Does the Exchange Rate Belong in Monetary Policy Rules? New Answers from a DSGE Model with Endogenous Tradability and Trade Frictions*

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Abstract

This paper develops a 2-region DSGE model that integrates the theory of comparative advantage or endogenous tradability into a monetary model with nominal and real rigidities. We find that without endogenous tradability there is no role for the exchange rate in optimized monetary policy rules. But with endogenous tradability the exchange rate can play a much more fundamental role in facilitating or slowing down adjustments in the real economy, and it enters the optimized policy rule.

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I Introduction

The benefits of exchange rate flexibility lie in its ability to change the relative prices of goods in the presence of nominal rigidities. Friedman (1953) first argued that a flexible exchange rate regime is desirable as a shock absorber, and this has been followed by a long subsequent literature. The implications for the conduct of domestic monetary policy have however been the subject of much debate. In the closed economy literature, several important papers[1] have found that welfare optimizing monetary policy results in a complete stabilization of the domestic price level, with no trade-off between output gap stabilization and domestic price stability. Many key contributions to the recent open economy literature[2] have found conditions (but also exceptions) under which these results carry over to an open economy setting, which means specifically that there is no need for monetary policy to explicitly consider the exchange rate. However, these papers share an important set of common assumptions that may be violated in practice. They include producer currency pricing, perfect exchange rate pass-through, and a lack of real rigidities in international trade. The literature has thus far concentrated on the pricing assumption, by replacing the producer currency pricing assumption with local currency pricing. It can then be shown that it becomes optimal to either have a completely fixed exchange rate, or at least to have a very significant role for the exchange rate in the monetary policy rule.[3] The empirical evidence for the pricing assumption is a subject of much debate, with Corsetti and Pesenti (2005) arguing that an intermediate degree of pass-through may be most appropriate, with developing countries likely closer to a high pass-through than industrialized countries.[4]

In this study we will argue that another and thus far overlooked set of factors may play a key role in determining whether the exchange rate should enter monetary policy rules. They concern the endogenous determination of the range of goods that a country exports and imports, together with real rigidities in both exporting and importing. For importing we assume that there are costs, in terms of both cost and time, of initiating and reversing new import supplier relationships. For exporting, there is a cost to switching between purely domestic production on the one hand and production for both domestic and foreign markets on the other. We find that in a baseline model with producer currency pricing but without these features the optimized linear monetary policy rule has a zero weight on deviations of the real exchange rate from its long-run trend. When endogenous determination of the range of exports and imports is added together with export switching costs, the exchange rate assumes an important role, with real appreciations requiring monetary easing. Adding real import rigidities significantly increases the optimal coefficient on the real exchange rate.

To derive these results we develop a two-country DSGE model that integrates the theory of comparative advantage of Dornbusch, Fisher and Samuelson (1977) into a monetary model with real rigidities and with sticky prices and wages. In this model the nominal exchange rate can play a much more fundamental role in facilitating or slowing down adjustments in the real economy. To illuminate the implications for monetary policy we subject the model to standard types of shocks. We then study macroeconomic performance using

[1] The key papers are King and Wolman (1996), Goodfriend and King (1997) and Rotemberg and Woodford (1997).

[2] See Gali and Monacelli (2005), Benigno and Benigno (2003) and Obstfeld and Rogoff (2002).

[3] See Smets and Wouters (2002), Devereux and Engel (2003) and Corsetti and Pesenti (2005).

[4] Goldberg and Knetter (1997) and Campa and Goldberg (2005) find that in industrialized countries the degree of short-run pass-through to import prices is roughly 50 percent, and close to 100 percent in the long run. But for many developing countries the consensus is that pass-through to import prices is very much higher, for example Burstein, Eichenbaum and Rebelo (2005).

monetary policy interest rate rules that add a term for real exchange rate deviations from trend to the conventional inflation and output gap terms.

The model builds on the monetary, stochastic general equilibrium model of comparative advantage of Naknoi (2004). Heterogeneity in productivity and proportional trade costs determine which goods are exported, imported or not traded in equilibrium. In this environment trade is significantly more responsive to shocks than in conventional models, which tend to underpredict the volatility of trade flows relative to GDP. In the short run, this endogeneity of the trade pattern amplifies the expenditure switching effect of exchange rates, as firms transit into and out of exporting. At the same time, the transitions cause aggregate productivity to fluctuate, in the same manner as in the real models of Ghironi and Melitz (2005). These transitions generate additional output volatility that monetary policy must stabilize.

We also assume that it is costly to belong to the set of exporters. The cost is time-variant and generates smaller trade responses in the short run than in the long run. It is similar to the fixed cost of entering into exporting in Ghironi and Melitz (2005). Exporters that transit in and out of exporting in the short run is not a far-fetched assumption. Trade economists have identified year-to-year transitions into and out of exporting from micro data in the U.S., Colombia and Mexico. For example, the duration of trade relationships of the U.S. with its trading partners at the product level is found to vary from 3 to 5 years.[5] These studies indicate that the exporting decision is not a long-run issue. It is better viewed as a medium-run phenomenon with some degree of persistence.

The model makes three departures from Naknoi (2004). First, we assume that importers take time and find it costly to build new relationships with foreign suppliers. This time to build markets assumption is similar to time to ship in Backus, Kehoe and Kydland (1994). It generates a low short-run elasticity of substitution between domestic goods and imported goods, despite a high long-run elasticity. Because this friction reduces the short-run real trade response, it has important implications for monetary policy.

Second, we introduce vertical integration, with endogenous tradability only observed at the level of intermediate goods.[6] This was introduced partly for realism, as it allows the model to generate observed trade to GDP ratios without postulating unrealistically high import shares in production and consumption. But in addition it doubles the effects of the time-to-build-markets assumption, which we make at both the intermediate and final goods levels.

Third, to obtain a fully specified business cycle model we introduce investment and capital accumulation. We assume time to build in investment subject to quadratic investment adjustment costs. Together with the assumption of habit persistence in consumption this implies that domestic demand responds sluggishly, thereby generating plausible responses to standard shocks.

To the best of our knowledge, our model is the first two-country monetary business cycle model that embeds endogenous tradability in a setting with significant nominal and real rigidities. Nominal rigidities in price and wage setting allow for a meaningful analysis of optimal monetary policy, which would not be possible in the flexible-price models of Betts and Kehoe (2001), Bergin and Glick (2003) and Ghironi and Melitz (2005). We can therefore compare our results to those of the large literature on optimal monetary

[5] See Bernard and Jensen (2004), Roberts and Tybout (2001), Aitken, Hanson and Harrison (1997), and Besedes and Prusa (2006).

[6] Obstfeld and Rogoff (2000) argue that the expenditure switching channel largely operates through relative prices in the intermediate goods sector.

policy in open economies cited above.

We describe our model in the next section. Section III discusses calibration, Section IV presents our results, and Section V concludes.

II The Global Endogenous Tradability Model (GETM)

The model economy consists of two countries, referred to as Home and Foreign. The countries have identical preferences and identical final and intermediate goods technologies but different technologies in primary production. Countries differ in size, with the population of Home being α and that of Foreign $(1-\alpha)$. We concentrate on the economic decisions of Home agents, as the corresponding decisions of Foreign agents are mirror images. Note that we express variables in absolute rather than in per capita terms, as this simplifies the exposition.

Each economy consists of a representative household, a government, and multiple layers of firms. Households consume, supply labor, and accumulate capital. The most upstream level of firms is primary producers, who obtain capital and labor inputs from households, the latter subject to sticky nominal wages. Primary producers differ by their level of productivity relative to producers in the other country. They endogenously decide on three modes of activity, quitting production if they are not competitive with imports from abroad, producing only for the domestic market if they are competitive domestically but not abroad, and producing for both the domestic and the foreign market if their competitors abroad are not competitive. The next layer of production is intermediates firms, which combine domestic and foreign varieties and then sell them either domestically or abroad. The final layer is final goods producers, who combine domestic and foreign inputs with an exogenously nontradable fixed input to produce final output for domestic consumers, investors, and the government. We assume that international trade at any stage is subject to an iceberg type trading cost τ, where a fraction $1-\tau$ of goods is lost in shipping. The government is Ricardian and decides on an interest rate rule for monetary policy. The structure of the model economy in terms of goods and factor flows is illustrated in Figure 1.

A Households

Each individual household i maximizes lifetime utility which has three arguments, consumption C_t^i which exhibits external habit persistence that is parameterized by v, leisure $(\alpha - L_t^i)$, where L_t^i is labor effort and α is the time endowment, and real money balances $m_t^i = M_t^i/P_t$, where P_t is the price of final output. Denoting the intertemporal elasticity of substitution by σ, we have

$$(1) \qquad Max \quad E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{S_t^c \left(C_t^i - \nu C_{t-1}\right)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} + \psi \frac{\left(1-L_t^i\right)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} + \psi_n \frac{\left(m_t^i\right)^{1-\epsilon}}{1-\epsilon} \right\} ,$$

where E_t is the expectation conditional on information available at time t, and S_t^c is a preference or demand shock given by

$$(2) \qquad S_t^c = \rho_c S_{t-1}^c + (1-\rho_c) + u_t^c \ .$$

Capital accumulation is subject to a time-to-build technology, with a $T+1$-period lag between a new investment start I_t^i and the point at which that investment leads to an addition to the currently productive capital stock K_t^i:

(3) $$K_{t+1}^i = (1-\Delta)K_t^i + I_{t-T}^i S_{t-T}^{inv} \ .$$

The term S_t^{inv} represents a shock to the productivity of investment spending, specifically to the rate at which such spending is translated into additions to the capital stock. It is given by

(4) $$S_t^{inv} = \rho_{inv} S_{t-1}^{inv} + (1-\rho_{inv}) + u_t^{inv} \ .$$

Changes in investment starts are subject to an external quadratic adjustment cost

(5) $$\Phi_t^I = \frac{\phi^I}{2}\left(\left(\frac{I_t^i}{I_{t-1}}\right) - 1\right)^2 \ .$$

This and all other adjustment costs are assumed to be redistributed back to households in lump-sum fashion. Each investment start represents a commitment to a spending plan over $T+1$ periods, starting in the period of the investment start and ending one period before capital becomes productive. The shares of the investment project to be disbursed in each period are given by $\omega_j, \ j = 0, ..., T$, with $\Sigma_{j=0}^T \omega_j = 1$. The actual investment J_t^i is therefore given by

(6) $$J_t^i = \Sigma_{j=0}^T \omega_j I_{t-j}^i \ .$$

In what follows we choose final output as our numeraire, and the lower case price and return variables p and r are in terms of this numeraire. The nominal exchange rate is S_t, and the real exchange rate is $s_t = (S_t P_t^*)/P_t$. The gross rate of currency depreciation is denoted by ε_t, and π_t and π_t^* are the gross domestic and foreign inflation rates.

Households in Home can hold money M_t^i and two other types of financial assets. Nominally non-contingent domestic currency government bonds, bought in period t and maturing in $t+1$, and paying off i_t units of domestic currency in $t+1$, are denoted by $\tilde{F}_t^i$, with a real stock of $\tilde{f}_t^i = \tilde{F}_t^i/P_t$. Nominally non-contingent foreign currency bonds are denoted by F_t^i, with a real stock of $f_t^i = (S_t F_t^i)/P_t$. They are assumed to pay off $i_t^* \zeta_t$ units of foreign currency in $t+1$, where i_t^* is the gross nominal interest rate in the rest of the world and ζ_t is a shock to uncovered interest parity given by

(7) $$\zeta_t = \rho_\zeta \zeta_{t-1} + (1-\rho_\zeta) + u_t^\zeta \ .$$

The international bond is assumed to be the only internationally traded asset. Households face a quadratic cost associated with holding the stock of this bond. This is required in the usual fashion to ensure stationarity of the economy's net foreign asset position. The cost is given by

(8) $$\Phi_t^f = \frac{\phi^{f1}}{2}\left(\frac{f_t^i}{gdp_t}\right)^2 + \frac{\phi^{f2}}{2}\left(\frac{ca_t^i}{gdp_t}\right)^2 \ ,$$

where the first term represents a cost of deviating from a zero net foreign asset to GDP position, and the second a cost of deviating from a zero current account to GDP position, where $ca_t = f_t^i - \frac{f_t \varepsilon_t}{\pi_t}$. While this is mostly a computational device, there are also good empirical justifications, as for example emphasized by Kollmann (2004).

In addition to financial assets, households own two types of real assets, domestically produced capital K_t^i and a factor V_t^i that is in fixed supply at the aggregate level. The latter is introduced to capture the role of exogenously nontraded goods in the economy, as the assumption that all goods are tradable under zero trading costs seems too extreme.

Households' real income consists of real wages $w_t L_t^i$, real returns on capital $r_t^k K_t^i$, rents on the fixed factor $r_t^v V_{t-1}^i$, interest on international bonds $f_{t-1}^i \frac{i_{t-1}^* \zeta_{t-1} \varepsilon_t}{\pi_t}$ and on domestic bonds $\tilde{f}_{t-1}^i \frac{i_{t-1}}{\pi_t}$, lump-sum government net taxes Tx_t^i/P_t, profit redistributions Π_t^i/P_t from firms, and lump-sum redistributions of adjustment costs A_t^i/P_t. The household also earns the net capital gains from appreciations of the price of the fixed factor p_t^V.

Household expenditure consists of consumption spending C_t^i, investment spending J_t^i, spending on investment adjustment costs, and a quadratic cost of adjusting nominal wages along the lines of Rotemberg (1982). The latter is extended to costs of adjusting the rate of change of the wage relative to the past observed aggregate wage inflation rate, as pioneered by Ireland (2001) and also used by Laxton and Pesenti (2003). Specifically, the real wage adjustment cost is given by

(9)
$$\Phi_t^w = \frac{\phi^w}{2} w_t L_t \left(\frac{\pi_t^{w^i}}{\pi_{t-1}^w} - 1 \right)^2 ,$$

where $\pi_t^{w^i} = W_t^i / W_{t-1}^i$ is the (gross) household specific rate of wage inflation and π_t^w is the aggregate rate of wage inflation.

