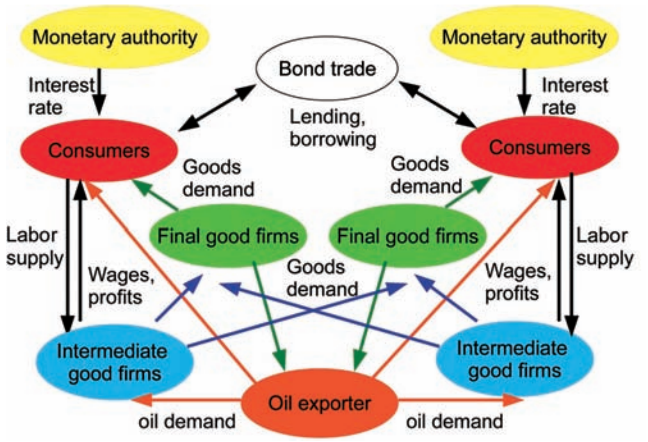
shocks and asks, under what conditions does globalization generate a tailwind or a headwind? Finally, section 5 concludes.

2. The Model

Our paper takes as its starting point the model of Campolmi (2008). Following Campolmi (2008), we considered a world of three countries: home and foreign, which can be thought of as the G-7 and the BRIC economies, respectively, and an oil producer, which sells its endowment of oil and spends the associated revenues on consumption of goods from both the developing and developed worlds. We modified the model of Campolmi (2008) in several ways to take account of different channels through which oil may affect the transmission of shocks. In particular, we introduced additional headwind channels. First, we assumed that oil is directly consumed by households instead of being used only in production. In this way, we accounted for a direct headwind effect on households. Second, we introduced a constant elasticity of substitution (CES) production function and assumed that oil and labor are complements in the production process. This enabled us to capture an increased demand for oil resulting from the productivity increase and thus strengthened the headwind effect via marginal costs. Third, we assumed that financial markets are internationally incomplete. This assumption implies that international risk sharing is not complete. As a result, consumers in the developed world have a limited ability to switch their consumption toward cheaper goods from the developing world. Thus, the strength of the tailwind effect coming from the cheaper goods in the developing world is reduced. Finally, following the literature (e.g., Obstfeld and Rogoff 2000b), we assumed that home and foreign goods are substitutes and introduced a CES aggregator for home and foreign goods.

The home and foreign economies consist of consumers, firms producing final goods, and firms producing intermediate goods. In addition, there is a monetary authority in each country that sets interest rates. Figure 4 shows how consumers and firms in the three countries interact. In what follows, we discuss the maximization problems faced by agents in the domestic economy, derive their first-order conditions, and simply state the analogues for the foreign economy.

Figure 4. The Model Economy



2.1 Households

The economy consists of a unit continuum of households. The representative household—household j—derives utility from consuming home and foreign goods and disutility from working. Its problem is to maximize the current and present discounted value of its utility streams subject to its budget constraint. Mathematically we can write this as

$$\max E_t \sum_{r=0}^{\infty} \beta^r \left(\frac{\sigma}{\sigma - 1} \left(\frac{c_{t+r}(j)}{c_{t+r-1}^{\psi_{hab}}} \right)^{\frac{\sigma-1}{\sigma}} - \kappa_h \frac{\sigma_h}{\sigma_h + 1} h_{t+r}(j)^{\frac{\sigma_h+1}{\sigma_h}} \right) \tag{1}$$

subject to

$$\begin{aligned} B_{t+r}(j) = B_{t+r-1}(j)(1 + r_{t+r-1}) - P_{t+r}c_{t+r}(j) \\ + P_{t+r}w_{t+r}(j)h_{t+r}(j) + D_{t+r}(j), \end{aligned} \tag{2}$$

where β is the discount factor, σ is the intertemporal elasticity of substitution, σ_h is the elasticity of labor supply, κ_h is the weight on leisure in the utility, ψ_{hab} is the parameter governing the degree of external habits in consumption, $c(j)$ is j's aggregate consumption, c is aggregate (economy-wide) consumption, $h(j)$ is j's supply of labor (total hours worked), $B(j)$ is household j's end-of-period holdings of domestically issued bonds, r is the domestic nominal interest rate, P is the domestic price level, $w(j)$ is the real wage earned by j, and $D(j)$ represents the share of profits made by domestic firms that is distributed to household j. We note that we assumed international financial markets to be incomplete in the sense that it is impossible to fully insure against country-specific risk.

Following the literature, we also assumed that households have access to financial markets that enable them to insure against idiosyncratic wage risk. Given this assumption, individual household consumption will equal aggregate consumption. The first-order conditions for consumption, domestic bond holdings will then imply that

$$(c_t)^{-\frac{1}{\sigma}-\psi_{hab}\left(\frac{1}{\sigma}-1\right)} c_{t-1}^{\psi_{hab}\left(\frac{1}{\sigma}-1\right)} = \beta(1+r_t)E_{t+r}\left(\frac{c_{t+1}^{-\frac{1}{\sigma}}}{1+\pi_{t+1}}\right), \quad (3)$$

where π_t is the aggregate inflation rate in the home economy.

For the foreign economy, we assumed that its budget constraint is given by

$$\begin{aligned} S_t B_t^*(j) &= S_t B_{t-1}^*(j)(1+i_{t-1}) - P_t^* c_t^*(j) + P_t^* w_t^*(j) h_t^*(j) \\ &\quad + D_t^*(j) - \frac{\chi_{bf}}{2}(S_t B_t^*(j))^2. \end{aligned} \quad (4)$$

Here $c^*(j)$ is foreign household j's aggregate consumption, c^* is aggregate foreign consumption, $h^*(j)$ is foreign household j's supply of labor (total hours worked), S is the nominal exchange rate (units of foreign currency per unit of domestic currency), $B^*(j)$ is foreign household j's end-of-period holdings of home bonds, r^* is the foreign nominal interest rate, $w^*(j)$ is the real wage earned by foreign household j, and $D^*(j)$ represents the share of profits made by foreign firms that is distributed to foreign household j. The final term represents the costs to foreign investors of adjusting their holdings of domestic bonds and ensures that the net foreign asset position of the two economies is pinned down in the steady state (see, e.g., Benigno 2009). In particular, we assumed that in the steady state, neither economy is a net borrower from or a net lender to the other. To reduce notation, we also assumed that no foreign bonds are issued in or out of the steady state—i.e., all international borrowing or lending is carried out via home bonds. The first-order conditions for the foreign economy are

$$\left(c_t^*\right)^{-\frac{1}{\sigma}-\psi_{hab}\left(\frac{1}{\sigma}-1\right)}\left(c_{t-1}^*\right)^{\psi_{hab}\left(\frac{1}{\sigma}-1\right)} = \beta\left(1+r_t^*\right)E_t\left(\frac{c_{t+1}^{*-\frac{1}{\sigma}}}{1+\pi_{t+1}^*}\right), \tag{5}$$

$$\left(c_t^*\right)^{-\frac{1}{\sigma}-\psi_{hab}\left(\frac{1}{\sigma}-1\right)}\left(c_{t-1}^*\right)^{\psi_{hab}\left(\frac{1}{\sigma}-1\right)} = \beta(1+r_t)E_t\left(\frac{c_{t+1}^{*-\frac{1}{\sigma}}}{1+\pi_{t+1}^*}\frac{S_{t+1}}{S_t(1+\chi_{bf}S_tB_t^*)}\right). \tag{6}$$

We combined equations (5) and (6) to obtain the uncovered interest parity condition:

$$\frac{1+r_t}{1+r_t^*} = \frac{S_t(1+\chi_{bf}S_tB_t^*)}{E_tS_{t+1}}. \tag{7}$$

Now, we assumed that aggregate consumption is a CES aggregator of consumption of (domestically produced) final goods and consumption of oil:

$$c_t = \left((1-\psi_{c,o})c_{h,t}^{\frac{\sigma_c-1}{\sigma_c}} + \psi_{c,o}c_{o,t}^{\frac{\sigma_c-1}{\sigma_c}}\right)^{\frac{\sigma_c}{\sigma_c-1}}, \tag{8}$$

where σ_c is the elasticity of substitution between goods and oil consumption, $\psi_{c,o}$ is the share of oil in the home consumption, c_h is consumption of home-produced final goods, and c_o is consumption of oil. If we defined the aggregate price index to be the minimum level of expenditure necessary to give a particular level of consumption, then we obtained the following:

$$1 = (1-\psi_{c,o})^{\sigma_c}p_{h,t}^{1-\sigma_c} + \psi_{c,o}^{\sigma_c}p_{o,t}^{1-\sigma_c}, \tag{9}$$

where p_h and p_o are the relative (to the aggregate consumer price index) prices of home final goods and oil, respectively. Note that all relative prices represent the price of a unit of that particular good purchased in the home economy relative to the price of a unit of the home consumption good purchased in the home economy.

Demand for the two goods (conditional on aggregate demand) will be given by

$$c_{h,t} = (1 - \psi_{c,o})^{\sigma_c} p_{h,t}^{-\sigma_c} c_t, \tag{10}$$

$$c_{o,t} = \psi_{c,o}^{\sigma_c} p_{o,t}^{-\sigma_c} c_t. \tag{11}$$

The analogous equations for the foreign country are

$$1 = \left(1 - \psi_{c,o}^*\right)^{\sigma_c} \left(p_{f,t}^*\right)^{1-\sigma_c} + \left(\psi_{c,o}^*\right)^{\sigma_c} (q_t p_{o,t})^{1-\sigma_c}, \tag{12}$$

$$c_{o,t}^* = \psi_{c,o}^{*\sigma_c} (q_t p_{o,t})^{1-\sigma_c} c_t^*, \tag{13}$$

$$c_{f,t}^* = \left(1 - \psi_{c,o}^*\right)^{\sigma_c} p_{f,t}^{*1-\sigma_c} c_t^*, \tag{14}$$

where $\psi_{c,o}^*$ is the share of oil in the foreign consumption, p_f^* is the relative price of the foreign final good, q is the real exchange rate, c_o^* is foreign consumption of oil, and c_f^* is foreign consumption of foreign-produced final goods.

2.2 *Wage Setting*

We supposed that individual workers are monopolistic suppliers of their own types of labor. Therefore, they will have market power and be able to set wages. Demand for a particular household's worker j can be derived from the cost minimization problem of firms and is given by

$$h_t(j) = \left(\frac{w_t(j)}{w_t}\right)^{-\sigma_w} h_t, \tag{15}$$

where σ_w is the elasticity of demand for differentiated labor, w is the economy-wide real wage, and h is the economy-wide supply of labor. Note that the total labor supplied by household j is given by $h_t(j) = \int_0^1 h_{t,j}(i)di$, where $h_{t,j}(i)$ is labor supplied by household j to firm i. Following Erceg, Henderson, and Levin (2000), we assumed that in each period, only a fraction of workers, $(1 - \alpha_w)$, are able to reset their wages optimally.

