New Keynesian Open Economy Models versus The Six Major Puzzles in International Macroeconomics*

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May 1, 2004

PRELIMINARY AND INCOMPLETE

Abstract

In this paper, we ask the following question: Can a New Keynesian Open Economy Model explain six major puzzles in International Macroeconomics, as documented by Obstfeld and Rogoff (2000*b*)? These puzzles are (1) the home bias in trade puzzle, (2) the high investment-savings correlation, (3) the home bias in equity portfolio puzzle, (4) the low international consumption correlation, (5) the purchasing power parity puzzle and (6) the exchange rate disconnect puzzle. To answer the question, we use a modified version of the Galí and Monacelli (1999, 2002, 2003) model, which consists of a small open economy versus the rest of the world, and includes complete markets, Calvo sticky prices, monopolistic competition, and trade costs.

1 Introduction

In this paper, we analyze the quantitative features of a New Keynesian Open Economy Model as an example of its class.[1] We focus especially on six puzzles in international macroeconomics explained by Obstfeld and Rogoff (2000*b*), henceforth OR (2000*b*), i.e., (1) the home bias in trade puzzle, (2) the high investment-savings correlation, (3) the home bias in equity portfolio puzzle, (4) the low international consumption correlation, (5) the purchasing power parity puzzle and (6) the exchange rate disconnect puzzle.

*This research project was financially supported by a doctoral grant of the the German Academic Exchange Service (DAAD). I thank Bartosz Mackowiak, Mathias Trabandt and Harald Uhlig for helpful comments. Correspondence: Institute of Economic Policy I, School of Business and Economics, Humboldt–Universität, Spandauer Str. 1, D-10178 Berlin, Germany; ried@wiwi.hu-berlin.de

[1] A survey on New Open Economy Models can be found in Lane (2001).

The model used is based on Galí and Monacelli (2002), henceforth GM (2002). We use it as a prototype of New Keynesian Open Economy Models,[2] with their main building blocks, i.e., a forward looking type of a Phillips curve, a kind of an IS-curve, and Calvo (1983) sticky prices. The open economy assumptions are a small open economy versus the rest of the world, modelled as the limiting case of a two country world with one country infinitely small such that it does not influence the other, producer currency pricing, and complete financial markets. We modify the model by including costs of trade, following the suggestion by OR (2000*b*).

We find that the model can easily explain puzzles (1) and (3), thanks to the combination of trade costs and a "degree of openness" parameter, which can be seen as closely related to a home bias in preferences parameter as mentioned in OR (2000*b*). The investment-savings puzzle can only be addressed indirectly through the relation between the current account and the real interest rate, where the expected negative relation between net exports and the real interest rate is reproduced. Apart from the exchange rate persistence the model cannot reproduce puzzles (4) to (6).

Compared to a case without trade costs, moderate trade costs of 25 % lead to better results for all the puzzles. While puzzles (1) and (3) can now be solved with smaller and therefore more reasonable parameter values and the result of puzzle (2) remains stable, it is possible to address also the last three puzzles. For the consumption correlation there are parameter values which result in the numbers seen in the data, though one has to look out for them quite a long time. The high exchange rate volatility of the data can be achieved by a combination of four ingredients. First, a high risk aversion as in Chari et al. (2001), second, trade costs of more than 50 percent, third, a low import share on GDP (the model's parameter α),[3] and fourth, an international correlation of productivity of not more than about 50 percent.[4]. The "disconnectedness" of real exchange rate volatility, i.e., the fact that real exchange rates are by far more volatile than any other macroeconomic aggregate – one part of the "disconnect" puzzle – can also be solved.

Nonetheless, the model cannot fully explain the second dimension of the disconnect puzzle, i.e., the low correlation between the real exchange rate and all other macroeconomic aggregates. And the parameter values necessary to solve the consumption correlation puzzle and the exchange rate volatility are not standard.

The remainder of the paper is organized as follows. In section two,

[2]McCallum and Nelson (2001, p. 10) call the GM model a "standard" model that they use as a benchmark with which to compare their own model.

[3]This is in accordance with the argument in Hau (2001) that less open economies experience a higher exchange rate volatility: we choose a value of roughly 20 percent, as is true for an arithmetic average of Germany, Japan and the U.K. (the "G3")

[4]This, again, holds for the "G3"

we present the model. Section three shows the parameter choices and the results. In section four we conduct a sensitivity analysis. A summary concludes the paper.