The period t budget constraint, whose multiplier is denoted by λ_t, is therefore given by

(10)
$$\begin{aligned} f_t^i + \tilde{f}_t^i + m_t^i \quad = \quad & f_{t-1}^i \frac{i_{t-1}^* \xi_{t-1} \varepsilon_t}{\pi_t} + \tilde{f}_t^i \frac{i_{t-1}}{\pi_t} + \frac{m_{t-1}^i}{\pi_t} \\ & + w_t L_t^i + r_t^K K_t^i + r_t^v V_{t-1}^i + p_t^V \left(V_{t-1}^i - V_t^i \right) \\ & - C_t^i - J_t^i - \Phi_t^I - \Phi_t^f - \Phi_t^w \\ & + (\Pi_t^i / P_t) + (A_t^i / P_t) - (T x_t^i / P_t) \; . \end{aligned}$$

We assume that initial holdings of bonds, money, capital and fixed factors are identical for all households. This implies that each household has the same present discounted value of income, and that all households' marginal conditions are identical, including a synchronization of wage setting behavior. We can therefore drop the index i from the household problem. Every household maximizes (1) subject to (3), (5), (6), (8), (9), (10), and the demand for their labor. The first-order conditions for consumption, bonds and the fixed factor are given by

(11)
$$S_t^c \left(\frac{C_t - vC_{t-1}}{1 - v} \right)^{-\frac{1}{\sigma}} = \lambda_t ,$$

(12)
$$1 = \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \frac{i_t}{\pi_{t+1}} \right) ,$$

(13)
$$1 + \phi^{f1} \frac{f_t}{gdp_t} + \phi^{f2} \frac{ca_t}{gdp_t} = \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \frac{i_t^* \zeta_t \varepsilon_{t+1}}{\pi_{t+1}} \right) ,$$

(14)
$$1 = \beta_t E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \frac{p_{t+1}^V + r_{t+1}^V}{p_t^V} \right) .$$

Optimal investment and capital accumulation are given by

(15)
$$\Sigma_{j=0}^T \omega_j \beta^j \lambda_{t+j} + \lambda_t \phi^I \left(\frac{I_t - I_{t-1}}{I_{t-1}} \right) = \beta^T \lambda_{t+T} q_{t+T} S_t^{inv} ,$$

$$\lambda_t q_t = E_t \left\{ \beta \lambda_{t+1} \left[r^k_{t+1} + q_{t+1}(1-\Delta) \right] \right\} \ . \tag{16}$$

Next, we consider an individual household's wage setting decision. We assume that primary producers demand a labor composite that is a CES aggregate over all labor varieties supplied by households, with time-varying elasticity of substitution θ^w_t. The cost minimization problem of an individual varieties producer indexed by z is given by

$$\underset{L^i_t(z), i\in[0,1]}{Min} \int_0^1 W^i_t L^i_t(z) di \ \ s.t. \ L_t(z) = \left(\int_0^1 L^i_t(z)^{\frac{\theta^w_t - 1}{\theta^w_t}} di \right)^{\frac{\theta^w_t}{\theta^w_t - 1}} \ . \tag{17}$$

This produces a set of labor demand equations for each labor variety $L^i_t(z)$ that, given identical relative wages facing each producer, is straightforward to aggregate so as to obtain total demand for each variety L^i_t:

$$L^i_t = \left(\frac{W^i_t}{W_t} \right)^{-\theta^w_t} L_t \ \ , \ \ W_t = \left(\int_0^1 \left(W^i_t \right)^{1-\theta^w_t} di \right)^{\frac{1}{1-\theta^w_t}} \ . \tag{18}$$

Households maximize their utility from leisure subject to labor demand (18), the budget constraint (10) and the wage inflation adjustment cost (9). We obtain the following equation for wage dynamics:

$$\begin{aligned} &\lambda_t w_t L_t (\theta^w_t - 1) + \lambda_t w_t L_t \phi^w \left(\frac{\pi^w_t}{\pi^w_{t-1}} - 1 \right) \frac{\pi^w_t}{\pi^w_{t-1}} - \beta_t E_t \left[\lambda_{t+1} w_{t+1} L_{t+1} \phi^w \left(\frac{\pi^w_{t+1}}{\pi^w_t} - 1 \right) \frac{\pi^w_{t+1}}{\pi^w_t} \right] = \\ &\theta^w_t \psi L_t (\alpha - L_t)^{-\frac{1}{\sigma}} \ . \end{aligned} \tag{19}$$

We allow for wage markup shocks. In particular, the exogenously time-varying wage markup is given by

$$\mu^w_t = \frac{\theta^w_t}{\theta^w_t - 1} \ , \tag{20}$$

which is subject to i.i.d. shocks

$$\mu^w_t = \bar{\mu}^w \left(1 + u^w_t \right) \ . \tag{21}$$

B Primary Producers

Primary production follows the specification of Naknoi (2004), adding capital inputs and costs of switching between exporting and producing only for the domestic market. Specifically, there is a continuum of goods varieties indexed by $z \in [0,1]$. Firms endogenously decide whether to belong to one of three types of firms depending on their productivity. The most productive ones, indexed by H, produce both for the domestic market and for exports because they are more competitive than foreign firms in the foreign market even after incurring a proportional trading cost τ. Those with intermediate productivity, indexed by N, produce only for the domestic market because they are sufficiently competitive domestically against foreigners handicapped by the trading cost, but for the same reason they cannot compete with foreigners in the foreign market. Finally, those with the lowest productivity choose to quit production because they cannot compete with foreign imports in the domestic market.

For each variety there is a large number of perfectly competitive firms producing output y_t from labor $\ell_t(z)$ and capital $k_t(z)$ using the following technology:

$$y_t(z) = a(z) x_t \ell_t(z)^\gamma k_t(z)^{(1-\gamma)} \ . \tag{22}$$

The first two elements on the right hand side are firm-specific productivity $a(z)$ and aggregate or total factor productivity (TFP) x_t. Firm-specific productivity determines the pattern of comparative advantage between countries. We normalize productivity in Foreign to one, $a^*(z) = 1 \; \forall z$, and for Home we assume a productivity schedule that is exponentially declining in z as follows:

$$a(z) = Ne^{-nz} \; . \tag{23}$$

The long run relative productivity of the most productive Home variety is therefore Nx/x^*, while n is the rate at which relative productivity declines, a parameter that will generally have to be larger for smaller countries. Comparative advantage of course implies that Home does not need to have an absolute advantage in any good in order for it to produce some part of world output. This means that $Nx < x^*$ is feasible.

Comparative advantage together with trading costs make tradedness of intermediate goods endogenous. For each producer, optimality requires that the price of its variety equals marginal cost, which in turn equals marginal factor cost divided by productivity. Marginal factor cost is given by

$$mc_t = \frac{(w_t)^\gamma \left(r_t^k\right)^{1-\gamma}}{\gamma^\gamma (1-\gamma)^{(1-\gamma)}} \; , \tag{24}$$

and the optimality condition becomes

$$p_t(z) = \frac{mc_t}{x_t a(z) \chi_t} \; . \tag{25}$$

A Home producer of variety z will produce so long as the price $P_t(z)$ he is able to charge given his marginal cost does not exceed the price $(S_t P_t^*(z))/(1-\tau)$ that an importer from Foreign of the same variety is able to charge given his marginal cost and trading costs. Given the declining relative productivity pattern in Home there will therefore be a maximum level of z above which Home will rely entirely on imports from Foreign. We denote this time-varying level by z_t^h. Equally, a Foreign producer of variety z will produce so long as his price $P_t^*(z)$ does not exceed the price $(P_t(z))/(S_t(1-\tau))$ that an importer from Home of the same variety is able to charge. There will therefore be a minimum level of z, denoted z_t^l, below which Foreign will rely entirely on imports from Home. We can combine these two conditions on prices with the marginal cost conditions for Home and Foreign producers (25). But before doing so we need to discuss export adjustment costs.

We assume that entering the export trade involves additional costs such as extra marketing costs and costs of building a geographically larger distribution network. Conversely, exiting the export trade involves benefits that can be conceptualized as the scrap value of overseas sale operations as in the industrial organization literature. The functional form of these costs and benefits is of the iceberg-type, that is costs which melt a fraction of productivity $a(z)$ or $a^*(z)$ for new entrants, and which conversely freeze additional water that adds to the productivity iceberg for firms that exit. The dependence of such costs on entry and exit is captured by making them a function of the change in the range of varieties produced for exports between last period and this period. In particular, for Home exporters the effective relative productivity is given by $(x_t/x_t^*)\chi_t^l a(z)$,[7] where

$$\chi_t^l = 1 - \phi^a \left(\frac{z_t^l - z_{t-1}^l}{z_{t-1}^l} \right) \; . \tag{26}$$

[7] Note our assumption that these costs or benefits apply to all exporters ex-post, regardless of whether they switched status. This is done for analytical tractability but without loss of generality, as it only affects the interpretation and calibration of the parameter ϕ^a.

For Foreign exporters the effective relative productivity is given by $(x_t/x_t^*)(1/\chi_t^h)$, where

$$\chi_t^h = 1 - \phi^a \left(\frac{z_{t-1}^h - z_t^h}{z_{t-1}^h} \right) . \tag{27}$$

The effect of these costs is to make exporters' relative productivity schedule steeper around the cutoff points z_{t-1}^l and z_{t-1}^h of last period. For the example of a favorable domestic productivity shock, this means that some formerly nontraded varieties continue to only be produced for the domestic market even though before taking account of export adjustment costs the producer could now produce more cheaply than foreigners. But as soon as that nontraded goods producer decides to become an exporter he faces a lower level of productivity.

Combining the above discussion we obtain the following conditions for the range of Home and Foreign produced varieties:

$$\frac{mc_t}{mc_t^* s_t} \leqq \frac{x_t N e^{-nz}}{x_t^*(1-\tau)\chi_t^h} \text{ for } z \in [0, z_t^h] , \tag{28}$$

with equality at $z_t = z_t^h$, and

$$\frac{mc_t}{mc_t^* s_t} \geqq \frac{x_t N e^{-nz}(1-\tau_t)\chi_t^l}{x_t^*} \text{ for } z \in [z_t^l, 1] , \tag{29}$$

with equality at $z_t = z_t^l$. The first expression says that a Home producer's marginal cost has to be below its Foreign competitor's marginal cost, but allowing for the fact that a potential Foreign competitor's cost also includes the trade cost and export adjustment cost hurdles. The second condition expresses the equivalent requirement for the Foreign producer. We define $\delta_t = z_t^h - z_t^l$.

Having determined the ranges of goods produced by the exports and nontraded goods sectors, it is then trivial to determine these sectors' demand for inputs. Letting $L_{t,H} = \int_0^{z_t^l} \ell_t(z)dz$, $K_{t,H} = \int_0^{z_t^l} k_t(z)dz$ and $Y_{t,H} = \int_0^{z_t^l} y_t(z)dz$, and similarly for sector N, we can write, for $j = H, N$:

$$w_t L_{t,j} = \gamma Y_{t,j} , \tag{30}$$

$$r_t^k K_{t,j} = (1-\gamma) Y_{t,j} . \tag{31}$$

C Intermediates Producers

The producer of intermediates D_t is a price-taker in both his input and his output markets, with his (flexible) output price given by P_t^D. He uses inputs of export goods $D_{t,H}$,[8] nontraded goods $D_{t,N}$ and import goods $D_{t,F}$, with the following CES production function:

$$\begin{aligned} D_t &= \left[\int_0^1 y_t(z)^{\frac{\theta^D-1}{\theta^D}} dz \right]^{\frac{\theta^D}{\theta^D-1}} \\ &= \left[\left(z_t^l\right)^{\frac{1}{\theta^D}} \left(D_{t,H}\right)^{\frac{\theta^D-1}{\theta^D}} + \left(\delta_t\right)^{\frac{1}{\theta^D}} \left(D_{t,N}\right)^{\frac{\theta^D-1}{\theta^D}} + \left(1-z_t^h\right)^{\frac{1}{\theta^D}} \left(D_{t,F}\right)^{\frac{\theta^D-1}{\theta^D}} \right]^{\frac{\theta^D}{\theta^D-1}} . \end{aligned} \tag{32}$$

[8] These are goods in the varieties range $z \in [0, z_t^l)$ that are both exported and used at home.

The sub-baskets of intermediate goods are given by

(33)
$$D_{t,H} = \left[\left(\frac{1}{z_t^l}\right)^{\frac{1}{\theta^D}} \int_0^{z_t^l} (y_t(z))^{\frac{\theta^D-1}{\theta^D}} dz\right]^{\frac{\theta^D}{\theta^D-1}},$$
$$D_{t,N} = \left[\left(\frac{1}{\delta_t}\right)^{\frac{1}{\theta^D}} \int_{z_t^l}^{z_t^h} (y_t(z))^{\frac{\theta^D-1}{\theta^D}} dz\right]^{\frac{\theta^D}{\theta^D-1}},$$
$$D_{t,F} = \left[\left(\frac{1}{1-z_t^h}\right)^{\frac{1}{\theta^D}} \int_{z_t^h}^{1} (y_t(z))^{\frac{\theta^D-1}{\theta^D}} dz\right]^{\frac{\theta^D}{\theta^D-1}},$$

where the price sub-indices for each of these baskets can be shown to be

(34)
$$P_{t,H} = \left[\frac{1}{z_t^l} \int_0^{z_t^l} P_t(z)^{1-\theta^D} dz\right]^{\frac{1}{1-\theta^D}},$$
$$P_{t,N} = \left[\frac{1}{\delta_t} \int_{z_t^l}^{z_t^h} P_t(z)^{1-\theta^D} dz\right]^{\frac{1}{1-\theta^D}},$$
$$P_{t,F} = \left[\frac{1}{1-z_t^h} \int_{z_t^h}^{1} P_t(z)^{1-\theta^D} dz\right]^{\frac{1}{1-\theta^D}}.$$

Using our results on the pricing of individual varieties, and dividing through by the numeraire price level, we can rewrite these price indices in terms of aggregate variables as

(35)
$$p_{t,H} = \frac{mc_t}{x_t a_{t,H}},$$
$$p_{t,N} = \frac{mc_t}{x_t a_{t,N}},$$
$$p_{t,F} = p_{t,F}^* \frac{s_t}{1-\tau_t},$$

and similarly for Foreign. The sectorial productivity terms in the denominators of the first two expressions can be derived through analytical integration over the appropriate sub-intervals of goods varieties productivities.[9] We have[10]

(36)
$$a_{t,H} = \left[\frac{1}{z_t^l} \int_0^{z_t^l} a(z)^{\theta^D-1} dz\right]^{\frac{1}{\theta^D-1}}$$
$$= N\chi_t^l \left[\frac{\left(1-e^{-n(\theta^D-1)z_t^l}\right)}{n(\theta^D-1)z_t^l}\right]^{\frac{1}{\theta^D-1}},$$

(37)
$$a_{t,N} = \left[\frac{1}{\delta_t} \int_{z_t^l}^{z_t^h} a(z)^{\theta^D-1} dz\right]^{\frac{1}{\theta^D-1}}$$
$$= \left[\frac{\left(e^{-n(\theta^D-1)z_t^l} - e^{-n(\theta^D-1)z_t^h}\right)}{n(\theta^D-1)\delta_t}\right]^{\frac{1}{\theta^D-1}}.$$

[9] Note again that a critical implication of endogenous tradability is that the aggregate productivity level of a country is endogenous to the production choices of its firms.

[10] The Foreign aggregate productivity terms are simpler, with $a_{t,F}^* = \chi_t^h$ and $a_{t,N}^* = 1$.

Intermediates producers face a cost, in terms of both time and resources, of adjusting the imported goods component of production $D_{t,F}$. First, it takes time to build up new supplier relationships that allow the volume of imports to increase. We model this by assuming that the stock of import orders $D_{t,F}$ that is filled in any given quarter is predetermined, while it takes T periods for new orders O_t^{DF} to add to the existing order stock. Furthermore, we assume for simplicity that the existing order stock declines at the rate $\Delta^{df} = 1/(1+T)$, so that the entire stock of orders turns over completely within $T+1$ periods.[11]

We therefore have

$$D_{t,F} = (1-\Delta^{df})D_{t-1,F} + O_{t-T}^{DF} \ . \tag{38}$$

In addition to these time costs there is also a resource cost to changing the amount of orders, which represents the resources spent on foreign field offices and market reconnaissance. Let the import orders of intermediates producer i equal $O_t^{DF,i}$, and lagged aggregate orders O_{t-1}^{DF}. Then we have the following real resource cost in terms of imported intermediates:

$$\Phi_t^{DF} = \frac{\phi^{df}}{2} O_t^{DF,i} \left(\frac{\frac{O_t^{DF,i}}{D_t}}{\frac{O_{t-1}^{DF}}{D_{t-1}}} - 1 \right)^2 \ . \tag{39}$$

Let the marginal utility of an additional unit of domestic currency be given by $\Lambda_t = \lambda_t/P_t$. Then the profit maximization problem for a representative intermediates producer is

$$\begin{aligned} &Max\ E_0 \sum_{t=0}^{\infty} \beta^t \Lambda_t \left\{ P_t^D \left[(z_t^l)^{\frac{1}{\theta^D}} (D_{t,H})^{\frac{\theta^D-1}{\theta^D}} + (\delta_t)^{\frac{1}{\theta^D}} (D_{t,N})^{\frac{\theta^D-1}{\theta^D}} \right.\right. \\ &\left. +(1-z_t^h)^{\frac{1}{\theta^D}} (D_{t,F})^{\frac{\theta^D-1}{\theta^D}} \right]^{\frac{\theta^D}{\theta^D-1}} - P_{t,H}D_{t,H} - P_{t,N}D_{t,N} - P_{t,F}\left[D_{t,F} + \Phi_t^{DF}\right] \\ &\left. +q_t^{DF} P_{t,F} \left[(1-\Delta^{df})D_{t-1,F} + O_{t-T}^{DF} - D_{t,F} \right] \right\} \ . \end{aligned} \tag{40}$$

The solution to this problem for $D_{t,H}$ and $D_{t,N}$ is

$$p_t^D \left(\frac{z_t^l D_t}{D_{t,H}} \right)^{\frac{1}{\theta^D}} = p_{t,H} \ , \tag{41}$$

$$p_t^D \left(\frac{\delta_t D_t}{D_{t,N}} \right)^{\frac{1}{\theta^D}} = p_{t,N} \ . \tag{42}$$

The condition for $D_{t,F}$ is

$$\lambda_t p_{t,F} q_t^{DF} = \beta \lambda_{t+1} p_{t+1,F} q_{t+1}^{DF} (1-\Delta^{df}) + \lambda_t \left[p_t^D \left(\frac{(1-z_t^h)D_t}{D_{t,F}} \right)^{\frac{1}{\theta^D}} - p_{t,F} \right] \ , \tag{43}$$

with an optimality condition for new import orders of

$$\phi^{df} \lambda_t p_{t,F} \left(\frac{\frac{O_t^{DF}}{D_t}}{\frac{O_{t-1}^{DF}}{D_{t-1}}} - 1 \right) \left(\frac{\frac{O_t^{DF}}{D_t}}{\frac{O_{t-1}^{DF}}{D_{t-1}}} \right) = \beta^T \lambda_{t+T} p_{t+T,F} q_{t+T}^{DF} \ . \tag{44}$$

[11] Alternative assumptions for Δ^{df} are of course feasible and affect the rate at which new orders can change the stock of existing orders.