The problem for a worker able to reset his or her wage is to choose a wage $w(j)$ so as to maximize

$$\max E_t \sum_{r=0}^{\infty} \beta^r \alpha_w^r \left[c_{t+r}^{-\frac{1}{\sigma}} c_{t+r-1}^{\psi_{hab}\left(1-\frac{1}{\sigma}\right)} w_t(j) h_{t+r}(j) \right. \left. - \kappa_h \frac{\sigma_h}{\sigma_h+1} [h_{t+r}(j)]^{\frac{\sigma_h+1}{\sigma_h}} \right]. \qquad (16)$$

The first-order condition for this problem is

$$\widetilde{W}_t^{\frac{\sigma_h+\sigma_w}{\sigma_h}} = \frac{\sigma_w}{\sigma_w-1} W_t^{\frac{\sigma_w}{\sigma_h}} \frac{E_t \sum_{r=0}^{\infty} \beta^r (\alpha_w)^r \kappa_h \left[\left(\frac{W_t}{W_{t+r}} \right)^{-\sigma_w} h_{t+r} \right]^{\frac{\sigma_h+1}{\sigma_h}}}{E_t \sum_{r=0}^{\infty} \beta^r \alpha_w^r \frac{c_{t+r}^{-\frac{1}{\sigma}} c_{t+r-1}^{\psi_{hab}\left(1-\frac{1}{\sigma}\right)}}{P_{t+r}} \left(\frac{W_t}{W_{t+r}} \right)^{-\sigma_w} h_{t+r}}, \qquad (17)$$

where $\widetilde{W}$ is the nominal wage that will be set by all workers who are able to reset their wages and W is the economy-wide nominal wage. The aggregate wage index will be given by

$$W_t^{1-\sigma_w} = \alpha_w W_{t-1}^{1-\sigma_w} + (1-\alpha_w)(\widetilde{W}_t)^{1-\sigma_w}. \qquad (18)$$

Combining these two equations and log-linearizing gives the wage Phillips curve:

$$\widehat{\pi}_{w,t} = \frac{\sigma_h(1-\alpha_w)(1-\beta\alpha_w)}{(\sigma_h+\sigma_w)\alpha_w} \left(\frac{1}{\sigma_h}\widehat{h}_t + \frac{1}{\sigma}\widehat{c}_t - \psi_{hab}\frac{1-\sigma}{\sigma}\widehat{c}_{t-1} - \widehat{w}_t \right) + \beta E_t \widehat{\pi}_{w,t+1}, \qquad (19)$$

where $\widehat{\pi}_{w,t}$ is the (log) rate of nominal wage growth, which we assumed to be zero in the steady state. Other variables—i.e., $\widehat{h}$, $\widehat{c}$, and $\widehat{w}$—are the (log) deviations from the steady state of total hours, consumption, and the real wage, respectively. We note that, by definition,

$$\widehat{w}_t = \widehat{w}_{t-1} + \widehat{\pi}_{w,t} - \widehat{\pi}_t. \qquad (20)$$

The analogous equations for the foreign economy are

$$\widehat{\pi}^*_{w,t} = \frac{\sigma_h \alpha_w (1-\beta(1-\alpha_w))}{(\sigma_h+\sigma_w)(1-\alpha_w)} \left(\frac{1}{\sigma_h}\widehat{h}^*_t + \frac{1}{\sigma}\widehat{c}^*_t - \psi_{hab}\frac{\sigma-1}{\sigma}\widehat{c}^*_{t-1} - \widehat{w}^*_t \right) + \beta E_t \widehat{\pi}^*_{w,t+1}, \tag{21}$$

$$\widehat{w}^*_t = \widehat{w}^*_{t-1} + \widehat{\pi}^*_{w,t} - \widehat{\pi}^*_t. \tag{22}$$

2.3 Final-Goods-Producing Firms

The representative final-goods-producing firm combines intermediate goods produced at home and abroad to produce a final good. Trade takes place at the aggregate level. The home and foreign intermediates are aggregated using a CES technology:

$$y_{hd,t} = \left(\int_0^1 (y_{hd,t}(i))^{\frac{\sigma_d}{\sigma_d - 1}} di \right)^{\frac{\sigma_d - 1}{\sigma_d}}, \tag{23}$$

$$y^*_{fd,t} = \left(\int_0^1 (y^*_{fd,t}(i))^{\frac{\sigma_d}{\sigma_d - 1}} di \right)^{\frac{\sigma_d - 1}{\sigma_d}}. \tag{24}$$

The associated price indices are the following:

$$P_{hd,t} = \left(\int_0^1 (P_{hd,t}(i))^{1-\sigma_d} di \right)^{\frac{1}{1-\sigma_d}}, \tag{25}$$

$$P^*_{fd,t} = \left(\int_0^1 (P^*_{fd,t}(i))^{1-\sigma_d} di \right)^{\frac{1}{1-\sigma_d}}. \tag{26}$$

We assumed that final goods firms operate a CES production function in the two intermediate goods. In addition, we assumed that this sector is perfectly competitive. Hence, we can write the representative firm's problem mathematically as

$$\max p_{h,t} y_{h,t} - p_{hd,t} y^h_{hd,t} - \frac{p^*_{fd,t}}{q_t} y^{*,h}_{fd,t} \tag{27}$$

subject to

$$y_{h,t} = \left(\omega y^{h \frac{\sigma_i - 1}{\sigma_i}}_{hd,t} + (1-\omega) y^{*,h \frac{\sigma_i - 1}{\sigma_i}}_{fd,t} \right)^{\frac{\sigma_i}{\sigma_i - 1}}, \tag{28}$$

where ω is the weight of domestic intermediates in the domestic final goods production, σ_i is the elasticity of substitution between home and foreign intermediates, y_h is the output of the home final goods, y_{hd}^h is the amount of domestic intermediates used in the home economy, $y_{fd}^{*,h}$ is the amount of foreign intermediates used in the home economy, p_d is the relative price of domestic intermediates, and $\frac{p_{fd}^*}{q}$ is the relative price (in domestic currency) of imported foreign intermediates. The first-order conditions for this problem imply that

$$p_{h,t}^{1-\sigma_i} = \omega^{\sigma_i} p_{hd,t}^{1-\sigma_i} + (1-\omega)^{\sigma_i} \left(\frac{p_{fd,t}^*}{q_t}\right)^{1-\sigma_i}. \quad (29)$$

The foreign analogue of this equation is

$$p_{f,t}^{*1-\sigma_i} = \omega^{*\sigma_i} \left(p_{fd,t}^*\right)^{1-\sigma_i} + (1-\omega^*)^{\sigma_i} \left(p_{hd,t} q_t\right)^{1-\sigma_i}, \quad (30)$$

where ω^* is the weight of foreign intermediates in the foreign final goods production and p_{fd}^* is the relative price of foreign intermediates.

2.4 Intermediate-Goods-Producing Firms

There is a continuum of monopolistically competitive firms, each supplying a single differentiated intermediate good using oil and labor only. Production technology for firm i is given by the following equation:

$$y_{hd,t}(i) = A_t \left(\psi_{y,o} O_{hd,t}(i)^{\frac{\sigma_o - 1}{\sigma_o}} + (1-\psi_{y,o}) h_t(i)^{\frac{\sigma_o - 1}{\sigma_o}}\right)^{\frac{\sigma_o}{\sigma_o - 1}}, \quad (31)$$

where $O_{d,t}(i)$ is the oil demand for firm i; $h_t(i)$ is the labor demand of firm i, and $h_t(i) = [\int_0^1 h_{t,i}(j)^{\frac{\sigma_w - 1}{\sigma_w}} dj]^{\frac{\sigma_w}{\sigma_w - 1}}$, where $h_{t,i}(j)$ is the labor of household j employed by firm i; and A_t is an exogenous technology process. The cost minimization of firm i gives us

$$\frac{O_{hd,t}(i)}{h_t(i)} \left(\frac{p_{o,t}}{w_t}\right)^{\sigma_o} = \left(\frac{\psi_{y,o}}{1-\psi_{y,o}}\right)^{\sigma_o}, \quad (32)$$

$$h_{t,i}(j) = \left(\frac{w_t(i)}{w_t}\right)^{-\sigma_w} h_t(i). \quad (33)$$

Equation (32) shows that the oil–labor ratio is identical for all intermediate firms, which means that marginal cost is also identical for all firms:

$$mc_{hd,t} = \frac{1}{A_t}\left(\psi_{y,o}^{\sigma_o} p_{o,t}^{1-\sigma_o} + (1-\psi_{y,o})^{\sigma_o} w_t^{1-\sigma_o}\right)^{\frac{1}{1-\sigma_o}}. \qquad (34)$$

Intermediate firms have market power and choose their prices via maximization of discounted profits. But, as in Calvo (1983), we assumed that only a fraction of intermediate firms (denoted by $(1-\alpha_h)$) can change their prices each quarter. Following Smets and Wouters (2003) and Christiano, Evans, and Eichenbaum (2005), we also assumed that prices of firms that cannot change their prices are indexed to last period's inflation—i.e., $P_{hd,t} = P_{hd,t-1}(\frac{P_{hd,t-1}}{P_{hd,t-2}})^{\gamma_h}$ and γ_h is the degree of indexation. Profit maximization of firm i leads to the following first-order condition:

$$E_t \sum_{r=0}^{\infty} (\beta\alpha_h)^r U_c(c_{t+r}) y_{hd,t+r}(i) \left(\frac{\tilde{p}_{hd,t}(i)}{P_{hd,t+r}} p_{hd,t+r} \left(\frac{P_{hd,t-1+i}}{P_{hd,t-1}}\right)^{\gamma_h} - \frac{\sigma_d}{\sigma_d - 1} mc_{hd,t+r}\right) = 0. \qquad (35)$$

The aggregate price index of home intermediate goods (in accordance with equation (25)) is given by

$$P_{hd,t}{}^{1-\sigma_d} = \alpha_h \left(P_{hd,t-1}\left(\frac{P_{hd,t-1}}{P_{hd,t-2}}\right)^{\gamma_h}\right)^{1-\sigma_d} + (1-\alpha_h)(\tilde{p}_{hd,t}(i))^{1-\sigma_d}. \qquad (36)$$

Based on the above equations, we could derive the log-linearized Phillips curve (around the steady state) for home intermediates:

$$\widehat{\pi}_{hd,t} = \frac{1}{1+\beta\gamma_h}\frac{(1-\beta\alpha_h)(1-\alpha_h)}{\alpha_h}(\widehat{mc}_{hd,t} - \widehat{p}_{hd,t}) + \frac{\gamma_h}{(1+\beta\gamma_h)}\widehat{\pi}_{hd,t-1} + \frac{\beta}{(1+\beta\gamma_h)} E_t\widehat{\pi}_{hd,t+1}, \qquad (37)$$

where $\widehat{\pi}_{hd,t}$ represents inflation of home intermediates. The foreign analogue of this equation is

$$\widehat{\pi}^*_{fd,t} = \frac{1}{1+\beta\gamma^*_f}\frac{\left(1-\beta\alpha^*_f\right)\left(1-\alpha^*_f\right)}{\alpha^*_f}\left(\widehat{mc}^*_{fd,t} - \widehat{p}^*_{fd,t}\right) + \frac{\gamma^*_f}{\left(1+\beta\gamma^*_f\right)}\widehat{\pi}^*_{fd,t-1} + \frac{\beta}{\left(1+\beta\gamma^*_f\right)}E_t\widehat{\pi}^*_{fd,t+1}, \quad (38)$$

where $\widehat{\pi}^*_{fd,t}$ represents inflation of foreign intermediates.