2 The Model

2.1 Environment

There are two countries, the home country (H) and the foreign country (the "rest of the world", F). If not mentioned otherwise, the following applies to both of them, where foreign variables are denoted by an asterisk. As agents, there are infinitely long living households, who experience utility from consumption of home and of foreign goods, firms, that produce in monopolistic competition, governments collecting taxes, paying transfers and conducting monetary policy with an interest rate rule. The same applies to the foreign economy, except that foreign households' consumption of home goods is negligibly small for them. Transportation of a good from one country to the other decreases its quantity by the factor Ξ, which can be understood as "iceberg melting".

2.1.1 Preferences

A representative household decides about its expected whole life labor supply and consumption to maximize its utility, which is assumed to be separable between the two elements consumption C_t and hours of labor N_t:

$$E_0 \sum_{t=0}^{\infty} \beta^t [U(C_t) - V(N_t)] \ , \tag{1}$$

where U is defined as $U(C_t) \equiv \frac{C_t^{1-\sigma}}{1-\sigma}$ and V as $V(N_t) \equiv \frac{N_t^{1+\varphi}}{1+\varphi}$ with σ the constant of relative risk aversion and $1/\varphi$ the elasticity of labor supply. Consumption C_t is composed of

$$C_t = \left[(1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \ . \tag{2}$$

$C_{F,t}$ and $C_{H,t}$ are indices related to the consumption of foreign and domestic products, respectively, which are themselves integrals over all firms $i \in [0;1]$:

$$C_{X,t} = \left(\int_0^1 C_{X,t}(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}} \ , \ X = H, F, \tag{3}$$

with η being the elasticity of substitution between domestic and foreign goods, and ϵ the elasticity of substitution between goods of the same country.

2.1.2 Endowment

Each household is endowed with one unit of time per period.

2.1.3 Technology

Each firm $i \in [0;1]$ produces its output $Y_t(i)$ with production technology $Y_t(i) = A_t N_t(i)$, where $\log(A_t) = a_t = \rho_a a_{t-1} + \epsilon_t$ is stochastic productivity. Firms in the rest of the world face an analogous situation, i.e. $Y_t^*(i) = A_t^* N_t^*(i)$. Their productivity evolves according to $\log(A_t^*) = a_t^* = \rho_a^* a_{t-1}^* + \epsilon_t^*$.

2.1.4 Information

Households have complete information up to and including the current period, and they have rational expectations about future periods. The same applies to firms and governments.

2.2 Competitive Equilibrium

Households work at firms in their own country, pay lump-sum taxes, and trade nominal bonds which include shares in firms of all countries. Firms hire labor, produce, and sell their good at home and abroad under monopolistic competition. They set prices for all markets in domestic currency (producer currency pricing) according to the Calvo (1983) price stickiness. Finally, they receive a wage subsidy τ. Governments receive lump- sum taxes T_t, pay wage subsidies, and are not allowed to have debt. Monetary policy is made by setting the nominal interest rate.

2.2.1 Competitive Equilibrium: Households

The budget constraint domestic households are faced with each period t is

$$\int_0^1 [P_{H,t}(i)C_{H,t}(i) + P_{F,t}(i)C_{F,t}(i)]di + E_t\{Q_{t,t+1}D_{t+1}\} \leq D_t + W_t N_t + T_t \ , \tag{4}$$

with $Q_{t,t+1}$ the stochastic discount factor for nominal payoffs, for which $E_t(Q_{t,t+1}) = \frac{1}{R_t}$ holds, D_{t+1} the nominal payoff in period $t+1$ of a portfolio held at the end of period t, W_t the nominal wage and T_t a lump-sum transfer or tax. Foreign households similarly face (with an asterisk denoting a foreign variable):

$$\int_0^1 [P_{H,t}(i)C_{H,t}(i) + P_{F,t}(i)C_{F,t}(i)]di + E_t\{Q_{t,t+1}D_{t+1}\} \leq D_t + W_t^* N_t^* + T_t^* \ , \tag{5}$$

Prices are given as follows: The consumer price index (CPI) comprises all consumption goods, i.e., domestic and foreign goods, and is given by

$$P_t \equiv [(1-\alpha)P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta}]^{\frac{1}{1-\eta}} \ , \tag{6}$$

where $P_{H,t}$ and $P_{F,t}$ are the price indices of domestic and foreign goods, respectively, given by

$$P_{j,t} \equiv \left(\int_0^1 P_{j,t}(i)^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}} \quad \forall j \in \{H, F\} \ . \tag{7}$$