Note that the shadow price of the existing order stock q_t^{DF} is zero in steady state, but positive when there is a positive shock to the demand for imports that temporarily raises the marginal product of imports above the real import price. This specification of intermediates imports ensures both a delayed and gradual response of import volumes to shocks. Overall real trade rigidities of course also include the export adjustment costs mentioned above. On the other hand, endogenous tradability will push towards an ultimately larger response of trade volumes to real exchange rate changes, because firms can choose not only the quantity of exports they produce but also whether they wish to enter the export market in the first place.

D Final Output Producers

Final output producers are perfectly competitive price takers in their input markets and monopolistically competitive in their output market. Their production decisions are identical across producers, and we will therefore omit a firm specific index.[12] The first step in final output production is to combine tradables produced by domestic intermediates producers $Z_{t,H}$ with tradables produced by foreign intermediates producers $Z_{t,F}$ to produce the **tradables composite** T_t, with the following technology:

$$T_t = \left[(\xi_T)^{\frac{1}{\theta^T}} \left(Z_{t,H}\right)^{\frac{\theta^T-1}{\theta^T}} + (1-\xi_T)^{\frac{1}{\theta^T}} \left(Z_{t,F}\right)^{\frac{\theta^T-1}{\theta^T}} \right]^{\frac{\theta^T}{\theta^T-1}} . \tag{45}$$

As for intermediates producers, changing the level of imports $Z_{t,F}$ is subject to a time to build markets technology. We let P_t^T be the marginal cost of the composite T_t, P_t^{ZH} and P_t^{ZF} the prices of domestic and imported inputs, and we define Φ_t^{ZF} as

$$\Phi_t^{ZF} = \frac{\phi^{zf}}{2} O_t^{ZF,i} \left(\frac{\frac{O_t^{ZF,I}}{T_t}}{\frac{O_{t-1}^{ZF}}{T_{t-1}}} - 1 \right)^2 . \tag{46}$$

The import order stock evolves according to

$$Z_{t,F} = (1-\Delta^{zf}) Z_{t-1,F} + O_{t-T}^{ZF} . \tag{47}$$

Then the optimization problem is

$$\begin{aligned} Max\ E_0 \sum_{t=0}^{\infty} \beta^t \Lambda_t \Bigg\{ & P_t^T \left[(\xi_T)^{\frac{1}{\theta^T}} \left(Z_{t,H}\right)^{\frac{\theta^T-1}{\theta^T}} + (1-\xi_T)^{\frac{1}{\theta^T}} \left(Z_{t,F}\right)^{\frac{\theta^T-1}{\theta^T}} \right]^{\frac{\theta^T}{\theta^T-1}} \\ & - P_t^{ZH} Z_{t,H} - P_t^{ZF} \left[Z_{t,F} + \Phi_t^{ZF} \right] + q_t^{ZF} P_t^{ZF} \left[(1-\Delta^{zf}) Z_{t-1,F} + O_{t-T}^{ZF} - Z_{t,F} \right] \Bigg\} . \end{aligned} \tag{48}$$

The solutions to this problem for $Z_{t,H}$ and $Z_{t,F}$ are given by

$$p_t^{ZH} = p_t^T \left(\frac{\xi_T T_t}{Z_{t,H}} \right)^{\frac{1}{\theta^T}} , \tag{49}$$

$$\lambda_t p_t^{ZF} q_t^{ZF} = \beta \lambda_{t+1} p_{t+1}^{ZF} q_{t+1}^{ZF} (1-\Delta^{zf}) + \lambda_t \left[p_t^T \left(\frac{(1-\xi_T) T_t}{Z_{t,F}} \right)^{\frac{1}{\theta^T}} - p_t^{ZF} \right] , \tag{50}$$

[12] The exception is in adjustment cost terms, where we need to distinguish between lagged external aggregate terms and current firm-specific terms.

with an optimality condition for new import orders of

$$\phi^{zf}\lambda_t p_t^{ZF}\left(\frac{\frac{O_t^{ZF}}{T_t}}{\frac{O_{t-1}^{ZF}}{T_{t-1}}}-1\right)\left(\frac{\frac{O_t^{ZF}}{T_t}}{\frac{O_{t-1}^{ZF}}{T_{t-1}}}\right)=\beta^T\lambda_{t+T}p_{t+T}^{ZF}q_{t+T}^{ZF}\ , \tag{51}$$

and a price of imports of

$$p_t^{ZF}=p_t^{ZF^*}\frac{s_t}{(1-\tau_t)}\ . \tag{52}$$

Final output Ω_t is a composite of the stock of the nontradable fixed factor V_t and of tradables T_t, with the CES production function given by

$$\Omega_t=\left[(\xi_O)^{\frac{1}{\theta_O}}\left(V_t\right)^{\frac{\theta_O-1}{\theta_O}}+(1-\xi_O)^{\frac{1}{\theta_O}}\left(T_t\right)^{\frac{\theta_O-1}{\theta_O}}\right]^{\frac{\theta_O}{\theta_O-1}}\ . \tag{53}$$

We denote the nominal/real marginal cost of Ω_t by P_t^O/p_t^O and the nominal/real rental cost of the fixed factor by R_t^V/r_t^V. Then cost minimization implies the following demands for tradables and nontradables:

$$T_t=(1-\xi_O)\Omega_t\left(\frac{p_t^T}{p_t^O}\right)^{-\theta_O}\ , \tag{54}$$

$$V=\xi_O\Omega_t\left(\frac{r_t^V}{p_t^O}\right)^{-\theta_O}\ . \tag{55}$$

Final output producers' **price setting** is subject to sticky inflation as in the wage setting decision outlined above. Specifically, we assume that all users of final output demand a CES composite of varieties supplied by final goods producers, with time-varying elasticity of substitution θ_t^p. The cost minimization problem of an individual user of final output indexed by z is given by

$$\underset{\Omega_t^i(z),i\in[0,1]}{Min}\int_0^1 P_t^i\Omega_t^i(z)di\ \ s.t.\ \Omega_t(z)=\left(\int_0^1\Omega_t^i(z)^{\frac{\theta_t^p-1}{\theta_t^p}}di\right)^{\frac{\theta_t^p}{\theta_t^p-1}}\ . \tag{56}$$

This produces a set of goods demand equations for each variety $\Omega_t^i(z)$ that, given identical relative prices facing each user of final output, is straightforward to aggregate so as to obtain total demand for each variety Ω_t^i:

$$\Omega_t^i=\left(\frac{P_t^i}{P_t}\right)^{-\theta_t^p}\Omega_t\ \ ,\ \ P_t=\left(\int_0^1\left(P_t^i\right)^{1-\theta_t^p}di\right)^{\frac{1}{1-\theta_t^p}}\ . \tag{57}$$

Final output producers maximize the present discounted value of their cashflow subject to their goods demand (57) the inflation adjustment cost

$$\Phi_t^p=\frac{\phi^p}{2}\Omega_t\left(\frac{\pi_t^i}{\pi_{t-1}}-1\right)^2\ , \tag{58}$$

and a fixed cost in terms of final output ω^O that is given by

$$\omega^O=\frac{1}{\theta^p}\left(1-\iota\right)\bar{\Omega}\ . \tag{59}$$

When $\iota = 0$, this fixed cost exactly offsets the steady state markup profits $\bar{\Omega}/\bar{\theta}^p$. For $\iota \in (0,1)$ the parameter ι denotes the share of markup profits that are retained as profits by the firm after fixed costs have been paid. We introduce this fixed cost term, which is familiar from Altig, Christiano, Eichenbaum and Linde (2005) who set $\iota = 0$, to be able to better calibrate investment and capital income shares in GDP, as explained in the calibration section. The profit maximization problem is therefore

$$Max \; E_0 \sum_{t=0}^{\infty} \beta^t \Lambda_t \left\{ \left(P_t^i - P_t^O\right) \left(\frac{P_t^i}{P_t}\right)^{-\theta_t^p} \Omega_t - P_t \Phi_t^p - P_t^O \omega^O \right\} . \tag{60}$$

After recognizing that all firms behave identically and therefore dropping the firm-specific indices i, the first order condition with respect to P_t^i is given by

$$\frac{\theta_t^p}{\theta_t^p - 1} p_t^O - 1 = \frac{\phi^p}{\theta_t^p - 1} \left(\frac{\pi_t}{\pi_{t-1}} - 1\right) \frac{\pi_t}{\pi_{t-1}} - \frac{\phi^p}{\theta_t^p - 1} \beta \frac{\lambda_{t+1}}{\lambda_t} \frac{\Omega_{t+1}}{\Omega_t} \left(\frac{\pi_{t+1}}{\pi_t} - 1\right) \frac{\pi_{t+1}}{\pi_t} . \tag{61}$$

We allow for price markup shocks. In particular, the exogenously time-varying price markup is given by

$$\mu_t^p = \frac{\theta_t^p}{\theta_t^p - 1} , \tag{62}$$

which is subject to i.i.d. shocks

$$\mu_t^p = \bar{\mu}^p \left(1 + u_t^p\right) . \tag{63}$$

E Government

Fiscal policy in both countries is Ricardian in that fiscal lump-sum taxes are endogenously adjusted to finance government spending, after taking seigniorage into account. To correctly calibrate steady state shares of consumption and investment in GDP, we assume a fixed amount of government spending G in each period. We also assume that the initial stock of nominal government debt is zero. Net taxes are determined by

$$Tx_t + M_t - M_{t-1} = G_t , \tag{64}$$

which maintains the stock of government debt at zero at all times. The benchmark policy rule that we consider for the Home economy is an extended version of the Taylor (1993) rule that allows for interest rate smoothing and that adds an additional real exchange rate feedback term:

$$i_t = \left(i_{t-1}\right)^{\lambda_i} \left(\frac{\bar{\pi}}{\beta}\right)^{1-\lambda_i} \left(\frac{\pi_{4,t}}{\bar{\pi}}\right)^{\lambda_\pi} \left(\frac{gdp_t}{\overline{gdp}}\right)^{\lambda_y} \left(\frac{s_t}{\bar{s}}\right)^{\lambda_s} . \tag{65}$$

The inflation target is given by $\bar{\pi}$ so that $\bar{\pi}/\beta$ is the long-run nominal interest rate. The central bank is assumed to respond to deviations of the the year-on-year inflation rate $\pi_{4,t} = \left(\pi_t \pi_{t-1} \pi_{t-2} \pi_{t-3}\right)^{\frac{1}{4}}$ from its target $\bar{\pi}$, and to the output gap and the real exchange rate gap. The output gap is a defined as the deviation of GDP from a 2-sided centered moving average of GDP with weights taken from the Hodrick-Prescott (HP) filter. While this measure of the output gap is imperfect, it helps to avoid some of the pitfalls with using alternative measures such as the flex-price output gap, or purely backward-looking measures that are based on one-sided versions of the HP filter that exclude the model's predicted levels of future GDP—see Appendix I for more details about the HP filter and the weights that we use. In effect, because we are using the model's predictions to help measure the underlying trend level of output it will produce measures of the business cycle that can account partly for supply shocks that shift the level of potential output. The measures will also be much less erratic and jumpy than flex-price measures of the output gaps that are influenced by data measurement problems.[13] In addition, in empirical versions of these models that produce competitive forecasts, following this approach in real time will result in significantly smaller revisions in the measures of the business cycle than what is obtained from one-sided applications of Hodrick-Prescott filter, which ignore information from the model's forecast of future output—see Juillard, Kamenik, Kumhof and Laxton (2007). Finally, and critically for this paper, the last term of the Taylor Rule includes a measure of the real exchange rate gap measured in exactly the same way as we measure the output gap. Including the real exchange rate gap is not standard, but the purpose of this paper is of course to analyze whether this term should be included in a world with endogenous tradability and real trade frictions. The Foreign central bank is assumed to follows a similar interest rate feedback rule, but without a real exchange rate feedback term.

F Equilibrium and the Current Account

In equilibrium households maximize lifetime utility, firms at all levels of production maximize the present discounted value of their cashflows, and the government follows its policies as outlined in the previous section. In addition, the following market clearing conditions hold (with an equivalent set of conditions for Foreign):[14]

$$L_t = L_{t,H} + L_{t,N} \ , \tag{66}$$

$$K_t = K_{t,H} + K_{t,N} \ , \tag{67}$$

$$Y_{t,H} = p_{t,H} D_{t,H} + s_t p^*_{t,H} D^*_{t,H} \ , \tag{68}$$

$$Y_{t,N} = p_{t,N} D_{t,N} \ , \tag{69}$$

$$D_t = Z_{t,H} + \frac{Z^*_{t,H}}{(1-\tau_t)} \ , \tag{70}$$

$$V_t = V \ , \tag{71}$$

$$\Omega_t = C_t + J_t + G_t + \omega^O \ . \tag{72}$$

Together with household and government budget constraints these clearing conditions imply the following current account equation:

$$f_{t-1} \frac{i^*_{t-1} \varepsilon_t}{\pi_t} + s_t p^*_{t,H} D^*_{t,H} + s_t p_t^{ZH^*} Z^*_{t,H} = f_t + p_{t,F} D_{t,F} + p_t^{ZF} Z_{t,F} \ . \tag{73}$$

Finally, international bond market clearing is given by

$$f_t + f^*_t s_t = 0 \ . \tag{74}$$

[13] Wage and price indicies contain significant noise components that induce measurement errors into flex-price measures of the output gap, which is one reason why they have not had much of an impact in policymaking deliberations. Another reason is that they typically are constructed by assuming that all of the economy's state variables—such as the capital stock—have always been determined by a flex-price economy.

[14] Notice that the presence of relative prices in the market clearing conditions for varieties composites in sectors H and N is due to the fact that the output composites Y are defined as additive in quantities while the input quantities D are defined as CES aggregates.

III Calibration

We calibrate the model with the euro area in mind, and therefore set the size of Home to be 25 percent of the world economy ($\alpha = 0.25$). Unless otherwise mentioned, parameters are assumed to be the same across the two countries. Consumers discount the future at the rate of 1 percent per quarter (4 percent per year) ($\beta = 0.99$). The intertemporal elasticity of substitution (σ) and the degree of habit persistence (ν) are 0.5 and 0.85, respectively. These coefficients, together with adjustment costs on consumption and investment, generate the lagged and hump-shaped responses to interest hikes typically found in empirical models.[15] The Frisch elasticity of labor supply, which is implied by σ and the steady state proportion of time worked,[16] is set equal to 0.5, which is standard for the macroeconomic literature, but at the high end of microeconomic estimates.

Average markups for both the euro area and the rest of the world are taken from Bayoumi, Laxton and Pesenti (2004). The steady-state labor market markup is set to 30% in Home and 16% in Foreign and in the goods markets it is set at 35% in Home and 23% in Foreign. Coefficients defining wage and price stickiness parameters have all been set to 400. These values were chosen to produce plausible impulse responses to standard shocks. Elasticities of substitution between Home and Foreign traded goods θ^D and θ^T were set equal to 1.5, as is standard in the macroeconomic literature. The elasticity of substitution between traded and exogenously nontraded goods θ^O is set to 0.8, following the evidence surveyed in Mendoza (2005).