2.5 Oil Producer

The oil-producing country spends its revenues on final goods produced in the two countries. To keep things simple, we supposed that the representative consumer in this country maximizes the following utility function:

$$\max E_t \sum_{r=0}^{\infty} \beta^r c_{O,t}, \quad (39)$$

where $c_{O,t} = ((1-\omega_O)(c_{O,h,t+r})^{\frac{\sigma_{c,O}-1}{\sigma_{c,O}}} + \omega_O(c_{O,f,t+r})^{\frac{\sigma_{c,O}-1}{\sigma_{c,O}}})^{\frac{\sigma_{c,O}}{\sigma_{c,O}-1}}$ and $\sigma_{c,O}$ is the elasticity of substitution between home and foreign goods in the oil-producing country, ω_O is the share of foreign goods in the consumer's basket, $c_{O,h}$ is the consumer's consumption of the home country's goods, and $c_{O,f}$ is the consumer's consumption of the foreign country's goods. The consumer's budget constraint is given by

$$p_{o,t+r}O_{t+r} = p_{h,t+r}c_{O,h,t+r} + \frac{p_{f,t+r}}{q_{t+r}}c_{O,f,t+r} = \frac{c_{O,t+r}}{q_{O,t+r}}, \quad (40)$$

where O is the (exogenous) supply of oil, q_O is the real exchange rate between the oil producer and the home economy, and we assumed that oil is costless to transport and that the oil producer does not have access to world capital markets; the oil producer simply recirculates the revenues from its production of oil. Solving this problem implies that

$$c_{O,h} = (1-\omega_O)^{\sigma_{c,O}}(p_h q_O)^{-\sigma_{c,O}}c_O, \quad (41)$$

$$c_{O,f} = \omega_O^{\sigma_{c,O}} \left(\frac{p_f q_O}{q} \right)^{-\sigma_{c,O}} c_O, \tag{42}$$

and the price index is given by

$$1 = \omega_O^{\sigma_{c,O}} \left(\frac{q_O p_f}{q} \right)^{1-\sigma_{c,O}} + (1 - \omega_O)^{\sigma_{c,O}} (q_O p_h)^{1-\sigma_{c,O}}. \tag{43}$$

2.6 Monetary Policy

The central bank in each country was assumed to operate a Taylor rule:

$$\widehat{r}_t = \rho_m \widehat{r}_{t-1} + (1 - \rho_m) \phi_\pi \widehat{\pi}_t, \tag{44}$$

$$\widehat{r}_t^* = \rho_m^* \widehat{r}_{t-1}^* + \left(1 - \rho_m^*\right) \phi_\pi^* \widehat{\pi}_t^*, \tag{45}$$

where ρ_m and ρ_m^* are the smoothing parameters and ϕ_π and ϕ_π^* are the weights on inflation in the Taylor rule.

2.7 Market Clearing and Some Definitions

We assumed that in the steady state, neither country is a net borrower from or net lender to the other country; that is, $B = 0$. Out of the steady state, if the home economy is running a current account deficit, it will sell domestic bonds to foreign economy; if it is running a surplus, it will buy domestic bonds from foreign households. Of course, the world as a whole cannot borrow. Hence, we have the world aggregate resource constraint:

$$c_t + \frac{c_t^*}{q_t} = p_{hd,t} y_{hd,t} + \frac{p_{fd,t}^*}{q_t} y_{fd,t} - p_{o,t} \left(O_{hd,t} + O_{fd,t}^* \right). \tag{46}$$

The following set of equations represents the market clearing conditions for the final goods market in the two countries, the intermediate goods market in the two countries, and the market for oil:

$$y_{h,t} = c_{h,t} + c_{O,h,t}, \tag{47}$$

$$y_{f,t}^* = c_{f,t} + c_{O,fd,t}^*, \tag{48}$$

$$O_t = O_{hd,t} + O_{fd,t}^* + c_{o,t} + c_{o,t}^*. \tag{49}$$

Finally, we present the definition of consumer price inflation (CPI) and its components (in the log-linearized form). Consumer price inflation is a weighted average of non-oil and oil inflation:

$$\widehat{\pi}_t = d_h \widehat{\pi}_{h,t} + d_o \widehat{\pi}_{o,t}, \tag{50}$$

where the weights represent steady-state ratios: $d_h = (1 - \psi_{c,o})^{\sigma_c} \overline{p}_h^{1-\sigma_c}$ and $d_o = \psi_{c,o}^{\sigma_c} \overline{p}_o^{1-\sigma_c}$. Non-oil inflation is a weighted average of domestically produced intermediate inflation and imported intermediate inflation:

$$\widehat{\pi}_{h,t} = d_{hd} \widehat{\pi}_{hd,t} + d_{fd} \big(\widehat{\pi}^*_{fd,t} - \widehat{\Delta S}_t \big), \tag{51}$$

where the weights are $d_{hd} = \omega^{\sigma_i} \frac{\overline{p}_{hd}^{1-\sigma_i}}{\overline{p}_h}$ and $d_{fd} = (1-\omega)^{\sigma_i} \left(\frac{\overline{p}^*_{fd}}{\overline{q p_h}} \right)^{1-\sigma_i}$. Similar relations hold for the foreign economy.

2.8 Equilibrium

An equilibrium in this world is one in which consumers in both economies are maximizing their utilities, firms in both countries are maximizing their profits, and trade is balanced. In the appendix, we present the steady-state equations of the model together with the log-linearized equations that represent its equilibrium.

3. Calibration

The values of our parameters are shown in table 1. The home economy represents G-7 countries, and the foreign economy represents BRIC countries. We took the United States as a representative G-7 economy. Our calibration thus follows Smets and Wouters (2007) and Bodenstein, Erceg, and Guerrieri (2011), as in these papers the home economy is calibrated based on U.S. data. We divide the description of our calibration into three parts: parameters that are common across countries, parameters that are specific to countries, and the nominal environment parameters. Parameters that are specific to countries are the ones that describe shares of oil and imports in the economies. Here we try to capture the average oil and import shares in the G-7 economies (for our home economy) and the BRIC economies (for our foreign economy).

Table 1. Parameter Values

Description	Parameter	Description	Parameter
Parameters Common Across Countries			
Discount Rate	$\beta = 0.99$	Inter. Elasticity of Substitution	$\sigma = 0.66$
External Habits in Consumption	$\psi_{hab} = 0.8$	Cost of Holding Home Bonds	$\chi_{bf} = 0.01$
Labor Supply Elasticity	$\sigma_h = 0.5$	Labor Demand Elasticity	$\sigma_w = 6.4$
Demand Elasticity btw. Differentiated Goods	$\sigma_d = 10$	Oil Sub. Elasticity	$\sigma_o = 0.4$
Sub. Elasticity between H and F Goods	$\sigma_i = 1.5$		
Parameters Specific to Countries			
Weight of Oil in Consumption (H)	$\psi_{c,o} = 0.021$	Weight of Oil in Consumption (F)	$\psi^*_{c,o} = 0.0915$
Weight of Oil in Production (H)	$\psi_{y,o} = 0.008$	Weight of Oil in Production (F)	$\psi^*_{y,o} = 0.095$
Weight of Imports in Production (H)	$\omega = 0.67$	Weight of Imports in Production (F)	$\omega^* = 0.82$
Weight of Foreign Goods in the Utility (O)	$\omega_O = 0.5$		
Nominal Environment			
Probability of Not Changing Wage (H)	$\alpha_w = 0.73$	Probability of Not Changing Wage (F)	$\alpha^*_w = 0.73$
Probability of Not Changing Price (H)	$\alpha_h = 0.65$	Probability of Not Changing Price (F)	$\alpha^*_f = 0.65$
Degree of Price Indexation (H)	$\gamma_h = 0.22$	Degree of Price Indexation (F)	$\gamma^*_f = 0.22$
Interest Rate Smoothing Parameter (H)	$\rho_m = 0.8$	Interest Rate Smoothing Parameter (F)	$\rho^*_m = 0.8$
Weight on Inflation in the Int. Rule (H)	$\o_\pi = 2$	Weight on Inflation in the Int. Rule (F)	$\o^*_\pi = 2$

Following Bodenstein, Erceg, and Guerrieri (2011), we set the discount factor, β, to 0.99, implying a risk-free rate of around 4 percent per annum; the intertemporal elasticity of substitution, σ, to 0.66; and the external habits term on aggregate consumption, ψ_{hab}, to 0.8. We set values of κ_h and κ_f^* to ensure that the labor supply is unity in the steady state. Following Smets and Wouters (2007), we set the labor supply elasticity, σ_h, to 0.5 and the elasticity of labor demand, σ_w, to 6.4, implying wage markups of 1.2. We set the steady-state markups for the domestic and foreign intermediate-goods-producing firms to 1.11, which implies a value for σ_d of 10. We set the elasticity of substitution between labor and oil, σ_o, to 0.4. This number was taken from Bodenstein, Erceg, and Guerrieri (2011) and is similar to the long-run elasticity for crude oil as reported by Cooper (2003). The short-run elasticity of oil is much smaller (i.e., for the United States, the long-run elasticity is 0.45 while the short-run elasticity is 0.06, as noted by Cooper 2003), and thus we performed a sensitivity analysis on this parameter. Following Bodenstein, Erceg, and Guerrieri (2011), we decided to set the same value for the elasticity of substitution between produced final goods and oil in consumption—i.e., $\sigma_c = 0.4$. Following Hooper, Johnson, and Marquez (2000), who estimate long-run trade elasticities for G-7 countries, we set the elasticity of substitution between home and foreign goods, σ_i, to 1.5. Similarly, we set the elasticity of substitution between final goods for the oil producer, $\sigma_{c,O}$, to 1.5.

Parameters governing shares of imports were set to match shares of imports in GDP in G-7 and BRIC countries, which equaled 22 percent and 11 percent, respectively, from 2006 to 2010.[4] Shares of oil in consumption and production were set following Bodenstein, Erceg, and Guerrieri (2011). We set $\psi_{y,o}$ equal to 0.028 and $\psi_{c,o}$ equal to 0.023, implying a share of oil in gross output in the home economy of 4.2 percent, where one-third is used by households and the rest by firms. Similarly, for the foreign economy, we set $\psi^*_{y,o}$ equal to 0.057 and $\psi^*_{c,o}$ equal to 0.041, implying a share of oil in gross output in the foreign economy of 8.2 percent. Finally, we assumed that the oil producer spends half its income on each country's goods—that is, we set ω_O to 0.5. This parameter was set ad hoc, but our

[4]Source: Datastream.

sensitivity analysis showed that changes in values of this parameter do not affect substantially our results.