Here, ε measures the elasticity of substitution between firms i within each country. The same equations hold for the rest of the world, with the slight difference that, since the rest of the world's imports from the small open economy are so small, their weighting coefficient α^* is assumed to be negligible. This means that $P_{H,t}^*$, the price index of domestic products in foreign currency, has no influence on the world consumer price index for $\lim_{\alpha^* \to 0}$. This implies $P_{F,t}^* = P_t^*$, where an asterisk denotes the world economy.
The first differences of the logarithms of the price levels are the CPI inflation $\pi_t \equiv \log(P_t) - \log(P_{t-1})$ and the domestic goods (price index) inflation $\pi_{H,t} \equiv \log(P_{H,t}) - \log(P_{H,t-1})$.[5] For the world economy it follows from above that $\pi_{F,t}^* = \pi_t^*$.

2.2.2 Competitive Equilibrium: Firms

Due to employment subsidies τ, the firms' profits per unit of productivity are $P_t(i)Y_t(i) - (1-\tau)W_t N_t(i)/A_t$. Thus, the nominal marginal costs are $MC_t^n = (1-\tau)W_t/A_t$. In the Calvo (1983) staggered price setting scheme, the possibility to reset prices cannot be guaranteed at every period: each period, only the fraction $1-\theta$ of the firms can reset prices.[6]

2.2.3 Competitive Equilibrium: Governments

Domestic fiscal policy is faced with the following budget constraint: $T_t = \int_0^1 \tau W_t N_t(i) di$, with T lump sum taxes and τ an employment subsidy. The fiscal authority acts solely to offset the distortion through monopolistic competition. World fiscal policy symmetric, with variables T_t^*, τ^*, W_t^*, $N_t^*(i)$. Monetary Policy is modelled exogenously. Central Banks in both countries act according to a Taylor rule for the of the following kind:

$$r_t = \overline{rr}_t + \Phi_\pi \pi_{H,t} + \Phi_y (y_t - \bar{y}_t) \ , \tag{8}$$

[5]Throughout the paper small, Latin letters are used to denote that log-linearization has taken place.

[6]The assumption is "that each price-setter (or firm) is allowed to change his price whenever a random signal is 'lit up', see Calvo (1983), p. 383.

where r is a nominal short-term interest rate, $\overline{rr}$ the natural interest rate, π_H the domestic goods inflation rate, and $\bar{y}$ the natural level of output; natural meaning that the value would obtain in the absence of nominal frictions.

2.2.4 Competitive Equilibrium: Market Clearing

Goods markets: As there is no possibility to invest in capital, and as the small open economy is negligible for the "rest of the world", the foreign country's output supply equals its own consumption:

$$Y_t^* = C_t^* \ . \tag{9}$$

In the small open economy, output is consumed at home or abroad:

$$Y_t = C_{H,t} + C_{H,t}^* \ . \tag{10}$$

In the labor markets, firms set wages such that their demand of labor is supplied by the domestic agents. The (international) asset market is cleared if the nominal bond is in zero net supply. On the currency market, each countries' central bank supplies the amount of currency that is demanded.

2.2.5 Competitive Equilibrium: Trade

As in OR (2000*b*), it is assumed that there are "iceberg"-type costs of trade in the goods market (like transportation costs, tariffs etc.) which affect the economy such that only a fraction $1-\Xi$ of each good exported arrives at the destination market, whereas the other fraction Ξ "melts away" in the trade process. This effect shows up in the nominal exchange rate $\mathcal{E}_t$ – the price of foreign currency in terms of home currency – for the price of foreign goods:

$$P_{F,t} = \mathcal{E}_t P_{F,t}^*/(1-\Xi) \tag{11}$$

as well as for the price of home goods, which have to sell cheaper abroad:

$$P_{H,t} = \mathcal{E}_t P_{H,t}^*(1-\Xi) \ . \tag{12}$$

Log-linearizing (11) and (12) with defining $e_t \equiv \log(\mathcal{E}_t)$ and $\xi \equiv -\log(1-\Xi)$ results in

$$p_{F,t} = e_t + p_{F,t}^* + \xi \tag{13}$$

$$p_{H,t} = e_t + p_{H,t}^* - \xi \ . \tag{14}$$

For the (log) terms of trade $s_t \equiv \log(\mathcal{S}_t)$ – the price of foreign goods in terms of home goods – trade costs also enter as a constant:

$$s_t = p_{F,t} - p_{H,t} = e_t + p_{F,t}^* + \xi - p_{H,t} = e_t + p_t^* + \xi - p_{H,t} \ , \tag{15}$$

since $p^*_{F,t} = p^*_t$ as $\lim_{\alpha^* \to 0}$. The (log) real exchange rate $q_t \equiv \log(\mathcal{Q}_t)$ is given as follows:

$$q_t = e_t + p^*_t - p_t = s_t - \xi + p_{H,t} - p_t = (1-\alpha)s_t - \xi \ . \tag{16}$$

Because of the producer currency pricing trade costs have no influence on the firms' decisions of price setting. The law of one price obviously holds only in the case of zero trade costs. If domestic goods and foreign goods price indices are equal ($p_{H,t} = p_{F,t}$), α measures the share of foreign goods' consumption, which can be interpreted as a degree of openness. The situation around such a steady state can be expressed through log-linearization of (6)as

$$p_t = p_{H,t} + \alpha s_t \quad \text{and, following from that,} \quad q_t = (1-\alpha)s_t \ . \tag{17}$$

With the assumption of complete international financial markets, around the steady state we get a log-linear version of the *uncovered interest parity*

$$r_t - r^*_t = E_t\{\Delta e_{t+1}\} \ . \tag{18}$$

2.3 Analysis

2.3.1 Analysis: Households

The expenditures of the representative household are distributed optimally between all firms of a country as well as between home country and the rest of the world in the aggregate. The allocations will be:

$$C_{j,t}(i) = \left(\frac{P_{j,t}(i)}{P_{j,t}}\right)^{-\varepsilon} C_{j,t} \quad \forall j \in \{H, F\} \tag{19}$$

within each country, and for total consumption:

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \quad \text{and} \quad C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t \ . \tag{20}$$

Maximizing the household's utility function leads to a standard intratemporal equation linking marginal utilities of labor and consumption to the real wage:

$$C^\sigma_t N^\varphi_t = \frac{W_t}{P_t} \tag{21}$$

and a typical Euler equation:

$$\beta R_t E_t\left(\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{P_t}{P_{t+1}}\right)\right) = 1 \ . \tag{22}$$

Taking logarithms on both equations and defining $\rho \equiv -\log(\beta)$ yields

$$w_t - p_t = \sigma c_t + \varphi n_t \quad \text{and} \quad c_t = E_t\{c_{t+1}\} - \frac{1}{\sigma}(r_t - E_t\{\pi_{t+1}\} - \rho) \ . \tag{23}$$

It should be noted that, as we only took logarithms, β in (22) still remains, whereas in a log-linearization around the steady state β and, thereby, ρ drop out of the equation.[7] Nevertheless, in a situation close to the steady state this term is negligible. Equation (22) and its world analog[8] can be combined and iterated to get a relation for consumption in both economies:

$$C_t = \vartheta C_t^* \mathcal{Q}_t^{\frac{1}{\sigma}} \ , \tag{24}$$

where $\vartheta = \frac{\alpha^*}{\alpha}$ is the ratio of the two economies' imports. Log-linearizing the last equation up to a constant leads to:

$$c_t = c_t^* + \left(\frac{1-\alpha}{\sigma}\right) s_t \ . \tag{25}$$

2.3.2 Analysis: Firms

Since firms have market power in this model, prices are set higher than marginal costs, with a markup. Firms set their prices in such a way that for the expected duration of the price the current value is maximized, where firms can reset their prices in period t with probability $(1-\theta)$. Let $\overline{P}_{H,t}$ denote a price adjusted in period t. When getting the possibility to reset, firms maximize the present discounted value of their expected earnings:

$$\max_{\overline{P}_{H,t}} \sum_{k=0}^{\infty} \theta^k E_t\{Q_{t,t+k}[Y_{t+k}(\overline{P}_{H,t} - MC_{t+k}^n)]\} \ , \tag{26}$$

$$\text{s.t.} \quad Y_{t+k} \leq \left(\frac{\overline{P}_{H,t}}{P_{H,t+k}}\right)^{-\varepsilon} (C_{H,t+k} + C_{H,t+k}^*) \ , \tag{27}$$

where the constraint is the demand function firms face. The resulting price level is given by:

$$P_{H,t} = [\theta P_{H,t-1}^{1-\varepsilon} + (1-\theta)\overline{p}_{H,t}^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}} \ . \tag{28}$$