Turning to time-to-build lags, following Murchison, Rennison and Zhu (2004), we assume that it takes one quarter to plan an investment project and 5 quarters to complete it.[17] We assume that investment expenditure is spread equally over the $(T + 1)$-period life of the investment project. In addition, we set the adjustment cost parameters that govern investment dynamics to be consistent with the hump-shaped pattern seen in response to interest rate cuts that peak at around 4-6 quarters. The depreciation rate of private capital is 2.5 percent per quarter ($\Delta = 0.025$).

To reflect the difficulties of building and maintaining international supplier relationships compared to domestic supplier relationships, we assume a time-to-build markets lag of 2 quarters in both intermediate and final goods. This implies that the two depreciation rates Δ^{df} and Δ^{zf} of existing import orders equal 1/3. We choose adjustment cost parameters to generate plausible dynamics of imports following shocks. Similarly, setting $\phi^a = 0.2$ generates plausible transitions between exporting and non-exporting firms following shocks. The model therefore generates small changes in trade volumes in response to temporary real exchange rate fluctuations, but large changes in response to permanent shocks, as has been observed in practice—see Erceg, Guerrieri, and Gust (2003) and Laxton and Pesenti (2003). Finally, we set the parameters that determine

[15] Without the adjustment costs, higher parameter estimates may be needed. For example, Bayoumi, Laxton and Pesenti (2004) show that estimates as high as 5.0 and 0.97 are required for σ and ν to generate the hump-shaped responses to interest rate shocks that can be found in the ECB's Area-Wide Model (AWM) of the monetary transmission mechanism—see Fagan, Henry and Mestre (2001).

[16] As usual for this type of utility function one can calibrate either the Frisch elasticity or the proportion of time worked in steady state. We choose the former as it more significant for macroeconomic dynamics.

[17] Time-to-build dynamics are becoming an important feature of the new generation of macro models that are being designed inside central banks. For example, the work by Murchison, Rennison and Zhu (2004) at the Bank of Canada builds on earlier work at the Fed by Edge (2000a, 2000b). For more information on the importance of time-to-build dynamics for the internal propagation mechanism of DSGE models, see Casares (2004). In particular, Casares (2004) provides a very useful study showing the effects on macroeconomic dynamics of adding time-to-build lags that range between 1 and 8 quarters.

the endogenous risk premium on bonds to ensure that changes in the risk premium are sufficient to prevent implausibly large current account deficits.

The model is calibrated so that standard components of GDP have sizes compatible with their average shares in GDP in the data. The only difficulty here is the share of exogenously nontraded goods in GDP, which we assume to be 25 percent. Relative GDP in both countries is fixed by adjusting the Home aggregate productivity parameter x in accordance with relative GDP in the data, leaving $x^* = 1$. Government spending and private investment are each assumed to represent 18 percent of steady state GDP in each country, where the private investment ratio is fixed by choosing the production function parameter γ. Note that our previous choices of γ and Δ would typically make it impossible to independently fix the steady state capital share. There is however a solution to this in models with monopolistic competition, because the capital share does not only depend on the return to capital but also on the monopoly profits of firms minus their fixed costs. We therefore fix the steady state capital share in GDP at 36 percent in both Home and Foreign, by appropriately setting the fixed cost parameter ι. Exports and imports are assumed to be balanced in steady state, with an overall 20 percent exports and imports to GDP ratio in Home (and of course correspondingly smaller ratios in the larger Foreign), half of which is accounted for by intermediate goods and half by final goods. To calibrate trade in this way the parameters at our disposal are different from conventional models, at least at the level of intermediate goods. The parameter here is not an exogenous share parameter (like ξ_T at the level of final output) but the slope n of the relative productivity schedule.[18] We first choose trading costs to equal $\tau = 0.15$, and then obtain $n = 0.4$ as consistent with 20 percent exports and imports to GDP ratios. This relatively flat slope reflects the fact that we assumed Home to represent a fairly large share of the world economy. Finally, we set the parameters that determine the endogenous risk premium on bonds to ensure that changes in the risk premium are sufficient to prevent implausibly large current account deficits.

For monetary policy, we assume that the inflation targets in both Home and Foreign equal 2 percent per annum. The coefficients of the monetary policy rule are of course the subject of our analysis.

We work with a fairly stylized representation of the shock processes, which are assumed to be identical in both economies. The wage and price markup shocks are assumed to be equal in magnitude and their magnitudes have been calibrated so that they determine most of the variation in the inflation process at the business cycle frequency. Following recent empirical work we assume that there is no serial correlation in these shocks–see Smets and Wouters (2004), Juillard and others (2006) and Juillard and others (2007). In same empirical work demand shocks to consumption and investment have been found to be very significant for explaining variation in the real economy at business cycle frequency. Following Juillard and others (2006) we assume that the consumption and investment shocks are positively correlated (0.50) and that there exists significant positive serial correlation in the consumption shocks. We also consider shocks to the UIP equation, which have been found to be very important for explaining exchange rate variability and for these shocks we assume that they are highly serially correlated (0.75). In the section on sensitivity analysis we consider different assumptions about the shock processes to examine how the results change under alternative assumptions. We do not consider other sources of shocks such as permanent productivity shocks or shocks that affect specialization and openness, but leave the analysis of these additional shocks until the model has been fully estimated.

[18] The intercept N cannot be set independently of the aggregate productivity parameter x, whose calibration was discussed above.

Figure 2 reports the responses of GETM to a persistent 100 basis point hike in interest rates in the Home economy. The magnitude and hump-shaped response of GDP and consumption is similar to standard DSGE models such as the IMF's Global Economy Model (GEM) as well as reduced-form econometric models such as the ECB's Area-Wide Model (AWM) model—compare Figure 2 with Table 1. However, GETM shows significantly smaller investment responses for temporary shocks. This mainly reflects the time-to-build capital assumption in GETM, which tends to weaken the response of investment in response to temporary shocks. Conventional DSGE models such as GEM assume quadratic adjustment costs associated with changing the level of investment and abstract from time-to-build considerations—for a discussion of model properties with time-to-build dynamics see Murchison, Rennison, and Zhu (2004). Reduced-form models such as AWM are completely backward looking and so the responses to shocks should in principle represent an average response to temporary and permanent shocks. GETM's responses to permanent shocks will typically be larger as it takes longer to increase the capital stock and firms have the incentive to incur the adjustment costs. Interestingly, the responses of imports and exports are significantly stronger in GETM than in GEM and are more in line with the stronger responses of AWM.[19] Again, this reflects the key assumption in GETM that the supply of exports is more responsive to relative prices as firms are allowed to choose to produce goods for either the export or domestic market.

IV Results

The main goal of this section is to assess under what conditions standard monetary policy reaction functions such as the Taylor rule need to be modified to include information about the exchange rate. However, before proceeding to this analysis we first start by showing how GETM is different from other standard DSGE models and why endogenous tradability matters.

A How is GETM Different from Other Models?

Conventional monetary business cycle models cannot account for strong trends in trade volumes, nor can they explain how the monetary transmission mechanism changes over time as economies exploit greater specialization. The objective of GETM has been to develop a model that integrates trade theory into a monetary business cycle model. The basic assumption of the model is that trading costs restrict trade and result in lower levels of specialization and productivity. Figure 3 reports results that show the long-run effects on welfare, trade, GDP, consumption, investment and labor effort of lower trading costs. In the base-case calibration a reduction in trading costs of 15 percentage points raises the export-to-GDP ratio by almost 42 percentage points. As trading costs represent pure deadweight losses welfare improves significantly in both economies. In the Home economy GDP and investment rise by 9.0 percent and 8.4 percent, respectively. The increases in consumption in the Home economy are even larger (11.7 percent) than the gains in GDP as the terms of trade improves in favor of the Home economy. The welfare improvement in the Foreign economy is significant, but much smaller than in the Home economy. This reflects the assumption that the Foreign economy is much larger than the Home economy (0.75 versus 0.25) so there are smaller potential gains from trade. In both economies higher welfare is a result of higher levels of productivity, which increase

[19] These responses are reported in Fagan, Henry and Mestre (2001) and Bayoumi, Laxton and Pesenti (2004).

the sustainable level of real income. This results in an increase in the consumption of leisure—reduction in labor effort—that is one half as large as the increase in consumption of goods and services.

Figures 4 to 7 provide some sensitivity analysis. The base-case calibration of the Home economy assumes that its relative size is 0.25. Figure 4 considers the case of a small open economy that only represents 1 percent of the world's population. In this case the benefits of lower trading costs mainly accrue to the smaller economy and become larger. Indeed, in this case a 15 percentage point reduction in trading costs raises GDP by 14.8 percent, about 5 percentage points more than in the base case when it represented 25 percent of the world. Figures 5 and 6 report results for cases where the elasticity of substitution between imported goods and domestically produced goods is 1.00 and 3.0, instead of the base-case assumption of 1.5. As can be seen in the Figures, higher trade elasticities strengthen the responsiveness of trade flows, but have very little additional effects. For example, in the base case a reduction in trading costs of 15 percentage points increases the export-to-GDP ratio by 41.9 percentage points and this effect declines to 41.3 percentage points when the elasticity of substitution is 1.0 and rises to 44.1 percentage points when it is 3.0. However, in these cases the effects on GDP and consumption are almost identical. To isolate the different supply-side effects Figure 7 reports the results for a smaller labor supply elasticity (0.25 instead of the 0.50 that was used in the base case). A lower elasticity of labor supply strengthens the effects on GDP (10.2 versus 9.0 percent in the base case), consumption (11.7 versus 13.2 percent) and investment (8.4 versus 9.5 percent) as workers increase leisure relatively less in response to higher productivity.

B Optimal Simple Policy Rules

We now optimize the feedback and smoothing coefficients in the monetary policy rule (65). To do so we consider a general loss function where policymakers are assumed to care about variability in inflation, output, and exports:

$$L = L_1 var(\pi 4) + L_2 var(ygap) + L_3 var(xgap)\ . \tag{75}$$

The first two terms that place weights on inflation and output variability are standard. We argue there may be good reasons why policymakers might also care about variability in exports if there are significant frictions in shifting resources into the export sector. However, we do not make this element of the loss function critical for our results, rather we simply report results for alternative sets of weights and discuss the implications. In future extensions of the paper we plan to explore higher-order approximations of the model and possibly welfare analysis so that we can analyze the level effects on welfare and other variables that may arise from excessive variability in exports. But, it should be recognized that loss functions are a more flexible approach that is not dependent on the specific form chosen for the utility function. In addition, it allows for a simple characterization of preferences for policymakers, whose objectives may not wholly coincide with those of private agents, a phenomenon that is important in accounting for real-world policymaking.

For expositional purposes we define *inflation nutters* as policymakers that place a weight of 1 on inflation and zero weights on output and export variability. We define *output gappers* as policymakers that place equal weights on inflation and output gap variability; and *output-export gappers* as policymakers that place equal weights on variability in inflation, output gaps and export gaps. To rule out implausibly large magnitudes for interest rate variability we also assume that the objective function is minimized subject to a constraint that the standard deviation of the first difference of interest rates is less than or equal to 50 basis points.[20]

B.1 Base-Case Results

The top row of Table 2 reports the base-case results for *inflation nutters* when the exchange rate is in the reaction function and the second row reports the results for *inflation nutters* when it is excluded from the reaction function. The 3rd row reports the difference between the first 2 rows so that it is easier to see the additional variability imposed on the economy by ignoring variation in the exchange rate. The next 6 rows in the Table repeat the analysis for *output gappers* and *output-export gappers*. In each line we report the value of the loss function, the optimal parameters in the reaction function as well as the standard deviations for year-on-year inflation, output, exports and the real exchange rate, all measured as deviations from trend.

The results for *inflation nutters* produce a large weight on inflation in the reaction function and significant positive weights on the output gap and the exchange rate. This suggests that the output gap and exchange rate gaps have significant information content that is useful for helping to reduce variability in inflation. However, when we focus on the role of the latter by comparing the differences between the first 2 rows we can see that excluding the exchange rate results in a very small increase in the inflation variability of two basis points. Note, however, that there are significant increases in the variability of output and especially exports by ignoring exchange rate developments, so that while the losses of *inflation nutters* are little affected by ignoring output and exchange rate gaps, *inflation nutters* would impose significant losses on *output gappers* and *output-export gappers*. Indeed, the parameter estimates on inflation are much larger than what is typically observed in reaction functions, suggesting that policymakers are not *inflation nutters*, but instead place significant weight on real variables when they deliberate about interest rate decisions. Indeed, when we move to the cases of *output gappers* and *output-export gappers* we observe a significant decline in the weight on the inflation term and an increase in the weight on the output gap in the case of *output gappers* and an increase in the weight on the real exchange rate gap for the case of *output-export gappers*. For the case of the *output-export gappers* there is a significant reduction in variability in both output and exports at the cost of higher variability in inflation while for the *output gappers* excluding the exchange rate increases variabililty in both output and inflation. At this point the obvious question to ask is how these results are different from conventional monetary business cycle models that abstract from endogenous tradability. The next subsection answers that question.

B.2 The Role of Endogenous Tradability

It is straightforward in GETM to exclude endogenous tradability from the model by simply deleting the equations that determine the evolution of z_t^l and z_t^h, and then exogenizing these variables. This and eliminating trade frictions turns GETM into the standard open economy model that has been used extensively in the literature. Table 3 repeats the analysis above when we exclude endogenous tradability. Strikingly, the parameters on the exchange rate gap decline to practically zero and there is very little difference in all cases between the loss functions where the exchange rate gap enters the reaction function and those cases where it does not. This confirms earlier results obtained from other DSGE models that assume producer currency pricing, where the exchange rate has not been found to play a significant contribution in conventional mon-

[20] This is only slightly higher than the standard deviation of the first difference of short-term interest rates in the euro area.

etary reaction functions. A comparison of Tables 2 and 3 shows that shutting down this mechanism results in significantly less variability in inflation, output and exports.

To illustrate the differences in the two models we report the impulse response functions (IRFs) for an expansionary consumption shock in the Home economy. Figure 8 reports the results for the *output-export gapper* under the assumption of exogenous tradability and Figure 9 reports the results under endogenous tradability. In both cases we compare the IRFs with and without the exchange rate gap in the reaction function. With exogenous tradability the IRFs are virtually identical for interest rates, GDP, the real exchange rate, consumption, investment and trade volumes and, in fact, the only discernible difference is in the plot for year-on-year inflation. However, with endogenous tradability there are significant differences in the IRFs. The results without the exchange rate gap produce a much stronger tightening in real monetary conditions (higher interest rates and a more appreciated real exchange rate) which works to constrain the expansionary effects on GDP, consumption and investment. Note, however, that it also results in a larger contractionary effect on exports and produces a significant undershoot of inflation from the target.

B.3 Implications of Lower Trading Costs

Table 4 reports the results when trading costs are reduced from 0.15 in the base case to 0.10. As shown in Figure 3 this raises the steady-state exports to GDP ratio by about 15 percentage points. A comparison of these results with the base-case results reveals interesting differences. Export variability declines because as economies become more open they require smaller adjustments in exports and imports in percentage terms to accommodate domestic demand shocks. It is important to emphasize that this prediction is based on comparing the dynamics around 2 steady states and it may be difficult to distinguish this effect in real data from other effects when economies are in the process of moving from one steady state to another either because of changes in openness or long-run shifts in their net foreign asset positions. Not only is welfare permanently higher as a result of lower trading costs, but there are significantly smaller losses for policymakers that are *output-export gappers*.

B.4 Decomposition of Base-Case Results for Individual Types of Shocks

The advantage of simple monetary policy rules as guidelines for monetary policy is that they depend on a short list of variables. As such they are easier to understand and communicate than fully optimal rules, which will depend on the full list of model's shocks that is being considered. The optimized weights in simple monetary policy rules will represent *average* responses to shocks that will generally not be optimal for supply and demand shocks. To better understand the base-case results reported in Table 2 we recompute the optimal parameters in the simple policy rule under different assumptions about the shocks focusing on different types of shocks. Indeed, for this purpose we separate the shocks used in the base case into 3 types of shocks. The first type are demand shocks, which result in a positive short run covariance between output and inflation. The second type of shocks are wage and price markups, which result in a negative short run covariance between output and inflation. Lastly, to understand the role of UIP shocks we consider these shocks separately.