The nominal environment is described by parameters governing nominal wage and price rigidities and monetary policy. Because of a lack of data on BRIC economies, we used values from Smets and Wouters (2007) for both countries. We set the Calvo price parameters, α_h and α_f^*, to 0.65, implying that prices are, on average, reset once every three quarters. In addition, we set the price indexation parameters, γ_h and γ_f^*, to 0.22. We set the Calvo wage parameters, α_w and α_w^*, to 0.73, implying that wages are also adjusted every four quarters on average. Monetary policy followed a Taylor rule with interest-rate-smoothing parameter $\rho_m = 0.8$ and inflation coefficient $\rho_\pi = 2$.

4. Tailwinds vs. Headwinds

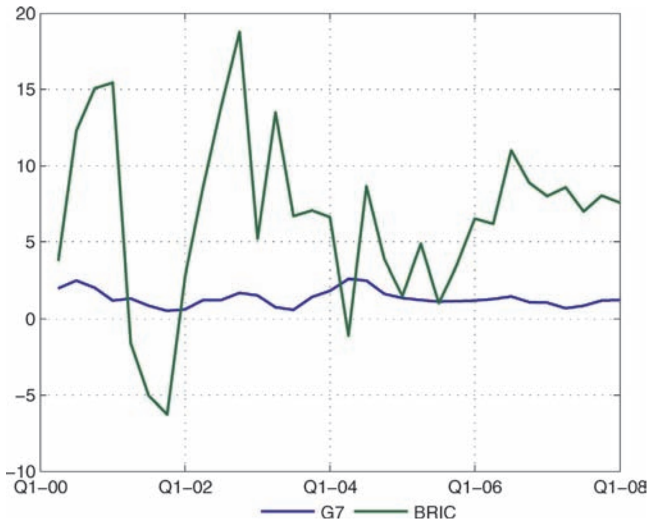
In this section, we use our model to answer the following question: Under what conditions might we expect the increase in productivity in the BRIC economies we have seen over recent years to lead to higher or lower inflation in the G-7?

4.1 Baseline Results

Figure 5 shows that the BRIC productivity growth has been consistently higher than that in the G-7 for most of the past decade. Moreover, from 2006 to 2008, the average productivity growth in BRIC countries increased. In this subsection, we consider the effects of a 1 percent shock to the foreign productivity level. We assume that the shock follows an AR(1) process with the autoregressive coefficient equal to 0.99. This assumption ensured that the effects of the shock would be felt for a long period of time; specifically, seventeen years after the initial shock, foreign productivity has grown by 50 percent more than home productivity.

Figure 6 shows the effects of the foreign productivity shock on home and foreign real and nominal variables. As can be seen, the shock leads to a temporary reduction in both home and foreign CPI inflation. This is driven mainly by falling home import inflation, which drops on impact to around 0.75 percent below its initial steady-state level. The foreign productivity increase leads to a

Figure 5. Four-Quarter Productivity Growth



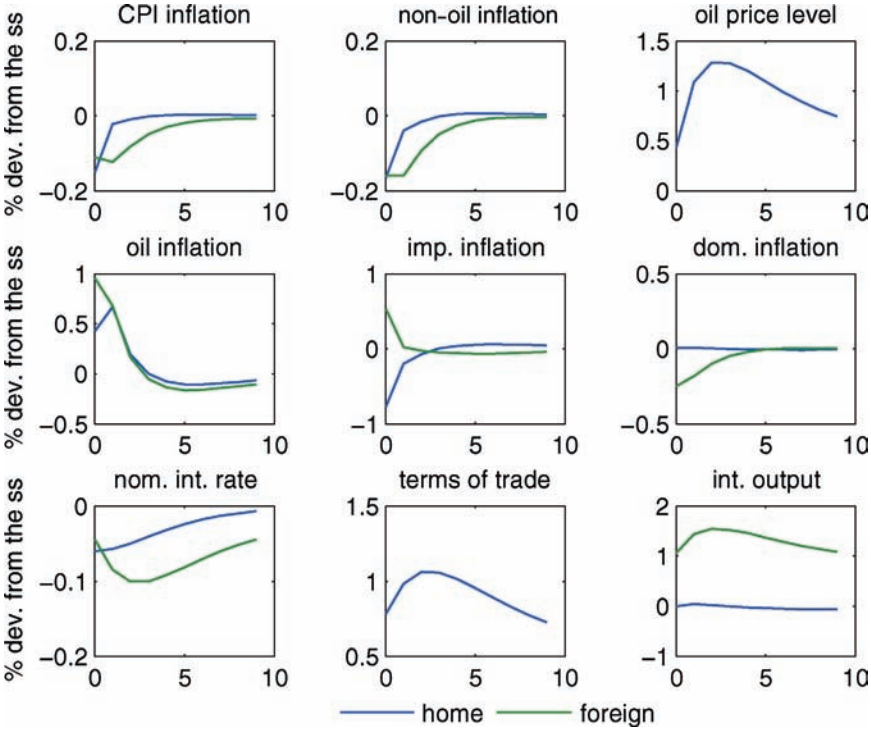
Data Source: Datastream.

decrease in foreign marginal cost and makes foreign goods cheaper. In our calibration, home and foreign goods are substitutes, and thus home consumers switch to foreign goods. Foreigners invest some of their increased wealth in home bonds, further facilitating a rise in home consumption, which leads to appreciation of domestic terms of trade and a decline in home output.[5] The appreciation of terms of trade leads to lower import prices and thus lower CPI inflation. This result is the tailwind effect of the foreign productivity shock.

But what is going on with oil prices? They rise and stay high for a couple of years. Oil prices are initially lower due to nominal and real rigidities that make demand for factor inputs decline after

[5]Note that this result depends crucially on our assumption that home and foreign goods are substitutes. This assumption in turn is governed by two parameters: intertemporal and intratemporal elasticities of substitution, which determine whether home and foreign goods are substitutes or complements in the utility. Two goods are substitutes in the utility when the marginal utility of one good decreases as the consumption of the other good increases; see Benigno and Benigno (2003).

Figure 6. The Effects of Foreign Productivity Shock on Home and Foreign Variables



the productivity increase (see Galí 1999).[6] The extent of the oil price increase also depends crucially on the degree of substitutability between oil and labor. Since oil and labor are complements, as demand for foreign goods increases, demand for both factor inputs in foreign production increases, which leads to a further increase in the price of oil. Moreover, the change in oil prices is also affected by the

[6]Note that the oil price increases by 1.2 percent at its peak in the third quarter after the shock hits. This rise may seem very small in comparison with the behavior of oil prices shown in figure 3. A shock to productivity growth would have potential for a larger increase in oil prices. However, this experiment would require the introduction of growth in the steady state. Yet, in our framework, we can approximate the shock to productivity growth by a series of consecutive 1 percent increases in the foreign productivity level. The approximation of this shock for ten years will result in an increase of oil prices by 60 percent. A similar point has been made by Campolmi (2008).

degree of substitution between home and foreign goods. That degree of substitution determines changes in home and foreign output and thus the overall demand for oil (more discussion on this point is in subsection 4.2).

The rise in oil prices acts to raise CPI inflation directly, via the effect on petrol prices, and indirectly, via the effect on marginal cost for intermediate producers. These channels combine to produce a headwind effect of the foreign productivity shock. Note also that while the tailwind effect is immediate, the headwind effect is delayed due to a hump-shaped response of oil prices.

Given our baseline calibration, we see that the tailwind effect outweighs the headwind effect and that home aggregate inflation is temporarily lowered relative to its steady-state rate. In our calibration, monetary policy follows a Taylor rule in each country, where interest rates respond to fluctuations in aggregate inflation. As a result, nominal interest rates in both countries fall. The decline is larger in the foreign country, in line with the decline in foreign marginal cost and foreign inflation. This decrease produces an appreciation of the home country's nominal exchange rate.

In the next subsection, we examine how sensitive these results are to our calibrated parameter values. In particular, we ask the following question: Under what conditions might the headwinds outweigh the tailwinds and inflation be raised relative to its steady state?

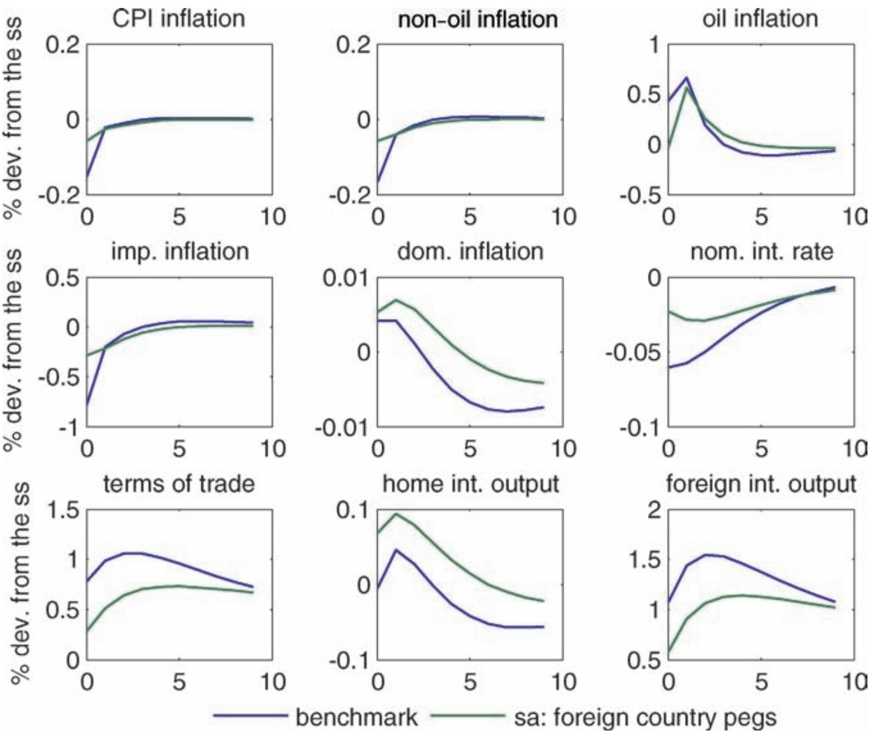
4.2 Sensitivity

In this subsection, we consider the sensitivity of our results—particularly the relative importance of headwinds and tailwinds—to changes in key parameters. In particular, we consider the effects of alternative foreign monetary policy, alternative elasticities of substitution between oil and labor, making flexible wages, variations in the degree of financial integration between our economies, and degree of substitution between home and foreign goods.