Only Demand Shocks Table 5 reports the results when we exclude all shocks except the 2 demand shocks in each region. For the case of *inflation nutters* and *output gappers* we observe very large parameters on both inflation and the output gap. And in both cases such policy rules are capable of reducing inflation variability to very low levels (below 0.2). These results should not be surprising given that monetary policy is best equipped to deal with such shocks as there is very little conflict between stabilizing inflation and stabilizing output. However, the fact that we do not observe such enormous feedback responses in the real world might indicate that it is not straightforward for policymakers to identify pure demand shocks. Interestingly, in both these cases the real exchange rate still plays a significant role in reducing inflation variability, except for *output-export gappers*, where the primary effect is in reducing export variability.

Only Supply Shocks Table 6 reports the results for the cases where we eliminate all the shocks expect the wage and price markup shocks. As supply shocks are the dominant source of shocks for explaining variability in inflation it should not be surprising that inflation variability is much higher than was the case for demand shocks. Here we observe a much less significant role for the exchange rate than for demand shocks.

Only UIP Shocks Table 7 completes the analysis and reports the results for the cases where we eliminate all shocks expect UIP shocks. In this case we should again expect to see a large role for the exchange rate, which is confirmed by larger coefficients on the exchange rate gap in the rule.

B.5 What About a Forward-Looking Taylor Rule?

In constructing internal forecasts several central banks rely upon forward-looking Taylor rules, which include a 1-year-ahead forecast of inflation rather than a contemporaneous measure of inflation. One potential interpretation of the earlier results is that the output gap and exchange rate gap include significant information content for helping to forecast future inflation developments and that this is the main explanation for why these variables have been found to be useful in minimizing the objective function. To address this issue we repeat the analysis above, but replace the inflation term in the reaction function with the model's 1-year-ahead forecast of inflation. The results are reported in Table 8. In most cases the value of the loss function is smaller and for the cases of *inflation nutters* and *output gappers* there is a smaller weight on the exchange rate gap. Also, relative to the base case the differences in the loss function for the reaction functions that include and exclude the exchange rate gap term diminishes, suggesting that the exchange rate has information that helps to project future movements in inflation that is useful for helping to minimize the loss function. However, for the case of the *output-export gappers* excluding information about the exchange rate still has significant deleterious effects on the value of the loss function as it can result in excessive variability in exports.

B.6 Sensitivity Analysis

Tables 9 and 10 explore the sensitivity of our results to changes in the baseline calibration that change the steady-state size of exports. Table 9 raises the steady-state exports-to-GDP ratio in the final goods sector from 10% to 50% by changing the share parameter ξ_T. This implies that any shock can be accommodated with a smaller relative change in exports, therefore the volatility of exports falls relative to the baseline. But because exports are more volatile than other components of GDP, the overall volatility of output increases. We find that this change in specification reduces the optimal coefficient on the real exchange rate gap, especially for the *output-export gapper*. The reason is that export volatility accounts for a smaller share of losses, therefore stabilizing exports by responding to the real exchange rate becomes less important. But of course this needs to be heavily qualified, in that the loss function weight on export volatility would presumably change as exports become a more important sector of the economy. Table 10 is more interesting. Here we raise the steady-state exports-to-GDP ratio in the intermediate goods sector from 10% to 30%, but in the intermediates sector this is not accomplished through changing a share parameter. Instead, for a given trading cost τ, we need to change the pattern of comparative advantage. To allow more goods to be traded, this pattern needs to be more pronounced, in other words the comparative advantage schedule has to become steeper. Specifically, in our calibration we go from $n = 0.4$ to $n = 0.8$. Relative to the change in the exports-to-GDP ratio, which is only half that of the previous example, we observe much larger reductions in export volatility and in the optimal coefficient on the real exchange rate, and not only for the *output-export gapper*. In fact, in the limit this type of change would lead to exogenous tradability, as with a near vertical comparative advantage schedule the range of traded goods would no longer be sensitive to shocks and to the real exchange rate.

We have also performed the sensitivity of our results to removing different combinations of endogenous tradability, export adjustment costs and import adjustment costs. The picture that emerges is that these effects are cumulative, in that the more of them are combined, the larger is the optimal monetary response to the real exchange rate gap.

Additional sensitivity analysis is in progress. Specifically, in ongoing work we trace out entire efficiency frontiers for a continuum of the inflation, output and export weights in the loss function, and we explore more extreme limiting assumptions.

V Conclusions

This paper develops a DSGE model that integrates the theory of comparative advantage or endogenous tradability into a monetary model with nominal and real rigidities. We found that without endogenous tradability there is no role for the exchange rate in optimized monetary policy rules. But with endogenous tradability the exchange rate can play a much more fundamental role in facilitating or slowing down adjustments in the real economy, and it enters the optimized policy rule. The role of the real exchange rate in the policy rule is even more significant when trade is subject to export and import adjustment costs.

We performed sensitivity analysis to see what are the key assumptions that give the exchange rate an important role in the monetary policy rule. Looking forward, we plan to extend this analysis by taking higher-order approximations of the model so that we can study the level effects on welfare and economic activity that may arise from excessive variability in trade flows.

References

[1] Aitken, B., Hanson, G. and Harrison, A. (1997), "Spillovers, Foreign Investment and Export Behavior", *Journal of International Economics*, **43(1-2)**, 103-132.

[2] Altig, D., Christiano, L., Eichenbaum, M. and Linde, J. (2005), "Firm-Specific Capital, Nominal Rigidities and the Business Cycle", Working Paper.

[3] Backus, D., Kehoe, P. and Kydland, F. (1994), "Dynamics of the Trade Balance and the Terms of Trade: the J-Curve?", *American Economic Review*, **84(1)**, 84-103.

[4] Balassa, B. (1964), "The Purchasing Power Doctrine: A Reappraisal", *Journal of Political Economy*, **72**, 585-596.

[5] Bayoumi, T., Laxton, D. and Pesenti, P. (2004), "Benefits and Spillovers of Greater Competition in Europe: A Macroeconomic Assessment", *ECB Working Papers*, No. 341.

[6] Benigno, G. and Benigno, P. (2003), "Price Stability in Open Economies", *Review of Economic Studies*, **70**, 743-764.

[7] Bergin, P., and Glick, R. (2003), "Endogenous Nontradability and Macroeconomic Implications", *NEBR Working Papers*, No. 9739.

[8] Bernard, A. and Jensen, J. (2004), "Why Some Firms Export", *Review of Economics and Statistics*, **86(2)**, 561-569.

[9] Becedes, T. and Prusa, T. (2006), "Ins, Outs and the Duration of Trade", *Canadian Journal of Economics*, **39(1)**, 266-295.

[10] Burstein, A., Eichenbaum, M. and Rebelo, S. (2005), "Large Devaluations and the Real Exchange Rate", *Journal of Political Economy*, **113(4)**, 742-84.

[11] Casares, M. (2002), "Time-To-Build Approach in A Sticky Price, Sticky Wage Optimizing Monetary Model", *ECB Working Paper Series*, No. 147.

[12] Campa, M and Goldberg, L. (2005), "Exchange Rate Pass-Through into Imports Prices", *Review of Economics and Statistics*, **87(4)**, 679-690.

[13] Corsetti, G. and Pesenti, P. (2005), "International Dimensions of Optimal Monetary Policy", *Journal of Monetary Economics*, **52(2)**, 281-305.

[14] Das S., Roberts, M. and Tybout, J. (2001), "Market Entry Costs, Producer Heterogeneity and Export Dynamics", *NBER Working Papers*, No. 8629.

[15] Devereux, M. and Engel, C. (2002), "Exchange Rate Pass-Through, Exchange Rate Volatility and Exchange Rate Disconnect", *Journal of Monetary Economics*, **49**, 913-940.

[16] Edge, R. (2000a), "The Effect of Monetary Policy on Residential and Structures Investment Under Differential Project Planning and Completion Times", *Board of Governors of the Federal Reserve System International Finance Discussion Papers*, No. 671.

[17] ______ (2000b), “Time-to-Build, Time-to-Plan, Habit-Persistence, and the Liquidity Effect”, *Board of Governors of the Federal Reserve System International Finance Discussion Papers*, No. 673.

[18] Devereux, M. and Engel, C. (2003), “Monetary Policy in the Open Economy Revisited: Price Setting and Exchange-Rate Flexibility”, *Review of Economic Studies*, **70(4)**, 765-83.

[19] Erceg, C., L. Guerrieri and C. Gust. (2003). “SIGMA: A New Open Economy Model for Policy Analysis. ” Draft Paper prepared for the Annual Centrla Bank Modelers’ Workshop, Amsterdam.

[20] Fagan, G., Henry, J. and Mestre, R. (2001), “An Area-Wide Model (AWM) for the Euro Area”, *ECB Working Papers*, No. 42.

[21] Faruqee, H. (2004), “Measuring the Trade Effects of EMU”, *IMF Working Papers*.

[22] Frankel, J. and Rose, A. (1998), “The Endogeneity of the Optimum Currency Area Criteria”, *The Economic Journal*, **108**, 1009-25.

[23] Friedman, M. (1953), “The Case for Flexible Exchange Rates”, in *Essays in Positive Economics*, Chicago University Press, 157-203.

[24] Gali, J. and Monacelli, T. (2005), “Monetary Policy and Exchange Rate Volatility in a Small Open Economy”, *Review of Economic Studies*, **72**, 707-734.

[25] Ghironi, F. and Melitz, M. (2005), “International Trade and Macroeconomic Dynamics with Heterogeneous Firms”, *Quarterly Journal of Economics*, **120(3)**, 865-915.

[26] Goldberg, P. and Knetter, M. (1997), “Goods Prices and Exchange Rates: What Have We Learned?”, *American Economic Review*, **35(3)**, 1243-1272.

[27] Gomes, T., Graham, C., Helliwell, J., Kano, T., Murray, J. and Schembri, L. (2004). “The EURO and Trade: Is There a Positive Effect?” Paper prepared for the Empirical Investigations in International Economics conference, June 9-11, 2004 at Ljubljana University, Ljubljana, Slovenia. Bank of Canada (forthcoming).

[28] Goodfriend, M. and King, R. (1997), “The New Neoclassical Synthesis and the Role of Monetary Policy”, *NBER Macroeconomics Annual*, **12**, 231-283.

[29] Halpern, L. and Wyplosz, C. (2001), “Economic Transformation and Real Exchange Rates in the 2000s: The Balassa-Samuelson Connection”, *Working Paper, Graduate Institute for International Studies*.

[30] Huang, X. and Liu, Z. (2004), “Production Interdependence and Welfare”, *ECB Working Paper*, No. 355.

[31] Hummels, D. and Klenow, P. (2005), “The Variety and Quality of a Nation’s Trade”, *American Economic Review*, **95(3)**, 704-723.

[32] Juillard, M., P. Karam, D, Laxton and P. Pesenti. (2004). “Welfare-Based Monetary Policy Rules in an Estimated Model of the US Economy. ” Paper prepared for the 2004 Meetings of the Annual American Economic Association Meetings, San Diego, California (Current draft available from authors).

[33] Juillard, M., Kamenik, O., Kumhof, M. and Laxton, D. (2007), "Measures of Potential Output from an Estimated DSGE Model of the United States", paper presented at a workshop on Issues in Measuring Potential Output, Ankara Turkey, January 16, 2007.

[34] King, R. and Wolman, A. (1996), "Inflation Targeting in a St. Louis Model of the 21st Century", *Federal Reserve Bank of St. Louis Review*, **78(3)**, 83-107.

[35] Kollmann, R. (2004), "Welfare Effects of a Monetary Union: The Role of Trade Openness", *Journal of the European Economic Association*, **2 (2-3)**, 289-301.

[36] Laxton, D. and Pesenti, P. (2003), "Monetary Policy Rules for Small, Open, Emerging Economies, *Journal of Monetary Economics*, **50**, 1109–46.

[37] Laxton, Douglas, and Robert Tetlow, 1992, "A Simple Multivariate Filter for the Measurement of Potential Output," Technical Report No. 59, (Ottawa: Bank of Canada), June.

[38] Levin, A., Wieland, V. and Williams, J. (2003), "The Performance of Forecast-Based Monetary Policy Rules Under Model Uncertainty", *The American Economic Review*, **93(3)**, 622-45.

[39] Lipschitz, L., Lane, T. and Mourmouras, A. (2002), "Capital Flows to Transition Economies: Master or Servant?", *IMF Working Papers*, No. 02/11, Washington: International Monetary Fund.

[40] Lucas, R.E. Jr.(1987), *Models of Business Cycles*, New York: Basil Blackwell.

[41] Lucas, R.E. Jr. (2003), "Macroeconomic Priorities", Working Paper, Department of Economics, University of Chicago.

[42] McCallum, J. (1995), "National Borders Matter: Canada-U.S. Regional Trade Patterns", *American Economic Review*, **85**, 615-23.

[43] Mendoza, E. (2005), "Real Exchange Rate Volatility and the Price of Nontradables in Sudden-Stop-Prone Economies", *NBER Working Papers*, No. 11691.

[44] Murchinson, S., Rennison, A. and Zhu, Z. (2004), "A Structural Small Open-Economy Model for Canada", Working Paper, Bank of Canada.

[45] Martins, J.O., Scarpetta, S. and Pilat, D. (1996), "Mark-Up Pricing, Market Structure and the Business Cycle", *OECD Economic Studies*, **27(II)**, 71-106.

[46] Melitz, M. (2003), "The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity", *Econometrica*, **71(6)**, 1695-1725.

[47] Micco, A., Stein, E. and Ordonez, G. (2003), "The Currency Union Effect on Trade: Early Evidence from EMU", *Economic Policy*, **37**, 313-56.

[48] Naknoi, K.(2004), "Real Exchange Rate Fluctuations and Endogenous Tradability", *Stanford Institute for Economic Policy Research Discussion Papers*, No. 03-017, Stanford University.

[49] Naknoi, K.(2007), "Real Exchange Rate Fluctuations, Endogenous Tradability and Exchange Rate Regimes", Working Paper, Purdue University.

[50] Obstfeld, M. and Rogoff, K. (1996), *Foundations of International Macroeconomics*, Cambridge, MA: MIT Press.

[51] ______ (2000), "New Directions for Stochastic Open Economy Models", *Journal of International Economics*, **50(1)**, 117-153.

[52] ______ (2002), "Global Implications of Self-Oriented National Monetary Rules", *Quarterly Journal of Economics*, **117(2)**, 503-35.

[53] Orphanides, A. (2003), "Historical Monetary Policy Analysis and the Taylor Rule", *Journal of Monetary Economics*, **50**, 983-1022.

[54] Rose, A.K. (2000). "One Money, One Market: Estimating the Effect of Common Currencies on Trade," Economic Policy 30: 7-45.

[55] ———. (2004). "A Meta-analysis of the Effect of Common Currencies on International Trade," NBER Working Paper No. 10373. (http://papers.nber.org/papers/w10373.pdf).

[56] Roberts, M. and Tybout, J. (1997), "An Empirical Model of Sunk Costs and the Decision to Export", *American Economic Review*, **87(4)**, 545-564.

[57] Rotemberg, J. (1982), "Sticky Prices in the United States", *Journal of Political Economy*, **90**, 1187-1211.

[58] Rotemberg, J. and Woodford, M. (1997), "An Optimiziation-Based Econometric Framework for the Evaluation of Monetary Policy", *NBER Macroeconomics Annual*, **12**, 297-316.

[59] Ruhl, K.J. (2003), "Solving the Elasticity Puzzle in International Economics", Working Paper, University of Minnesota.

[60] Samuelson, P. (1964), "Theoretical Notes on Trade Problems", *Review of Economics and Statistics*, **46**, 145-154.

[61] Smets, F., and Wouters, R. (2002). "Openness, Imperfect Exchange Rate Pass-Through and Monetary Policy", *Journal of Monetary Economics*, **49**, 947-81.

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

[63] Taylor, J. (1993), "Discretion Versus Policy Rules in Practice", *Carnegie-Rochester Conference Series on Public Policy*, **39**, 195-214.

[64] Zbaracki, M., Ritson, M., Levy, D., Dutta, S. and Bergen, M. (2004) "Managerial and Customer Costs of Price Adjustment: Direct Evidence from Industrial Markets", *The Review of Economics and Statistics*, **86(2)**, 514-33.

Table 1: A Comparison of GEM's Monetary Transmission Mechanism with the ECB's Model (AWM)

			Quarter							
Variable:	Model:	Sum	1	2	3	4	5	6	7	8
Real GDP:	*GEM Home*	-2.3	-0.2	-0.3	-0.3	-0.4	-0.4	-0.3	-0.3	-0.2
	ECB's AWW	-2.0	-0.1	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3
Consumption:	*GEM Home*	-2.0	-0.1	-0.2	-0.3	-0.3	-0.3	-0.3	-0.2	-0.2
	ECB's AWW	-1.9	-0.0	-0.2	-0.2	-0.3	-0.4	-0.3	-0.3	-0.3
Investment:	*GEM Home*	-7.5	-0.5	-0.9	-1.1	-1.2	-1.2	-1.0	-0.9	-0.7
	ECB's AWW	-7.8	-0.1	-0.5	-0.8	-1.2	-1.5	-1.4	-1.3	-1.2
Exports:	*GEM Home*	-1.3	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.1	-0.1
	ECB's AWW	-1.6	-0.1	-0.2	-0.3	-0.4	-0.3	-0.2	-0.2	-0.1
Imports:	*GEM Home*	-3.3	-0.2	-0.4	-0.5	-0.6	-0.5	-0.4	-0.3	-0.3
	ECB's AWW	-4.9	-0.2	-0.5	-0.7	-0.9	-0.9	-0.7	-0.6	-0.6
Real Exchange Rate:	*GEM Home*	3.5	1.2	1.0	0.7	0.4	0.2	0.0	-0.0	-0.0
	ECB's AWW	-1.0	0.5	0.3	0.0	-0.2	-0.5	-0.4	-0.4	-0.3
CPI	*GEM Home*	-0.5	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.1
	ECB's AWW	-0.4	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1

Table 2: Optimal Simple Rules Under Different Loss Functions: Baseline

	Loss	λ_i	λ_π	λ_{ygap}	λ_{sgap}	σ_π	σ_{ygap}	σ_{xgap}	σ_{sgap}
Inflation Nutter	0.44	0.92	1.09	0.14	0.06	0.67	0.81	2.61	1.91
	0.48	0.88	0.68	0.13		0.69	0.87	2.81	2.47
Difference	0.03	-0.04	-0.41	-0.01		0.02	0.06	0.20	0.56
Output Gapper	0.89	0.94	0.49	0.24	0.06	0.71	0.62	2.48	1.69
	1.03	0.92	0.29	0.18		0.73	0.70	2.70	2.23
Difference	0.14	-0.02	-0.20	-0.06		0.02	0.08	0.22	0.54
Output-Export Gapper	6.25	1.18	0.38	0.15	0.14	0.91	0.67	2.23	1.05
	8.25	0.95	0.20	0.18		0.77	0.68	2.68	2.22
Difference	1.99	-0.22	-0.18	0.04		-0.14	0.01	0.45	1.17

Table 3: Optimal Simple Rules Under Different Loss Functions: Exogenous Tradability

	Loss	λ_i	λ_π	λ_{ygap}	λ_{sgap}	σ_π	σ_{ygap}	σ_{xgap}	σ_{sgap}
Inflation Nutter	0.30	0.87	1.06	0.06	0.01	0.55	0.63	1.08	2.68
	0.31	0.86	0.99	0.06		0.55	0.63	1.08	2.77
Difference	0.00	-0.00	-0.07	-0.00		0.00	0.00	-0.00	0.09
Output Gapper	0.57	0.87	0.81	0.28	0.01	0.60	0.46	0.98	2.42
	0.58	0.86	0.70	0.25		0.60	0.46	0.98	2.58
Difference	0.00	-0.01	-0.10	-0.03		0.00	0.00	0.00	0.16
Output-Export Gapper	1.51	0.85	0.60	0.32	0.02	0.64	0.43	0.96	2.36
	1.51	0.85	0.54	0.28		0.64	0.43	0.96	2.53
Difference	0.01	-0.01	-0.06	-0.04		-0.00	0.01	0.00	0.17

Table 4: Optimal Simple Rules Under Different Loss Functions: tau = 0.10

	Loss	λ_i	λ_π	λ_{ygap}	λ_{sgap}	σ_π	σ_{ygap}	σ_{xgap}	σ_{sgap}
Inflation Nutter	0.42	0.91	1.19	0.10	0.06	0.65	1.00	1.94	1.99
	0.44	0.88	0.75	0.11		0.66	1.07	2.08	2.46
Difference	0.02	-0.03	-0.44	0.01		0.02	0.07	0.14	0.47
Output Gapper	0.99	0.95	0.45	0.21	0.06	0.71	0.70	1.66	1.57
	1.16	0.93	0.23	0.16		0.72	0.80	1.84	2.10
Difference	0.18	-0.01	-0.22	-0.06		0.01	0.11	0.18	0.53
Output-Export Gapper	3.53	1.05	0.32	0.21	0.10	0.82	0.67	1.55	1.28
	4.45	0.97	0.15	0.16		0.79	0.77	1.80	2.07
Difference	0.93	-0.09	-0.18	-0.05		-0.03	0.10	0.25	0.79

Table 5: Optimal Simple Rules Under Different Loss Functions: Demand Shocks Only

	Loss	λ_i	λ_π	λ_{ygap}	λ_{sgap}	σ_π	σ_{ygap}	σ_{xgap}	σ_{sgap}
Inflation Nutter	0.03	1.13	29.27	1.24	3.19	0.18	0.52	1.55	0.46
	0.04	0.73	2.29	0.17		0.20	0.53	1.82	1.08
Difference	0.01	-0.40	-26.98	-1.07		0.03	0.01	0.27	0.62
Output Gapper	0.26	2.00	28.23	4.62	8.20	0.18	0.48	1.50	0.34
	0.28	0.74	1.10	0.25		0.22	0.48	1.77	0.93
Difference	0.01	-1.26	-27.13	-4.37		0.04	-0.00	0.28	0.59
Output-Export Gapper	2.11	2.00	0.66	-0.18	0.25	0.53	0.55	1.23	0.41
	3.29	-0.00	3.57	0.36		0.27	0.48	1.73	0.78
Difference	1.18	-2.00	2.91	0.54		-0.26	-0.07	0.50	0.37

Table 6: Optimal Simple Rules Under Different Loss Functions: Markup Shocks Only

	Loss	λ_i	λ_π	λ_{ygap}	λ_{sgap}	σ_π	σ_{ygap}	σ_{xgap}	σ_{sgap}
Inflation Nutter	0.37	0.79	1.72	0.17	0.07	0.61	0.61	1.34	1.33
	0.38	0.76	1.16	0.12		0.61	0.65	1.38	1.51
Difference	0.00	-0.03	-0.56	-0.06		0.00	0.04	0.04	0.17
Output Gapper	0.50	0.94	1.29	0.94	0.11	0.66	0.26	1.02	0.93
	0.51	0.88	0.74	0.58		0.67	0.27	1.00	1.07
Difference	0.01	-0.06	-0.55	-0.35		0.01	0.00	-0.02	0.14
Output-Export Gapper	1.29	1.14	0.08	0.49	-0.00	0.78	0.17	0.80	0.98
	1.29	1.15	0.08	0.49		0.78	0.17	0.80	0.97
Difference	0.00	0.01	-0.00	0.00		-0.00	0.00	0.00	-0.01

Table 7: Optimal Simple Rules Under Different Loss Functions: UIP Shocks Only

	Loss	λ_i	λ_π	λ_{ygap}	λ_{sgap}	σ_π	σ_{ygap}	σ_{xgap}	σ_{sgap}
Inflation Nutter	0.02	0.95	1.16	0.00	0.11	0.15	0.24	1.39	1.08
	0.03	0.97	0.97	0.41		0.16	0.28	1.65	1.83
Difference	0.01	0.01	-0.19	0.41		0.02	0.04	0.25	0.75
Output Gapper	0.06	0.94	1.11	0.64	0.12	0.18	0.16	1.38	1.16
	0.07	0.91	0.69	0.75		0.19	0.19	1.59	1.73
Difference	0.01	-0.03	-0.42	0.11		0.01	0.03	0.21	0.56
Output-Export Gapper	1.44	1.97	2.30	0.93	0.26	0.48	0.22	1.08	0.62
	2.19	1.06	0.00	0.45		0.49	0.16	1.39	1.55
Difference	0.75	-0.91	-2.30	-0.48		0.01	-0.06	0.31	0.93

Table 8: Optimal Simple Rules Under Different Loss Functions: Four Quarter Ahead Inflation in the Rule

	Loss	λ_i	λ_π	λ_{ygap}	λ_{sgap}	σ_π	σ_{ygap}	σ_{xgap}	σ_{sgap}
Inflation Nutter	0.44	1.07	1.48	-0.00	0.02	0.66	0.81	2.61	2.10
	0.45	1.02	1.12	0.02		0.67	0.83	2.69	2.30
Difference	0.01	-0.05	-0.36	0.02		0.01	0.02	0.08	0.20
Output Gapper	0.88	0.97	0.74	0.17	0.04	0.71	0.61	2.45	1.73
	0.94	0.94	0.51	0.14		0.71	0.66	2.59	2.10
Difference	0.06	-0.03	-0.23	-0.03		-0.00	0.05	0.14	0.36
Output-Export Gapper	6.16	1.30	0.76	0.08	0.17	0.88	0.68	2.22	1.04
	7.64	0.93	0.45	0.15		0.72	0.65	2.59	2.08
Difference	1.49	-0.38	-0.31	0.06		-0.16	-0.02	0.37	1.04

Table 9: Optimal Simple Rules Under Different Loss Functions: Final Goods Exports Equal 50%

	Loss	λ_i	λ_π	λ_{ygap}	λ_{sgap}	σ_π	σ_{ygap}	σ_{xgap}	σ_{sgap}
Inflation Nutter	0.36	0.92	1.30	0.06	0.04	0.60	1.09	1.05	2.46
	0.37	0.89	0.94	0.07		0.61	1.16	1.10	2.86
Difference	0.01	-0.03	-0.36	0.01		0.01	0.07	0.06	0.40
Output Gapper	0.94	0.96	0.52	0.21	0.06	0.68	0.69	0.84	1.63
	1.09	0.94	0.25	0.16		0.69	0.79	0.92	2.19
Difference	0.15	-0.02	-0.27	-0.05		0.01	0.09	0.07	0.56
Output-Export Gapper	1.63	1.00	0.45	0.21	0.07	0.71	0.67	0.82	1.51
	1.92	0.96	0.20	0.17		0.72	0.77	0.90	2.17
Difference	0.28	-0.04	-0.25	-0.05		0.00	0.10	0.08	0.66

Table 10: Optimal Simple Rules Under Different Loss Functions: Intermeditate Goods Exports Share = 30% and Steeper Comparative Advantage Schedule

	Loss	λ_i	λ_π	λ_{ygap}	λ_{sgap}	σ_π	σ_{ygap}	σ_{xgap}	σ_{sgap}
Inflation Nutter	0.35	0.89	1.20	0.07	0.03	0.59	1.01	1.67	2.34
	0.36	0.87	0.95	0.07		0.60	1.05	1.74	2.63
Difference	0.01	-0.02	-0.25	0.00		0.01	0.05	0.07	0.29
Output Gapper	0.85	0.93	0.54	0.24	0.05	0.67	0.63	1.33	1.67
	0.95	0.92	0.33	0.18		0.67	0.70	1.44	2.13
Difference	0.10	-0.02	-0.22	-0.06		0.00	0.07	0.11	0.47
Output-Export Gapper	2.52	1.00	0.37	0.24	0.08	0.74	0.60	1.27	1.42
	2.99	0.94	0.22	0.19		0.71	0.68	1.42	2.11
Difference	0.47	-0.06	-0.15	-0.06		-0.03	0.08	0.15	0.69