We start by supposing that the foreign economy pegs its exchange rate to the home economy. Following Benigno, Benigno, and Ghironi (2007), the foreign peg can be described by the interest rule

$$(1 + r_t) = \left(1 + r_t^*\right)\phi\left(\frac{S_t}{\overline{S}}\right), \tag{52}$$

Figure 7. Benchmark Case versus the Case When Foreign Country Pegs



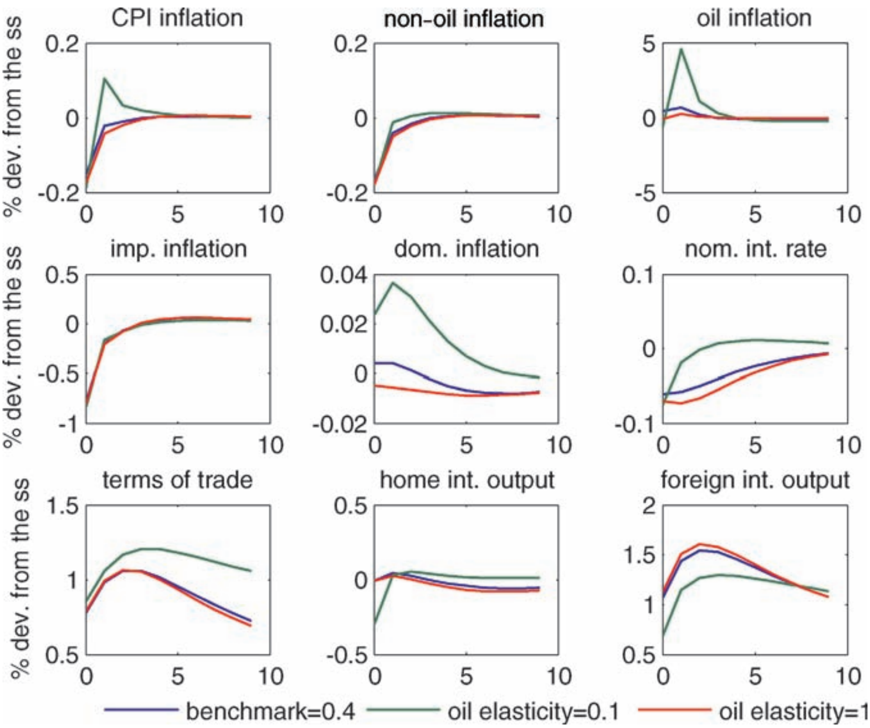
where function $\phi(.)$ is continuous, differentiable, and strictly increasing in a neighborhood of $\overline{S}$.[7] This rule means that foreign monetary policy will depend on domestic monetary policy. Figure 7 shows the responses of nominal and real variables to a foreign productivity shock with the foreign economy pegging its exchange rate. Foreign monetary policy response will be tight relative to the benchmark case, since the foreign central bank cannot lower its nominal interest rate (in order to match the fall in the natural real interest rate) because doing so would lead to a nominal depreciation. As a result,

[7] Benigno, Benigno, and Ghironi (2007) show that given the properties of function $\phi(.)$, there exists only one path in which the nominal exchange rate remains always fixed.

foreign output and, hence, oil prices will not increase as much as in the benchmark case. So on the one hand, a smaller tailwind effect will be coming from lower foreign output, and on the other hand, a smaller headwind effect will be coming from lower oil prices. Moreover, the terms-of-trade movement will be muted, and thus home output will actually increase a bit, leading to a higher increase in domestic inflation. Overall, CPI inflation decreases by less than in the benchmark case despite a smaller increase in oil prices, which will mean that the home nominal interest rate falls by less than in the benchmark case.

We next consider the effect of varying the elasticity of substitution between oil and labor. The empirical evidence on aggregate elasticity points to the fact that short-run elasticities are much smaller than long-run elasticities. Cooper (2003) finds that oil demand is highly inelastic in the short run and that the short-run elasticity is below 0.1 while the long-run elasticity is in the range of 0.2 to 0.6. Hughes, Knittel, and Sperling (2008) find that the short-run elasticity of oil differs substantially for the two recent periods of high oil prices—i.e., 2001 to 2006 and 1975 to 1980. They also find that the short-run elasticity of oil ranged between 0.034 and 0.077 for 2001 to 2006 and between 0.21 and 0.34 for 1975 to 1980. Our model does not allow for differences between short- and long-run oil elasticity. In our benchmark calibration, we set the oil elasticity to take its long-run value. However, we performed a sensitivity analysis in which we compared impulse responses under three alternative elasticities of oil and labor (see figure 8). Following Bodenstein, Erceg, and Guerrieri (2011), we analyzed elasticities lying between 0.1 and 1. A smaller value of elasticity between oil and labor is well suited to studying the short-run effects of the foreign productivity shock. In this situation, the foreign productivity increase leads to a stronger increase in demand for both oil and labor. The result is higher oil prices, and the headwind effect is stronger. At the same time, as oil prices rise more with the increase in foreign output, foreign output actually increases by less than in the benchmark, implying that the tailwind effect coming from cheaper foreign goods is going to be smaller. The overall effect is that, although the tailwind effect dominates in the first quarter, the headwind effect becomes more important once oil prices reach their peak, leading to an increase in CPI inflation in the next quarters.

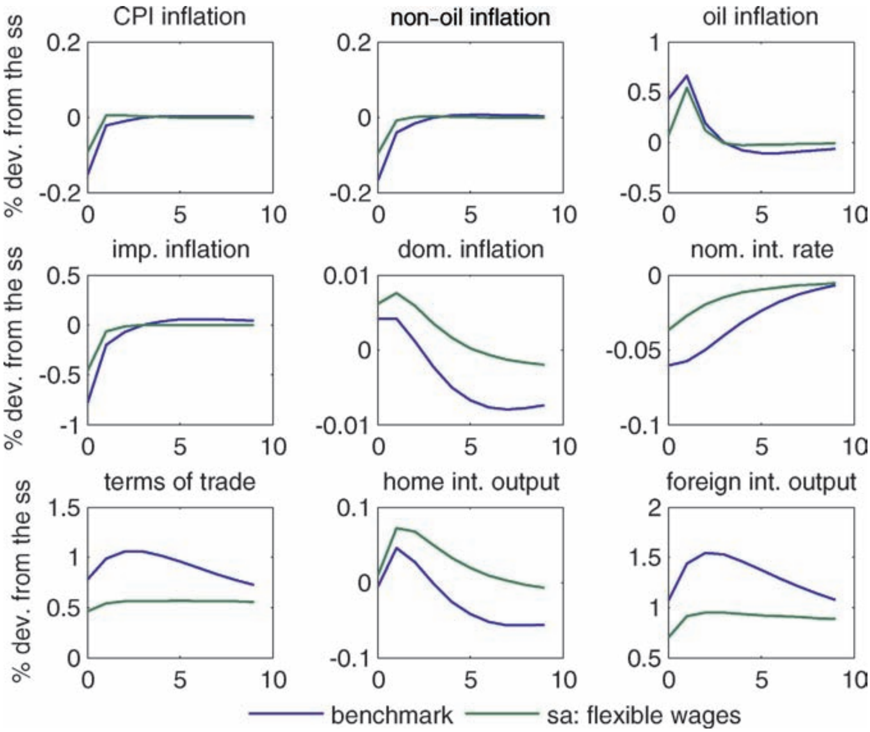
Figure 8. Varying Elasticity of Substitution between Oil and Labor



A higher elasticity between oil and labor means that oil prices will not increase by as much as in the benchmark case. In this situation, the foreign productivity increase will lead to a relatively much higher increase in demand for labor at the expense of oil. This development will have a stimulating effect on home output and will lead to a smaller marginal cost at home compared with the benchmark. As a result, domestic inflation will be smaller, which will translate into a reduced headwind effect and lower home CPI inflation.

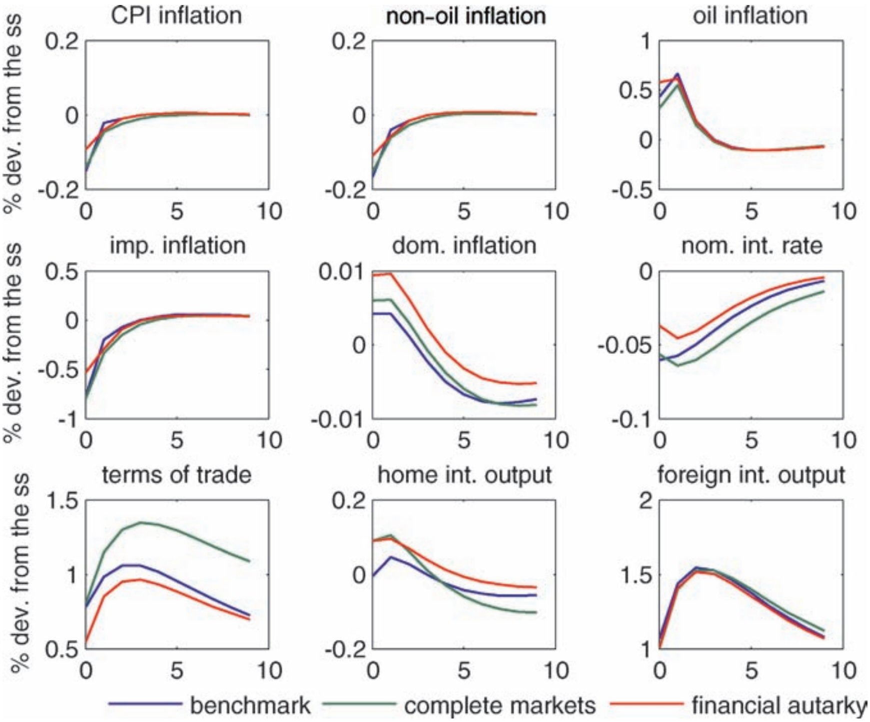
Blanchard and Galí (2010) argue that one of the factors that led to the recent rise in oil prices having a smaller effect on the world economy has been the increased flexibility in labor markets. In figure 9, we compare the effects of a foreign productivity shock when wages are perfectly flexible in both economies with our benchmark case. Real wages adjust quickly—i.e., foreign real wages increase on

Figure 9. Benchmark Case versus the Case When Wages Are Flexible



impact by more than in the benchmark case. This outcome limits the increase in foreign output and in foreign demand for oil. As a result, oil prices increase by less. The headwind effect coming from wages dominates the tailwind effect of lower oil prices and thus makes import prices at home decrease by less than in the benchmark, implying that the expenditure switching effect is reduced. However, this reduction is not enough to boost home intermediate output. Home intermediate output declines on impact as a result of the diminished final home demand (coming from higher import prices than in the benchmark). Yet wages at home rise, which results in higher domestic inflation. The net result is that although oil prices are smaller than in the benchmark, import inflation at home declines by less and domestic inflation increases by more. This result leads to a smaller decline in CPI inflation on impact than in the benchmark, followed

Figure 10. Varying Degree of Financial Integration

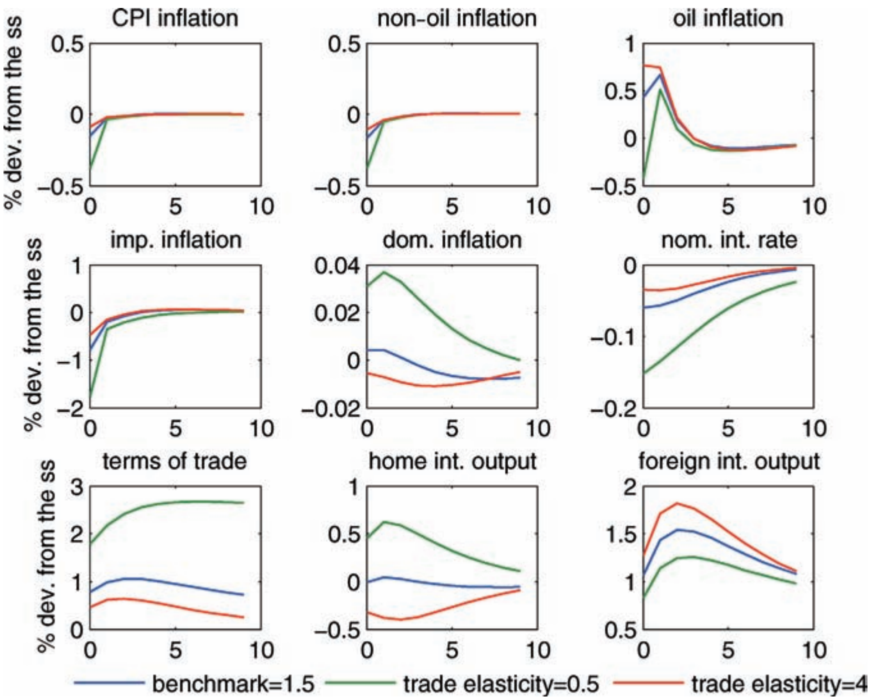


by a small increase in subsequent periods. We note that this finding contrasts with Blanchard and Galí (2010). However, Blanchard and Galí (2010) consider a different type of shock, which in our framework would qualify as a shock to oil supply.