Figure 1: Goods and Factor Flows in the Model Economy

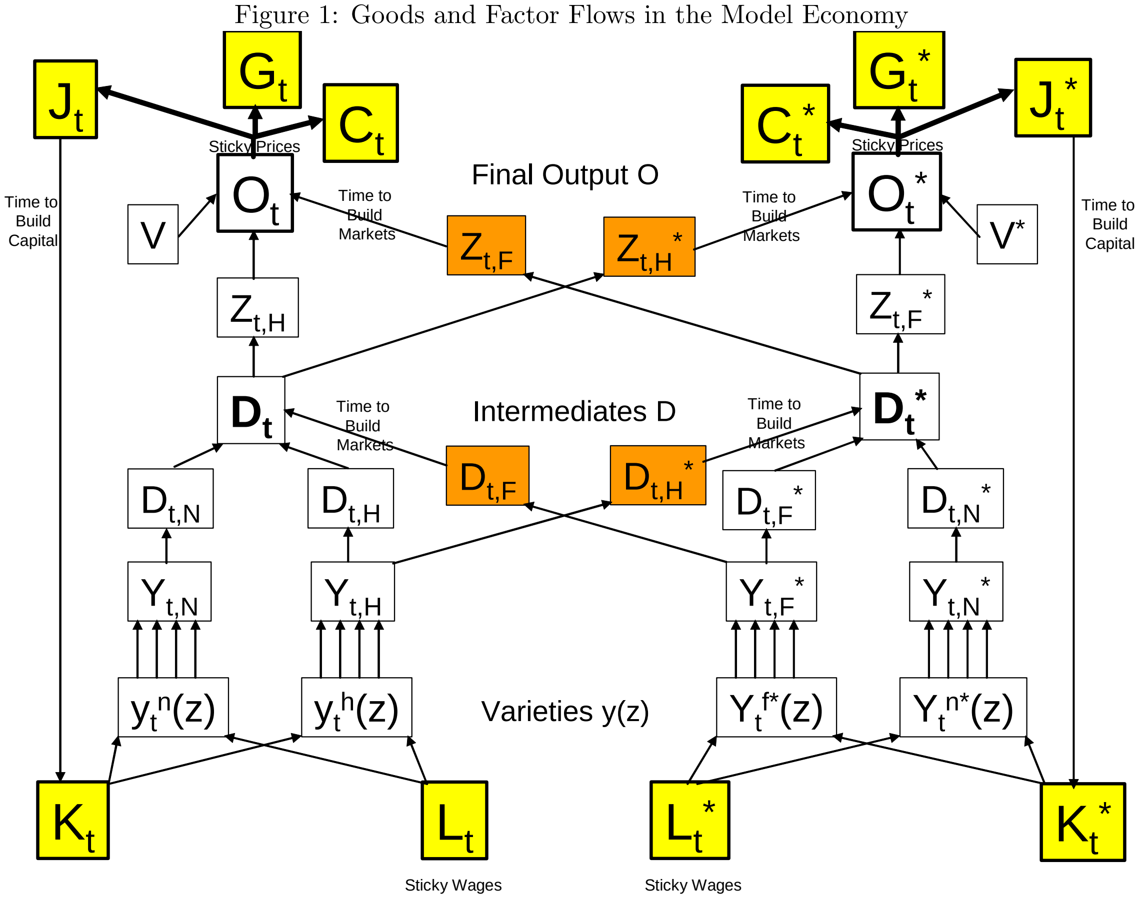


Figure 2: Home Economy Responses to a 100 Basis Point Interest Rate Hike

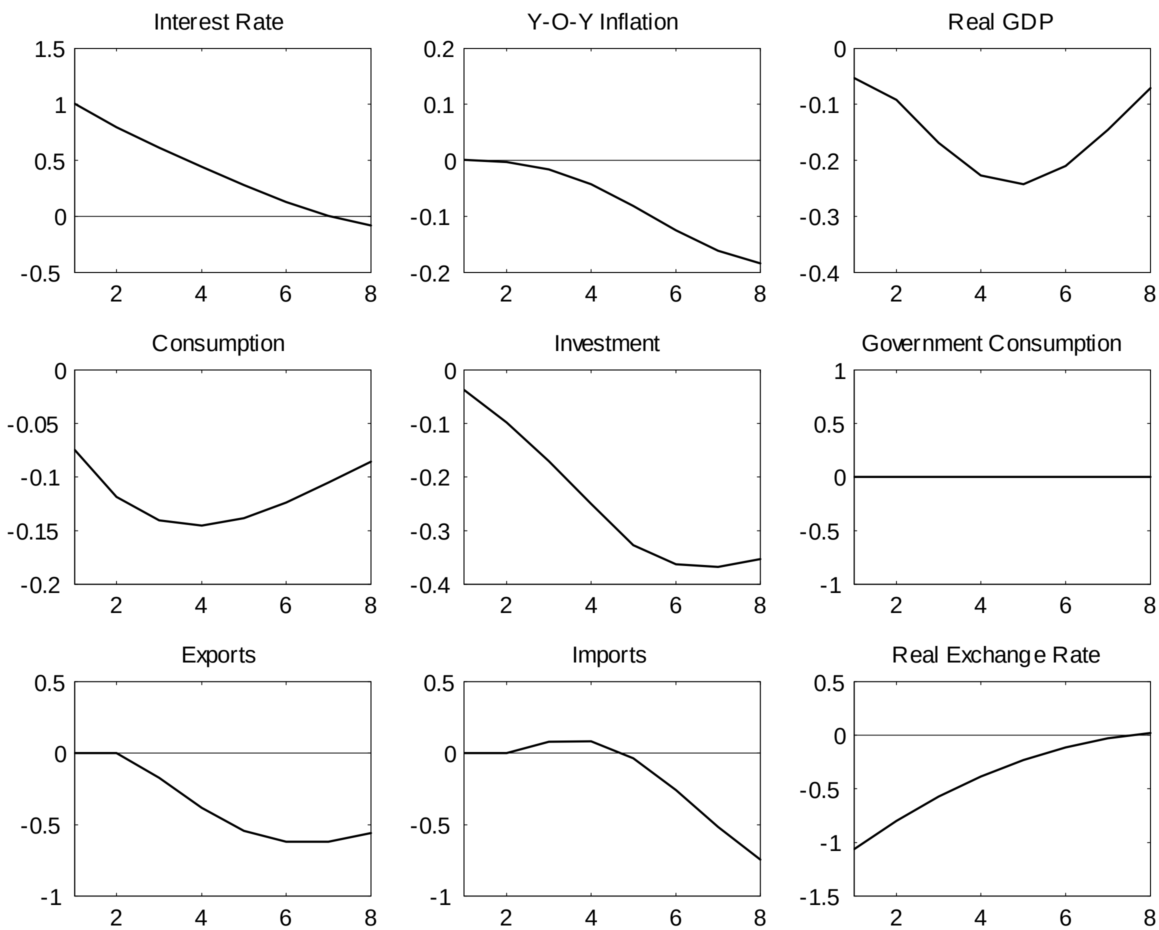


Figure 3: Long-Run Effects of Reducing Trading Costs—Base-Case Results

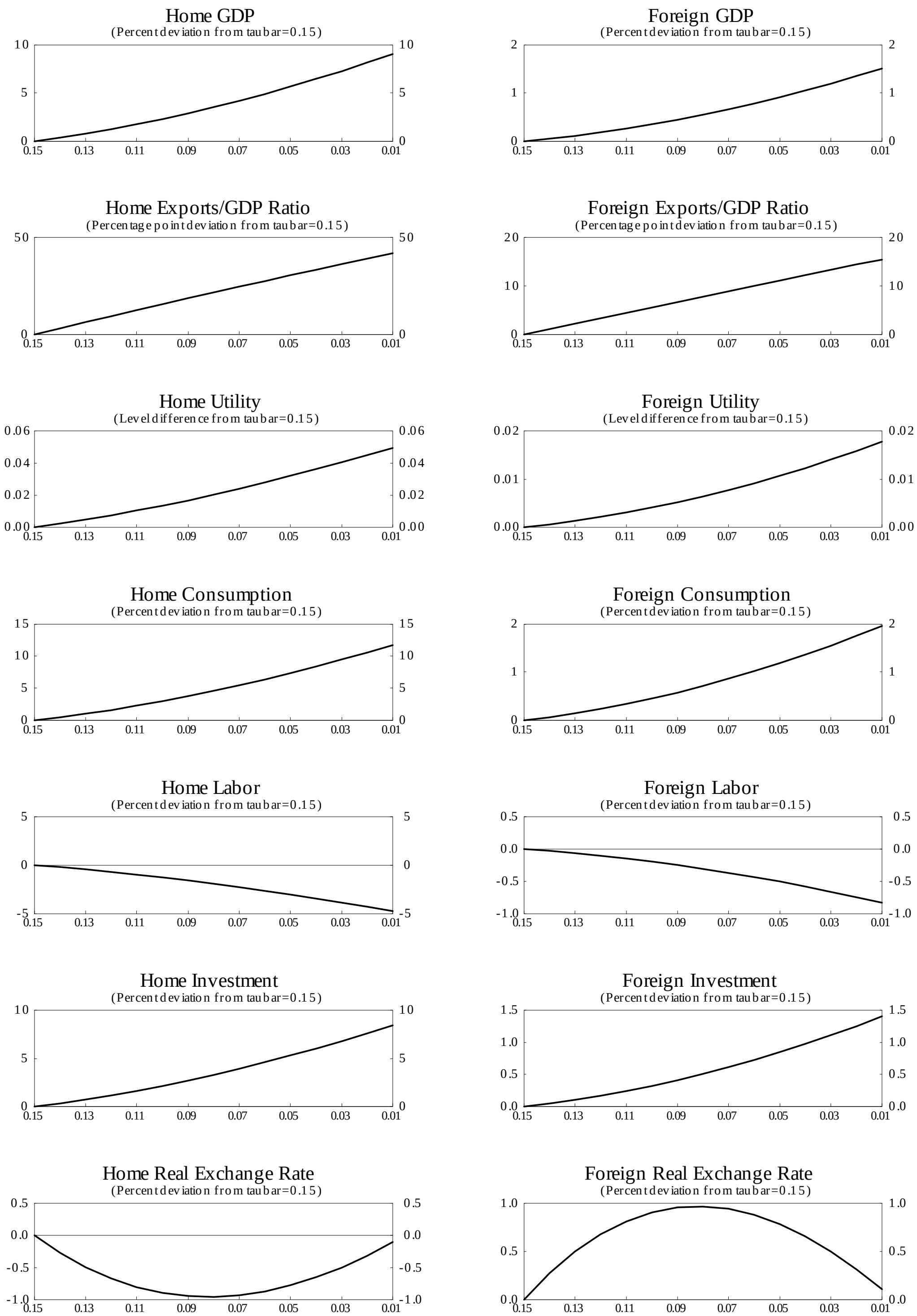


Figure 4: Long-Run Effects of Reducing Trading Costs—Smaller Relative Size of Home Economy

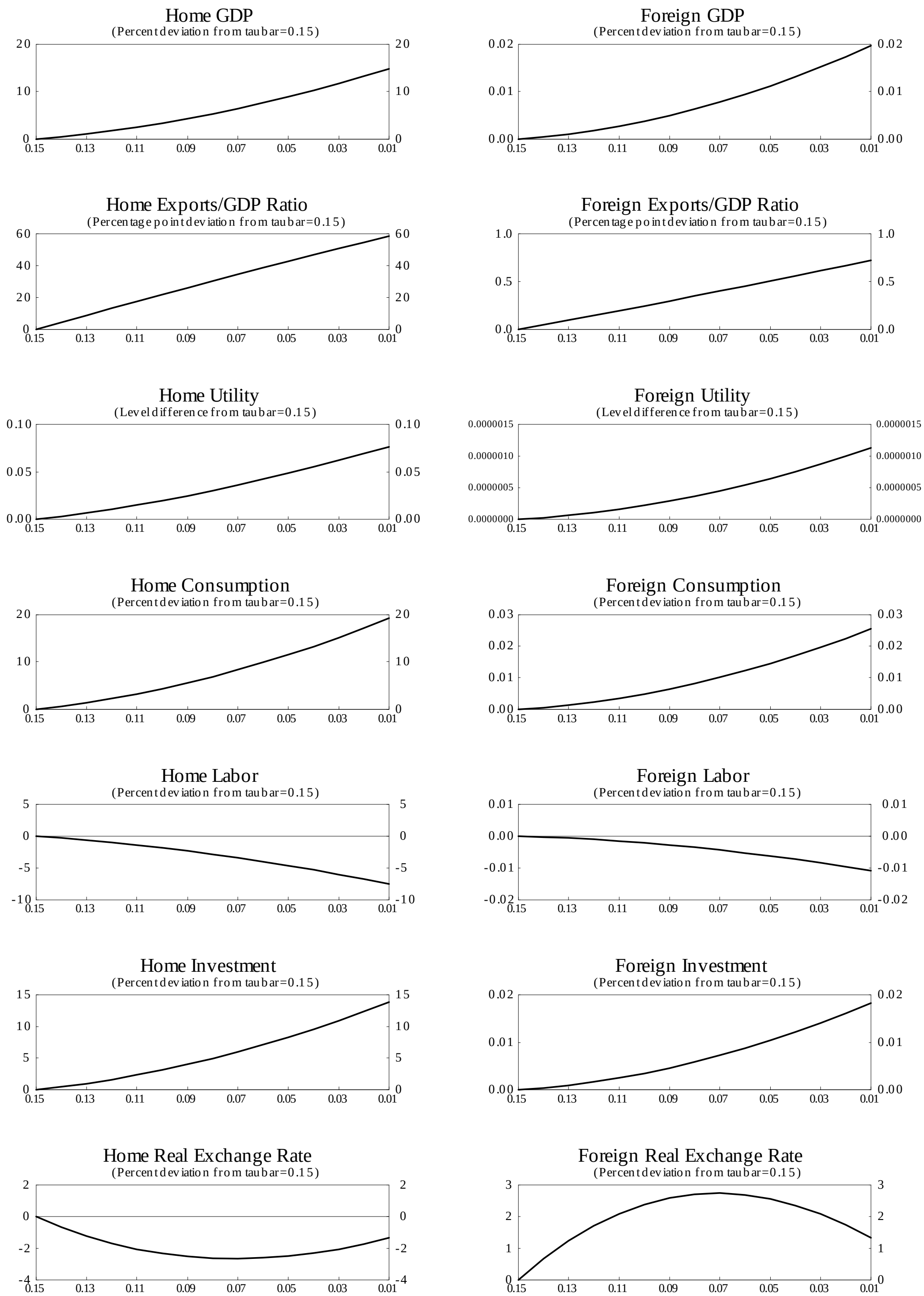


Figure 5: Long-Run Effects of Reducing Trading Costs—Lower Elasticity of Substitution Between Importables and Domestically-Produced Tradables

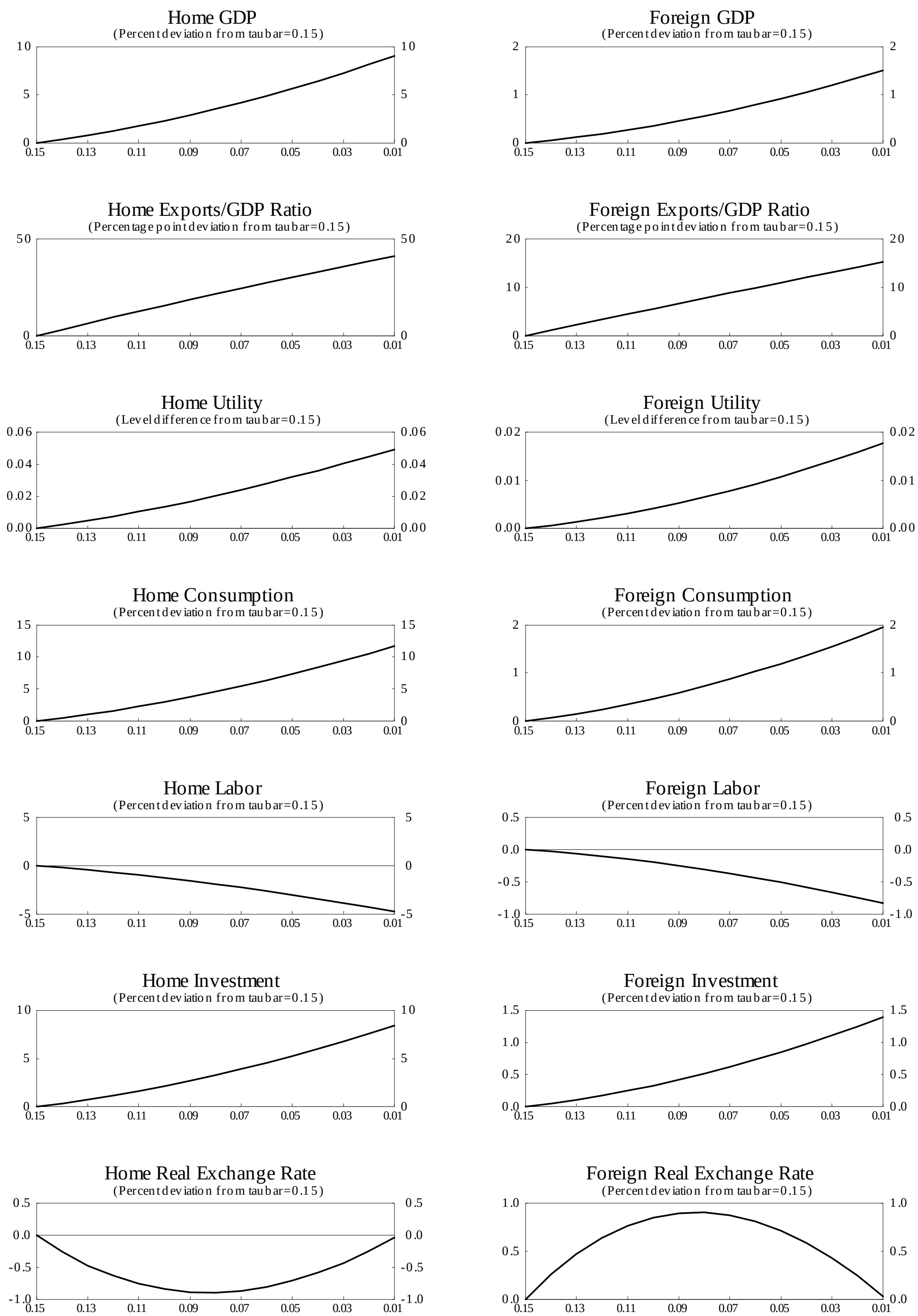


Figure 6: Long-Run Effects of Reducing Trading Costs—Higher Elasticity of Substitution Between Importables and Domestically-Produced Tradables