As described earlier, the tailwind effect of the foreign productivity shock depends on the strength of the expenditure switching toward foreign goods by home consumers. This effect in turn depends on the degree of financial integration between two economies and the degree of substitutability between home and foreign goods.

We compared our benchmark result concerning incomplete financial markets with two extreme cases of complete markets and financial autarky in figure 10. Under financial autarky, home consumers cannot benefit from cheaper foreign goods since trade has to be in balance. This constraint means that foreign output increases by less, which is reflected in smaller appreciation of terms of trade than in the

Figure 11. Varying Elasticity of Substitution between Home and Foreign Goods



benchmark. Consistently, the fall in import prices is less marked. As a result, home output actually increases, which is reflected in higher marginal cost and higher domestic inflation than in the benchmark. As a consequence, the decline in CPI inflation will be much smaller. In the case of complete markets, the expenditure switching effect is the strongest, which is reflected in the strong appreciation of home terms of trade and a fall in home output. Thus, the decline in CPI inflation is the highest.

There is no consensus in the literature on the value for the degree of substitutability between home and foreign goods. For example, Obstfeld and Rogoff (2000a) say that according to micro studies, the elasticity of substitution should be between 4 and 6. However, Corsetti, Dedola, and Leduc (2008) argue that assuming a low elasticity of substitution—i.e., below 0.5—helps reconcile with the international business-cycle stylized facts. Figure 11 compares our

Table 2. Sensitivity Analysis

Assumptions	Tailwinds	Headwinds		Effect on CPI Inflation
		Direct	Indirect	
Foreign Peg	↓	↓	↑	Decrease
Flexible Wages	↓	↓	↑	Increase
Low Oil Elasticity	↓	↑	↑	Increase
Financial Autarky	↓	↓	↑	Decrease
High Trade Elasticity	↓	↑	↓	Decrease

Notes: Tailwind effect refers to a decreased import inflation. Direct headwind effect refers to an increased oil inflation. Indirect headwind effect refers to an increased non-oil domestic inflation. Arrow down means that the effect is smaller. Arrow up means that the effect is bigger.

benchmark case with two alternative assumptions about elasticity of substitution: a low elasticity of 0.5 and a high elasticity of 4.

The high-elasticity case results in the smallest decline of home aggregate inflation, while the low-elasticity case leads to the highest decline in CPI inflation. This finding is due to the fact that when home and foreign goods are complements, a foreign productivity shock actually stimulates home output despite a stronger appreciation of terms of trade than in the benchmark. Home output increases because now home consumers do not want to switch to foreign goods at the expense of home goods but rather demand more of both types of goods. At the same time, import prices fall by more than in the benchmark (since home and foreign goods are complements). This fall is persistent, which produces a stronger tailwind effect for home aggregate inflation. The opposite situation occurs for the high-elasticity case.

In this section, we have analyzed how different assumptions about the structural properties of the model affect our benchmark results. Findings are summarized in table 2. We have identified factors that diminish the importance of the tailwind effect. But assuming only a low oil elasticity or a flexible labor market can result in an increased headwind effect that outweighs the tailwind effect and thus leads to an increase in home CPI inflation. This increase is delayed due to a hump-shaped response of oil prices.

5. Conclusions

In this paper, we analyzed the impact of a large productivity increase in a set of countries—which we thought of as the BRIC economies—on inflation in their trading partners, the G-7. We used a three-country DSGE model in which there are two symmetric oil-importing economies (home and foreign) and one oil-exporting country. We performed several experiments in which we disentangled the importance of different factors that shape inflation dynamics in the home country. We found that, in our baseline calibration, the foreign productivity shock resulted in a temporary fall in home CPI inflation: The favorable tailwind coming from the BRIC economies outweighed the headwind. This fall lasted only five quarters, since the home central bank was assumed to stabilize inflation. Our robustness analysis suggested that this result depends on the elasticity between oil and labor, home and foreign monetary policy, degree of labor market flexibility, degree of financial integration, and trade elasticity between home and foreign goods. We also found that the short-run value of the elasticity of oil or a flexible labor market leads to a headwind effect, which outweighs the immediate impact of the tailwind effect in the subsequent periods.

Although these results are certainly suggestive, an exact quantification of the effects of the rise of the BRIC economies would require a more in-depth estimation of asymmetries between the developed and developing economies. Moreover, it would be important to introduce productivity growth shocks and allow for different short- and long-run elasticities of oil. In addition, we could consider different pricing strategies of the exporting firms in our model.[8] This analysis has been left for future work. Finally, we have neglected the extensive margin of trade—that is, the creation and destruction of varieties of products. Recent work by Sbordone (2007) and Monacelli (2010) has emphasized the effects of this additional margin on the slope of the Phillips curve, and Corsetti (2007) has shown that the transmission of productivity shocks will depend on whether such shocks enhance efficiency or lower entry costs. It would be well worth investigating

[8]Rigobon and Gopinath (2008) find that in the case of the United States, exporting firms choose producer currency pricing, while the U.S. importing firms choose local currency pricing.

the effects that this margin might have on the relative importance of headwinds and tailwinds in domestic inflation.

Appendix

Steady State

We derived a deterministic steady state with a zero inflation rate. All the shocks A, A^*, and O took constant values. We denoted all steady-state variables with a bar. In the benchmark calibration, all elasticities were the same for the home and foreign economies.

The steady state can be defined as a solution to a system of equations that represent price aggregators, labor supply optimality conditions, factor demands, demand equations for both intermediate and final goods, an oil market clearing condition, and asset market conditions.

We present price aggregators in the home and foreign economies and the oil-producing economy. It is useful to define different bilateral real exchange rates: $q = \frac{PS}{P^*}$, where S represents the cost of one unit of P (aggregate price level in home economy) in terms of P^* (aggregate price level in the foreign economy); $q_O = \frac{PS_O}{P^O}$, where S_O represents the cost of one unit of P in terms of P^O (aggregate price level in the oil-producing economy); and $q_O^* = \frac{P^* S_O^*}{P^O}$, where S_O^* represents the cost of one unit of P^* in terms of P^O. As a result, we find the following relation between bilateral real exchange rates:

$$\overline{q}_O^* = \frac{\overline{q}_O}{\overline{q}}. \tag{53}$$

Price aggregators for final goods:

$$1 = (1 - \psi_{c,o})^{\sigma_c} \overline{p}_h^{1-\sigma_c} + \psi_{c,o}^{\sigma_c} \overline{p}_o^{1-\sigma_c}, \tag{54}$$

$$1 = \left(1 - \psi_{c,o}^*\right)^{\sigma_c} \left(\overline{p}_f^*\right)^{1-\sigma_c} + \left(\psi_{c,o}^*\right)^{\sigma_c} \left(\overline{p}_o^*\right)^{1-\sigma_c}, \tag{55}$$

where $\overline{p}_o^* = \overline{p}_o \overline{q}$.

$$1 = \omega_O^{\sigma_{c,O}} \left(\overline{q}_O^* \overline{p}_f^*\right)^{1-\sigma_{c,O}} + (1 - \omega_O)^{\sigma_{c,O}} (\overline{q}_O \overline{p}_h)^{1-\sigma_{c,O}}. \tag{56}$$

Price aggregators for intermediate goods:

$$\overline{p}_h^{1-\sigma_i} = \omega^{\sigma_i}\overline{p}_{hd}^{1-\sigma_i} + (1-\omega)^{\sigma_i}\left(\frac{\overline{p}_{fd}^*}{\overline{q}}\right)^{1-\sigma_i}, \tag{57}$$

$$\overline{p}_f^{*\,1-\sigma_i} = \omega^{*\sigma_i}\left(\overline{p}_{fd}^*\right)^{1-\sigma_i} + (1-\omega^*)^{\sigma_i}(\overline{p}_{hd}\overline{q})^{1-\sigma_i}. \tag{58}$$

Labor supply optimality conditions:

$$\overline{w} = \frac{\sigma_w}{\sigma_w - 1}\overline{c}^{\frac{1-\psi_{hab}(1-\sigma)}{\sigma}}\left(\frac{\overline{h}}{\kappa_h}\right)^{\frac{1}{\sigma_h}}, \tag{59}$$

$$\overline{w}^* = \frac{\sigma_w}{\sigma_w - 1}\overline{c}^{*\,\frac{1-\psi_{hab}(1-\sigma)}{\sigma}}\left(\frac{\overline{h}^*}{\kappa_h^*}\right)^{\frac{1}{\sigma_h}}. \tag{60}$$

First-order conditions of the profit maximization problem for intermediate firms determine factor demands:

$$\overline{h} = (1-\psi_{y,o})^{\sigma_o}\left(\frac{\overline{w}}{\overline{mc}_{hd}}\right)^{-\sigma_o}\overline{A}^{\sigma_o - 1}\overline{y}_{hd}, \tag{61}$$

where $\overline{mc}_{hd} = \frac{\sigma_d - 1}{\sigma_d}\overline{p}_{hd}$.

$$\overline{O}_{hd} = \psi_{y,o}^{\sigma_o}\left(\frac{\overline{p}_o}{\overline{mc}_{hd}}\right)^{-\sigma_o}\overline{A}^{\sigma_o - 1}\overline{y}_{hd}, \tag{62}$$

$$\overline{h}^* = \left(1-\psi_{y,o}^*\right)^{\sigma_o}\left(\frac{\overline{w}^*}{\overline{mc}_{fd}^*}\right)^{-\sigma_o}\overline{A}^{*\,\sigma_o - 1}\overline{y}_{fd}^*, \tag{63}$$

where $\overline{mc}_{fd}^* = \frac{\sigma_d - 1}{\sigma_d}\overline{p}_{fd}^*$.

$$\overline{O}_{fd} = \psi_{y,o}^{*\sigma_o}\left(\frac{\overline{p}_o\overline{q}}{\overline{mc}_{fd}^*}\right)^{-\sigma_o}\overline{A}^{*\,\sigma_o - 1}\overline{y}_{fd}^*. \tag{64}$$