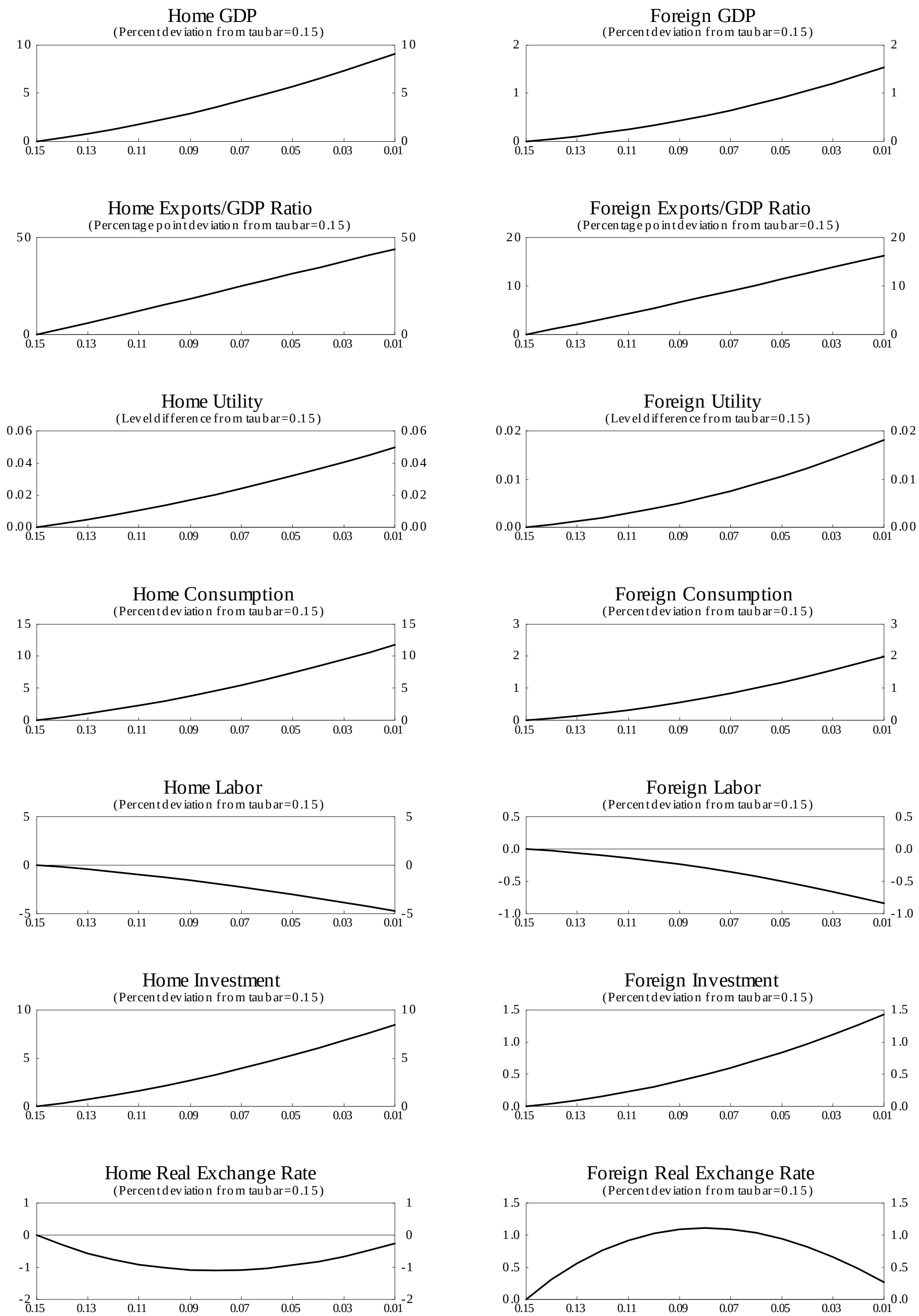


Figure 7: Long-Run Effects of Reducing Trading Costs—Less Elastic Labor Supply

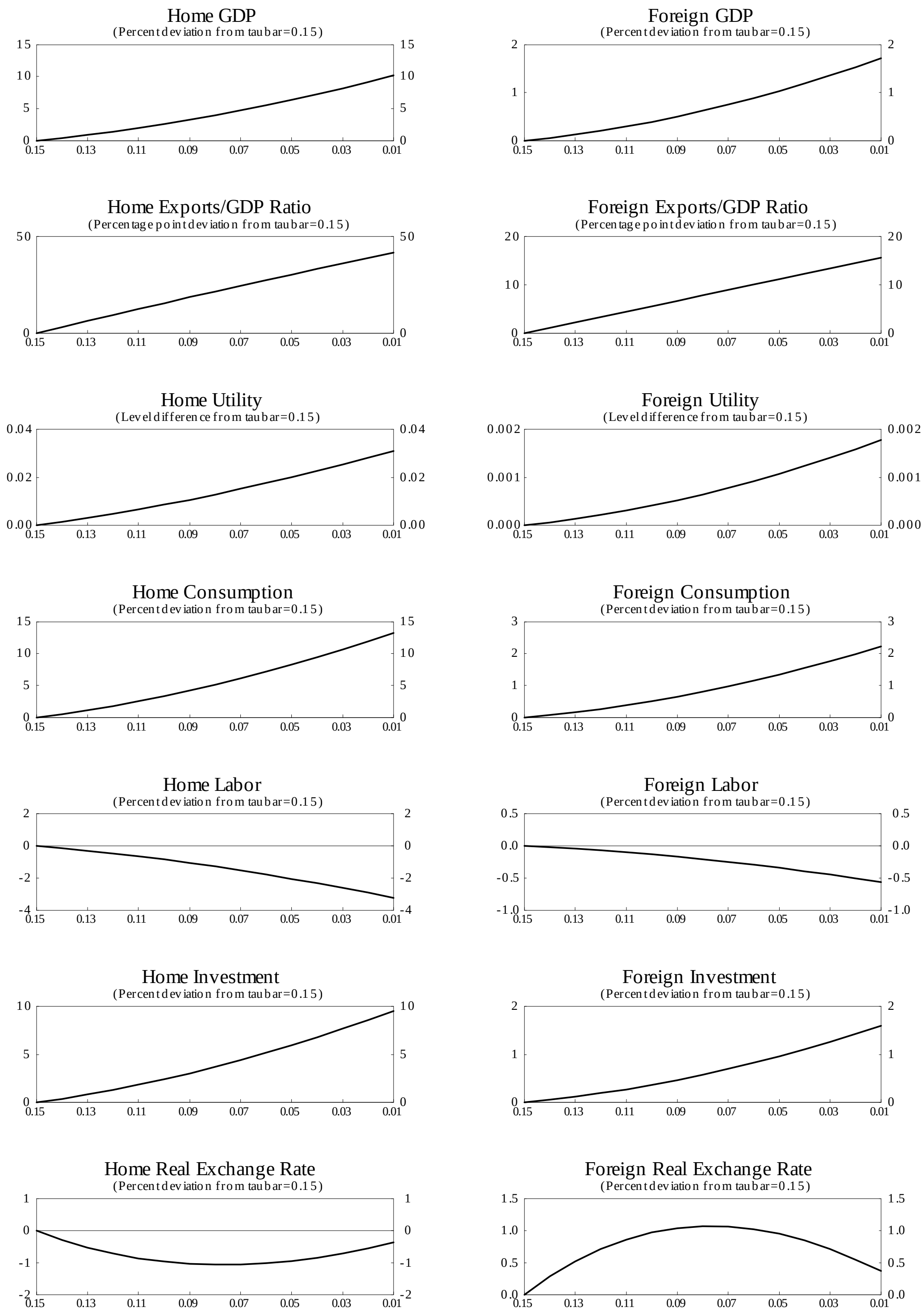


Figure 8: Impulse Response Functions Without Endogenous Tradability (Dashed Line is Without Exchange Rate in Reaction Function)

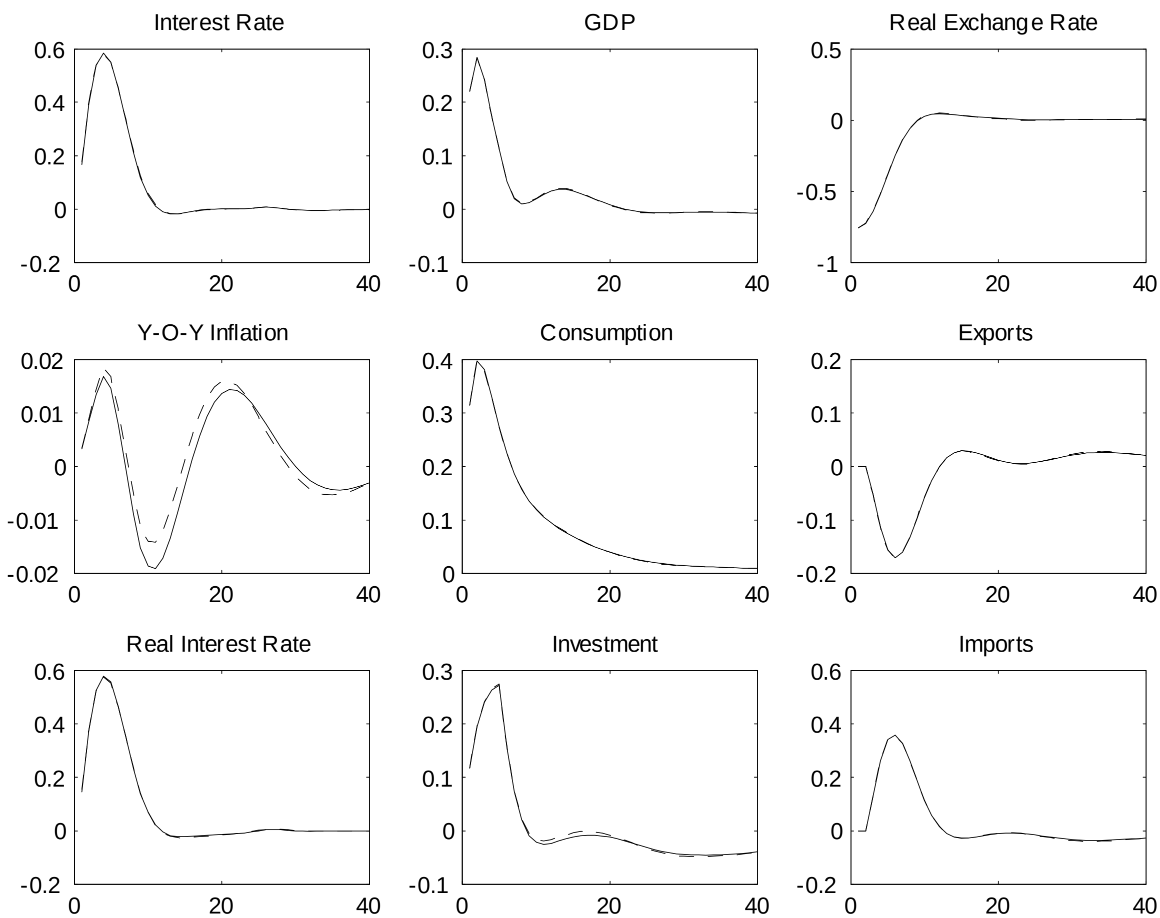
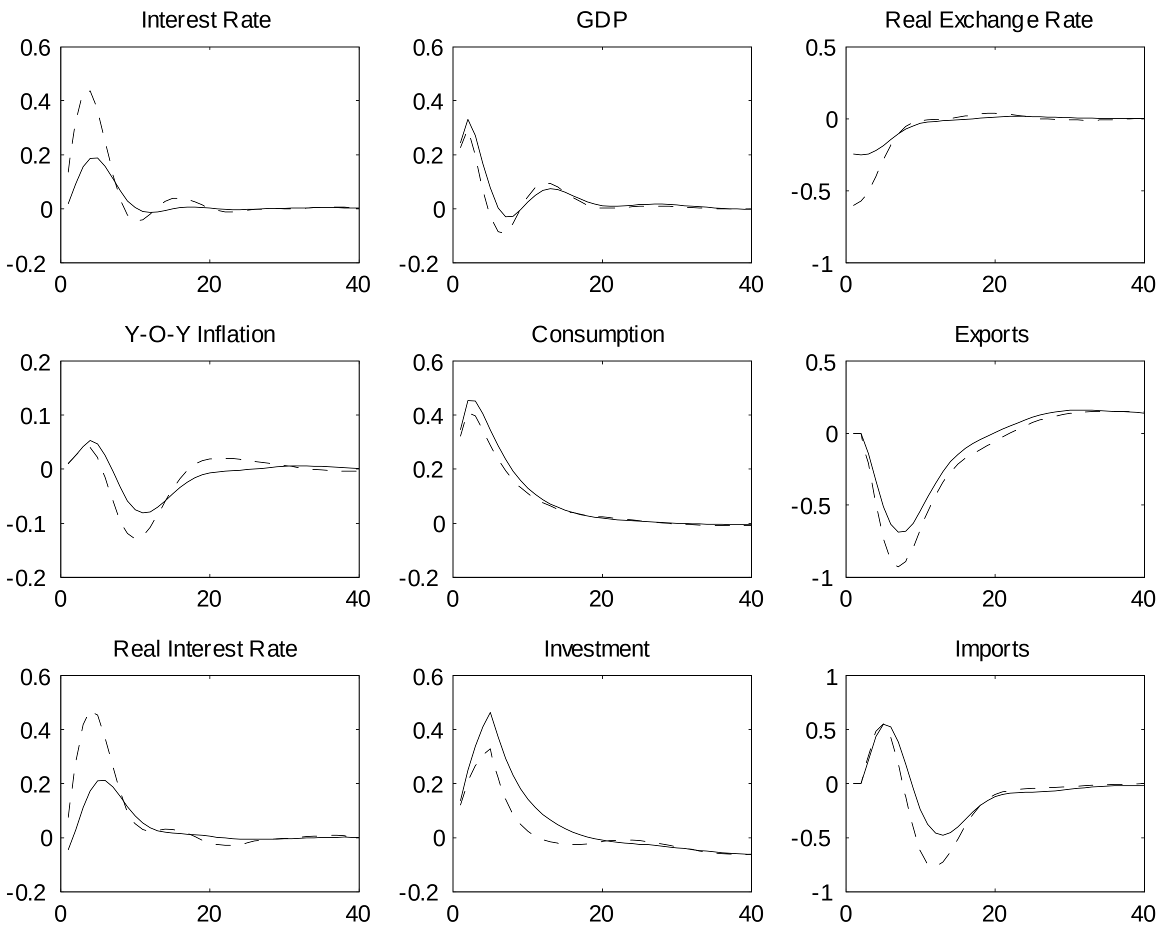


Figure 9: Impulse Response Functions With Endogenous Tradability (Dashed Line is Without Exchange Rate in Reaction Function)



Appendix: HP Filter Weights

The Hodrick-Prescott (HP) filter has been used extensively to obtain measures of output gaps in spite of the problems associated with using such a procedure in real time when the filter at the end of the sample becomes a one-sided backward-looking filter—see Laxton and Tetlow (1992). In an empirically estimated DSGE model of the U.S. economy Juillard, Kamenik, Kumhof and Laxton (2007) show that the severity of this end-of-sample problem can be mitigated significantly by using the model's multi-period forecasts of GDP. In their paper this is implemented by writing down the Kalman-filter representation of the HP filter, but an equivalent procedure can be obtained by simply constructing the 2-sided weights and then coding this equation directly.

The HP filter estimates obtained from series y_i of length T are obtained by minimizing the following function, where λ represents a parameter that penalizes changes in the second difference of the computed trend series τ_i:

$$Z = \sum_{i=1}^{T}(y_i - \tau_i)^2 + \lambda \sum_{i=1}^{T-2}[(\tau_{i+2-}\tau_{i+1}) - (\tau_{i+1-}\tau_i)]^2 \; . \tag{76}$$

Choosing τ_i to minimize Z requires $\partial Z/\partial \tau_i = 0$ for all i from 1 to T and then stacking the equations. Let τ and y represent vectors of length T, and let A represent a matrix with elements that are only a function of the HP curvature restriction λ:

$$A\tau = y \; . \tag{77}$$

Once the A matrix has been obtained the estimates of the trend series can be computed by simply finding the inverse of A. The elements of this matrix will also simply be a function of the curvature restriction λ:

$$\tau = A^{-1}y \; . \tag{78}$$

We will refer to A^{-1} as the weighting matrix. Assuming that $T = 49$ observations and $\lambda = 1600$ the dotted line in Figure 10 plots the first row of the weighting matrix that would determine the value of τ_i in the first period. Obviously, the estimates in this period can only depend on the current and future values of the series y, since by assumption it represents the 1st observation. The HP filter treats the end of the sample in a similar way except in this case the weighting scheme only depends on current and past values of the series—see the dashed line in Figure 10. Note that in this case the weight is quite high on the current and recent observations, which is why end-of-samples estimates from the HP filter tend to get pulled around a lot by movements in the actual series. The solid line in Figure 10 represents the weights in the middle of the sample ($i = 25$), in which case the weights are a symmetric function of past and future values of the series. The differences in weights between the in-samples estimates and end-of-sample estimates are enormous, explaining why HP output gaps can be revised substantially as new data are released and the sample is updated. Juillard, Kamenik, Kumhof and Laxton (2007) show that part of these problems with the HP filter can be overcome by using the weights from the middle of the sample and the model's forecasts for the series.

Figure 10: Hodrick-Prescott Filter Weights