Production functions for intermediate home and foreign goods:

$$\overline{y}_{hd} = A\left(\psi_{y,o}\overline{O}_{hd}^{\frac{\sigma_o - 1}{\sigma_o}} + (1-\psi_{y,o})\overline{h}^{\frac{\sigma_o - 1}{\sigma_o}}\right)^{\frac{\sigma_o}{\sigma_o - 1}}, \tag{65}$$

$$\overline{y}_{fd}^* = A\left(\psi_{y,o}^*\overline{O}_{fd}^{*\,\frac{\sigma_o - 1}{\sigma_o}} + \left(1-\psi_{y,o}^*\right)\overline{h}^{*\,\frac{\sigma_o - 1}{\sigma_o}}\right)^{\frac{\sigma_o}{\sigma_o - 1}}. \tag{66}$$

Demand functions for intermediate home and foreign goods:

$$\overline{y}_{hd} = \omega^{\sigma_i} \left(\frac{\overline{p}_{hd}}{\overline{p}_h}\right)^{-\sigma_i} \overline{y}_h + (1-\omega^*)^{\sigma_i} \left(\frac{\overline{p}_{hd}\overline{q}}{\overline{p}^*_f}\right)^{-\sigma_i} \overline{y}^*_f, \tag{67}$$

$$\overline{y}^*_{fd} = (1-\omega)^{\sigma_i} \left(\frac{\overline{p}^*_{fd}}{\overline{p}_h\overline{q}}\right)^{-\sigma_i} \overline{y}_h + \omega^{*\sigma_i} \left(\frac{\overline{p}^*_{fd}}{\overline{p}^*_f}\right)^{-\sigma_i} \overline{y}^*_f. \tag{68}$$

Demand functions for final home and foreign goods:

$$\overline{y}_h = (1-\psi_{c,o})^{\sigma_c}\overline{p}_h^{-\sigma_c}\overline{c} + (1-\omega_O)^{\sigma_{c,O}}(\overline{p}_h\overline{q}_O)^{-\sigma_{c,O}}\overline{c}_O, \tag{69}$$

$$\overline{y}^*_f = \left(1-\psi^*_{c,o}\right)^{\sigma_c}\overline{p}^{*\,-\sigma_c}_f\overline{c}^* + \omega_O^{\sigma_{c,O}}\left(\overline{p}^*_f\overline{q}^*_O\right)^{-\sigma_{c,O}}\overline{c}_O. \tag{70}$$

Market clearing condition for oil:

$$\overline{O} = \overline{O}_{hd} + \overline{O}_{fd} + \psi_{c,o}^{\sigma_c}\ \overline{p}_o^{-\sigma_c}\ \overline{c} + \psi_{c,o}^{*\sigma_c}(\overline{p}_o\overline{q})^{-\sigma_c}\overline{c}^*. \tag{71}$$

We assumed that in the steady state, neither country is a net borrower from or a net lender to the other country; that is, $\overline{B} = 0$. This assumption implies that in the steady state, expenditures in a given economy have to be equal to its revenues:

$$\overline{c} = \overline{p}_{hd}\overline{y}_d + \overline{p}_o\overline{O}_{hd}. \tag{72}$$

We can write a similar equation for the oil producer:

$$\overline{c}_O = \overline{q}_O\overline{p}_o\overline{O}. \tag{73}$$

Log-Linearized Equations

Euler equations (home and foreign):

$$\widehat{c}_t = \frac{1}{1+\psi_{hab}(1-\sigma)}(\psi_{hab}(1-\sigma)\widehat{c}_{t-1} + \widehat{c}_{t+1} - \sigma(\widehat{r}_t - \widehat{\pi}_{t+1})), \tag{74}$$

$$\widehat{c}^*_t = \frac{1}{1+\psi_{hab}(1-\sigma)}\left(\psi_{hab}(1-\sigma)\widehat{c}^*_{t-1} + \widehat{c}^*_{t+1} - \sigma\left(\widehat{r}^*_t - \widehat{\pi}^*_{t+1}\right)\right). \tag{75}$$

Uncovered interest parity condition:

$$\widehat{r}_t = \widehat{r}^*_t - \chi\widehat{b}_t - \widehat{\Delta S}_{t+1}. \tag{76}$$

Relative prices and price aggregators for final goods:

$$d_h\widehat{p}_{h,t} + d_o\widehat{p}_{o,t} = 0, \tag{77}$$

where $d_h = (1-\psi_{c,o})^{\sigma_c}\overline{p}_h^{1-\sigma_c}$ and $d_o = \psi_{c,o}^{\sigma_c}\overline{p}_o^{1-\sigma_c}$.

$$d_f^*\widehat{p}_{f,t}^* + d_o^*(\widehat{p}_{o,t} + \widehat{q}) = 0, \tag{78}$$

where $d_f^* = (1-\psi_{c,o}^*)^{\sigma_c}\overline{p}_f^{*\,1-\sigma_c}$ and $d_o^* = \psi_{c,o}^{*\ \sigma_c}\overline{p}_o^{*\,1-\sigma_c}$.

$$d_{ho}(\widehat{p}_{h,t} + \widehat{q}_{o,t}) + d_{fo}\big(\widehat{p}_{f,t}^* + \widehat{q}_{o,t}^*\big) = 0, \tag{79}$$

where $d_{ho} = (1-\omega_O)^{\sigma_{c,O}}(\overline{p}_h\overline{q}_O)^{1-\sigma_{c,O}}$ and $d_{fo} = \omega_O^{\sigma_{c,O}}(\overline{p}_f^*\overline{q}_O^*)^{1-\sigma_{c,O}}$.

Intermediate goods:

$$\widehat{p}_{h,t} = d_{hd}\widehat{p}_{hd,t} + d_{fd}\big(\widehat{p}_{fd,t}^* - \widehat{q}_t\big), \tag{80}$$

where $d_{hd} = \omega^{\sigma_i}\frac{\overline{p}_{hd}^{1-\sigma_i}}{\overline{p}_h}$ and $d_{fd} = (1-\omega)^{\sigma_i}(\frac{\overline{p}_{fd}^*}{\overline{q}\overline{p}_h})^{1-\sigma_i}$.

$$\widehat{p}_{f,t}^* = d_{fd}^*\widehat{p}_{fd,t}^* + d_{hd}^*(\widehat{p}_{hd,t} + \widehat{q}_t), \tag{81}$$

where $d_{fd}^* = \omega^{*\sigma_i}\overline{p}_{fd}^{*1-\sigma_i}$ and $d_{hd}^* = (1-\omega^*)^{\sigma_i}(\overline{p}_{hd}\overline{q})^{1-\sigma_i}$.

Wage dynamics:

$$\begin{aligned}\widehat{\pi}_{w,t} = {} & \frac{\sigma_h(1-\alpha_w)(1-\beta\alpha_w)}{(\sigma_h+\sigma_w)\alpha_w}\left(\frac{1}{\sigma_h}\widehat{h}_t + \frac{1}{\sigma}\widehat{c}_t - \psi_{hab}\frac{1-\sigma}{\sigma}\widehat{c}_{t-1} - \widehat{w}_t\right) \\ & + \beta E_t\widehat{\pi}_{w,t+1}, \end{aligned} \tag{82}$$

$$\begin{aligned}\widehat{\pi}_{w,t}^* = {} & \frac{\sigma_h\alpha_w(1-\beta(1-\alpha_w))}{(\sigma_h+\sigma_w)(1-\alpha_w)}\left(\frac{1}{\sigma_h}\widehat{h}_t^* + \frac{1}{\sigma}\widehat{c}_t^* - \psi_{hab}\frac{\sigma-1}{\sigma}\widehat{c}_{t-1}^* - \widehat{w}_t^*\right) \\ & + \beta E_t\widehat{\pi}_{w,t+1}^*. \end{aligned} \tag{83}$$

Note that

$$\widehat{\pi}_{w,t} = \widehat{w}_t - \widehat{w}_{t-1} + \widehat{\pi}_t, \tag{84}$$

$$\widehat{\pi}_{w,t}^* = \widehat{w}_t^* - \widehat{w}_{t-1}^* + \widehat{\pi}_t^*. \tag{85}$$

Inflation dynamics:

Inflation of intermediate goods:

$$\widehat{\pi}_{hd,t} = \frac{1}{1+\beta\gamma_h}\frac{(1-\beta\alpha_h)(1-\alpha_h)}{\alpha_h}(\widehat{mc}_{hd,t} - \widehat{p}_{hd,t}) + \frac{\gamma_h}{(1+\beta\gamma_h)}\widehat{\pi}_{hd,t-1} + \frac{\beta}{(1+\beta\gamma_h)}E_t\widehat{\pi}_{hd,t+1}, \quad (86)$$

where $\widehat{\pi}_{hd,t}$ represents inflation of home intermediates.

$$\widehat{\pi}^*_{fd,t} = \frac{1}{1+\beta\gamma^*_f}\frac{\left(1-\beta\alpha^*_f\right)\left(1-\alpha^*_f\right)}{\alpha^*_f}\left(\widehat{mc}^*_{fd,t} - \widehat{p}^*_{fd,t}\right) + \frac{\gamma^*_f}{\left(1+\beta\gamma^*_f\right)}\widehat{\pi}^*_{fd,t-1} + \frac{\beta}{\left(1+\beta\gamma^*_f\right)}E_t\widehat{\pi}^*_{fd,t+1}, \quad (87)$$

where $\widehat{\pi}^*_{fd,t}$ represents inflation of foreign intermediates. Note that

$$\widehat{\pi}_t = \widehat{\pi}_{hd,t} - (\widehat{p}_{hd,t} - \widehat{p}_{hd,t-1}), \quad (88)$$

$$\widehat{\pi}^*_t = \widehat{\pi}^*_{fd,t} - \left(\widehat{p}^*_{fd,t} - \widehat{p}^*_{fd,t-1}\right). \quad (89)$$

Definition of marginal costs:

$$\widehat{mc}_{hd,t} = m_o\widehat{p}_{o,t} + m_w\widehat{w}_t - \widehat{A}_t, \quad (90)$$

where $m_o = \frac{\psi_{y,o}^{\sigma_o}\overline{p}_o^{1-\sigma_o}}{\overline{mc}^{1-\sigma_o}}$ and $m_w = \frac{(1-\psi_{y,o})^{\sigma_o}\overline{w}^{1-\sigma_o}}{\overline{mc}^{1-\sigma_o}}$.

$$\widehat{mc}^*_{fd,t} = m^*_o(\widehat{p}_{o,t} + \widehat{q}_t) + m^*_w\widehat{w}^*_t - \widehat{A}^*_t, \quad (91)$$

where $m^*_o = \frac{\psi_{y,o}^{*\sigma_o}\overline{p}_o^{*1-\sigma_o}}{\overline{mc}^{*1-\sigma_o}}$ and $m^*_w = \frac{(1-\psi^*_{y,o})^{\sigma_o}\overline{w}^{*1-\sigma_o}}{\overline{mc}^{*1-\sigma_o}}$.

Goods market equilibrium:

$$\widehat{y}_{hd,t} = -\sigma_i\widehat{p}_{hd,t} + s_{hd}(\sigma_i\widehat{p}_{h,t} + \widehat{y}_{h,t}) + (1-s_{hd})\left(\widehat{y}^*_{f,t} - \sigma_i\widehat{q}_t + \sigma_i\widehat{p}^*_{f,t}\right), \quad (92)$$

where $s_{hd} = \omega^{\sigma_i}(\frac{\overline{p}_{hd}}{\overline{p}_h})^{-\sigma_i}\frac{\overline{y}_h}{\overline{y}_{hd}}$.

$$\widehat{y}^*_{fd,t} = -\sigma_i \widehat{p}^*_{fd,t} + s^*_{df}\big(\sigma_i \widehat{p}^*_{f,t} + \widehat{y}^*_{f,t}\big) + \big(1 - s^*_{fd}\big)(\widehat{y}_{h,t} + \sigma_i \widehat{q}_t + \sigma_i \widehat{p}_{h,t}), \tag{93}$$

where $s^*_{fd} = \omega^{*\sigma_i}(\frac{\overline{p}^*_{fd}}{\overline{p}^*_f})^{-\sigma_i}\frac{\overline{y}^*_f}{\overline{y}^*_{fd}}$.

Final goods:

$$\begin{aligned}\widehat{y}_{h,t} = &-(\sigma_c s_{hh} + \sigma_{c,o}(1 - s_{hh}))\widehat{p}_{h,t} \\ &+ s_{hh}\widehat{c}_t + (1 - s_{hh})(\widehat{c}_{o,t} - \sigma_{c,o}\widehat{q}_{o,t}),\end{aligned} \tag{94}$$

where $s_{hh} = (1 - \psi_{c,o})^{\sigma_c}\overline{p}_h^{-\sigma_c}\frac{\overline{c}}{\overline{y}_h}$.

$$\begin{aligned}\widehat{y}^*_{f,t} = &-(\sigma_c s_{ff} + \sigma_{c,o}(1 - s_{ff}))\widehat{p}^*_{f,t} + s_{ff}\widehat{c}^*_t \\ &+ (1 - s_{ff})(\widehat{c}_{o,t} - \sigma_{c,o}\widehat{q}_{o,t}),\end{aligned} \tag{95}$$

where $s_{ff} = (1 - \psi^*_{c,o})^{\sigma_c}\overline{p}_f^{-\sigma_c}\frac{\overline{c}^*}{\overline{y}^*_f}$.

Oil market clearing condition:

$$\begin{aligned}\widehat{O}_t = &\, s_{oh}\widehat{O}_{hd,t} + s^*_{of}\widehat{O}^*_{fd,t} - \sigma_c\big(s_{oc} + s^*_{oc}\big)\widehat{p}_{o,t} \\ &- \sigma_c s^*_{oc}\widehat{q}_t + s^*_{oc}\widehat{c}^*_t + s_{oc}\widehat{c}_t,\end{aligned} \tag{96}$$

where $s_{oh} = \frac{\overline{O}_{hd}}{\overline{O}}, s^*_{of} = \frac{\overline{O}^*_{fd}}{\overline{O}}, s_{oc} = \psi^{\sigma_c}_{c,o}\overline{p}_o^{-\sigma_c}\frac{\overline{c}}{\overline{O}}, s^*_{oc} = \psi^{*\sigma_c}_{c,o}(\overline{p}_o\overline{q})^{-\sigma_c}\frac{\overline{c}^*}{\overline{O}}$.

Production function:

$$\widehat{y}_{hd,t} = \widehat{A}_t + y_{do}\widehat{O}_{hd,t} + (1 - y_{do})\widehat{h}_t, \tag{97}$$

where $y_{do} = (\frac{\psi_{y,o}\overline{O}_{hd}}{\overline{y}_{hd}})^{\frac{\sigma_o - 1}{\sigma_o}}$.

$$\widehat{y}^*_{fd,t} = \widehat{A}^*_t + y^*_{do}\widehat{O}^*_{fd,t} + \big(1 - y^*_{do}\big)\widehat{h}^*_t, \tag{98}$$

where $y^*_{do} = (\frac{\psi^*_{y,o}\overline{O}^*_{fd}}{\overline{y}^*_{fd}})^{\frac{\sigma_o - 1}{\sigma_o}}$.

Factor demands:

$$\widehat{O}_{hd,t} = \widehat{y}_{hd,t} + (\sigma_o - 1)\widehat{A}_t + \sigma_o(\widehat{mc}_{hd,t} - \widehat{p}_{o,t}), \tag{99}$$

$$\widehat{O}^*_{fd,t} = \widehat{y}^*_{fd,t} + (\sigma_o - 1)\widehat{A}^*_t + \sigma_o\big(\widehat{mc}^*_{fd,t} - \widehat{p}_{o,t} - \widehat{q}_t\big). \tag{100}$$

Budget constraint of the oil exporter:

$$\widehat{c}_{O,t} = \widehat{q}_{O,t} + \widehat{p}_{o,t} + \widehat{O}_t. \tag{101}$$

Assets evolution:

$$\widehat{c}_t = \frac{1}{\beta\overline{c}}\widehat{b}_t + \frac{\overline{p}_{hd}\overline{y}_{hd}}{\overline{c}}(\widehat{p}_{d,t} + \widehat{y}_{hd,t}) - \frac{\overline{p}_o\overline{O}_{hd}}{\overline{c}}(\widehat{p}_{o,t} + \widehat{O}_{hd,t}) - \frac{1}{\overline{c}}\widehat{b}_t. \tag{102}$$

Relations between real exchange rates:

$$\widehat{q}_{O,t} = \widehat{q}_t + \widehat{q}^*_{O,t}, \tag{103}$$

$$\widehat{\Delta q}_t = \widehat{\Delta S}_t + \widehat{\pi}_t - \widehat{\pi}^*_t. \tag{104}$$

Monetary rules:

$$\widehat{r}_t = \phi_\pi(1 - \rho_m)\widehat{\pi}_t + \rho_m\widehat{r}_{t-1}. \tag{105}$$

$$\widehat{r}^*_t = \phi_{\pi^*}\left(1 - \rho^*_m\right)\widehat{\pi}^*_t + \rho^*_m\widehat{r}^*_{t-1}. \tag{106}$$

Oil supply process:

$$\widehat{O}_t = \rho_o\widehat{O}_{t-1} + \widehat{\epsilon}_{o,t}. \tag{107}$$

References

Bean, C. 2006. "Globalization and Inflation." *Quarterly Bulletin* (Bank of England) 46 (Q4): 468–75.

Benigno, G., and P. Benigno. 2003. "Price Stability in Open Economies." *Review of Economic Studies* 70 (4): 743–64.

Benigno, G., P. Benigno, and F. Ghironi. 2007. "Interest Rate Rules for Fixed Exchange Rate Regimes." *Journal of Economic Dynamics and Control* 31 (7): 2196–2211.

Benigno, P. 2009. "Price Stability with Imperfect Financial Integration." *Journal of Money, Credit, and Banking* 41 (s1): 121–49.

Blanchard, O., and J. Galí. 2010. "The Macroeconomic Effects of Oil Price Shocks: Why Are the 2000s So Different from the 1970s?" In *International Dimensions of Monetary Policy*, ed. J. Galí and M. Gertler, 373–421. Chicago: University of Chicago Press.

Bodenstein, M., C. Erceg, and L. Guerrieri. 2011. "Oil Shocks and External Adjustment." *Journal of International Economics* 83 (2): 168–84.

Borio, C., and A. Filardo. 2007. "Globalization and Inflation: New Cross-Country Evidence on the Global Determinants of Domestic Inflation." BIS Working Paper No. 227 (May).

Calvo, G. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12 (3): 383–98.

Campolmi, A. 2008. "Oil Price Shocks: Demand vs. Supply in a Two-Country Model." Magyar Nemzeti Bank Working Paper No. 2008/05.

Christiano, L., G. Evans, and M. Eichenbaum. 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." *Journal of Political Economy* 113 (1): 1–45.

Cooper, J. C. 2003. "Price Elasticity of Demand for Crude Oil: Estimates for 23 Countries." *OPEC Review* 27 (1): 1–8.

Corsetti, G. 2007. "New Open Economy Macroeconomics." CEPR Discussion Paper No. 6578.

Corsetti, G., L. Dedola, and S. Leduc. 2008. "International Risk Sharing and the Transmission of Productivity Shocks." *Review of Economic Studies* 75 (2): 443–73.

Erceg, C., D. Henderson, and A. Levin. 2000. "Optimal Monetary Policy with Staggered Wage and Price Contracts." *Journal of Monetary Economics* 46 (2): 281–313.

European Central Bank. 2006. "Effects of the Rising Trade Integration of Low-Cost Countries on Euro-Area Import Prices." *Monthly Bulletin* (European Central Bank) (August): 56 (Box 6).

Galí, J. 1999. "Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?" *American Economic Review* 89 (1): 249–71.

Hamilton, J. 2009. "Causes and Consequences of the Oil Shock of 2007–08." *Brookings Papers on Economic Activity* (Spring): 215–59.

Hooper, P., K. Johnson, and J. Marquez. 2000. "Trade Elasticities for the G-7 Countries." *Princeton Studies in International Economics* No. 87 (August).

Hughes, J. E., C. R. Knittel, and D. Sperling. 2008. "Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand." *Energy Journal* 29 (1): 93–114.

International Monetary Fund. 2006. "How Has Globalization Affected Inflation?" *World Economic Outlook* (April): 97–134.

Kilian, L. 2009. "Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market." *American Economic Review* 99 (3): 1053–69.

Lomax, R. 2007. "Perspectives on Current Monetary Policy." *Quarterly Bulletin* (Bank of England) 47 (Q1): 100–105.

Monacelli, T. 2010. "Comment on 'Globalization and Inflation Dynamics: The Impact of Increased Competition'." In *International Dimensions of Monetary Policy*, ed. J. Galí and M. Gertler, 579–90. Chicago: University of Chicago Press.

Nickell, S. 2005. "Why Has Inflation Been So Low Since 1999?" *Quarterly Bulletin* (Bank of England) 45 (Spring): 92–107.

Obstfeld, M., and K. Rogoff. 2000a. "New Directions for Stochastic Open Economy Models." *Journal of International Economics* 50 (1): 117–53.

———. 2000b. "The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?" In *NBER Macroeconomics Annual 2000*, ed. B. S. Bernanke and K. Rogoff, 339–412.

Rigobon, R., and G. Gopinath. 2008. "Sticky Borders." *Quarterly Journal of Economics* 123 (2): 531–75.

Sbordone, A. M. 2007. "Globalization and Inflation Dynamics: The Impact of Increased Competition." NBER Working Paper No. 13556.

Smets, F., and R. Wouters. 2003. "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area." *Journal of the European Economic Association* 1 (5): 1123–75.

———. 2007. "Shocks and Frictions in US Business Cycles: Bayesian DSGE Approach." *American Economic Review* 97 (3): 586–606.

Unalmis, D., I. Unalmis, and D. F. Unsal. 2008. "Oil Price Shocks, Macroeconomic Stability and Welfare in a Small Open Economy." University of York Discussion Paper No. 08/13.