Aggregation and log-linearizing around the steady state yields the (log) supply of output

$$y_t = n_t + a_t \ . \tag{29}$$

The log-linear price setting rule is

$$\overline{p}_{H,t} = \mu + (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k E_t\{mc_{t+k}^n\} \ , \tag{30}$$

[7] The constant ρ is left in the equation because the authors intend to compare different levels of welfare in the 2002 version of their paper. In Galí and Monacelli (1999), p. 7, the authors did not yet pay as much of their attention on welfare analysis.

[8] Under complete markets for nominal state contingent securities (See Monacelli (2002)), $\beta R_t E_t[(\frac{C_{t+1}^*}{C_t^*})^{-\sigma}(\frac{P_t^*}{P_{t+1}^*})(\frac{e_t}{e_{t+1}})] = 1$ holds.

where $\overline{p}_{H,t}$ is the newly set price in period t and $-\mu = -\log\left(\frac{\varepsilon}{\varepsilon-1}\right)$ is the markup that would be obtained in a situation of flexible prices.[9]

2.3.3 Analysis: Governments

The first part of both governments, conducting fiscal policy, sets the employment subsidy so that the distortion of monopolistic competition is offset. This implies

$$\tau = 1 - \left(1 - \frac{1}{\epsilon}\right)(1 - \alpha) \tag{31}$$

for the small open economy, and

$$\tau^* = \frac{1}{\epsilon} \tag{32}$$

for the world economy, where the α-term drops as the degree of openness there is essentially zero.[10]

For the second part, as in GM (2002), monetary policy in the world economy is able to effectively target inflation. Therefore, we have a fully stable world output gap and world inflation rate, so that we can set both variables to zero: $\tilde{y}_t^* = \pi_t^* = 0$.
This drives the world interest in (49) to its natural level, such that we get

$$r_t^* = \rho - \sigma(1 - \rho_a^*)\Gamma_0 a_t^* \ . \tag{33}$$

The authority for monetary policy in the small open economy sets its parameters such that it achieves zero domestic inflation for all periods, $\pi_{H,t} = 0 \quad \forall t$, and zero output gap in the small economy.[11] So from (50) it follows that the following equation holds:

$$r_t = \overline{rr}_t \quad \forall t \ , \tag{34}$$

i.e., the interest rate is at its natural level.[12] From the definitions of the exchange rates and the *terms of trade* it follows that

$$e_t = s_t = \frac{1}{1 - \alpha} q_t \tag{35}$$

[9] This is the usual result in this kind of models; see Romer (1996), pp. 285-286, or Chiang (1984), pp. 356-359.

[10] See GM (2003), p. 17 for a discussion.

[11] GM (2003) show in section 4 that this is indeed optimal.

[12] To be able to calculate impulse responses using (34) as policy rule one has to cope with the problem of indeterminacy: inserting (34) in (50), one can see that there is no unique solution to this problem. One way to circumvent indeterminacy is adding $\phi_\pi \pi_{H,t} + \phi_y \tilde{y}_t$ to the right hand side of (34) and assume $\phi_\pi > 1$ and $\phi_y \geq 0$. This will not change the model since both inflation and output gap will be zero for the given policy. See Galí (2001), pp. 22-23, and GM (2003), p. 18. In fact, the restrictions for positive ϕ_π and ϕ_y have to be such that $\kappa_\alpha(\phi_\pi - 1) + (1 - \beta)\phi_y > 0$.

Since domestic and world prices are constant, it follows from (17) that the domestic CPI price level is given by

$$p_t = \alpha e_t \ . \tag{36}$$

2.3.4 Analysis: Trade

As the consumption Euler equation (23) symmetrically holds for the world economy, we can use it to get

$$y_t^* = E_t\{y_{t+1}^*\} - \frac{1}{\sigma}(r_t^* - E_t\{\pi_{t+1}^*\} - \rho) \ . \tag{37}$$

For the small open economy, an analog can be achieved in four steps: first, relate domestic output to world output and the terms of trade,

$$Y_t = \vartheta Y_t^* \mathcal{S}_t^\eta \left((1-\alpha)\mathcal{Q}_t^{\frac{1}{\sigma}-\eta} + \alpha \right) \ . \tag{38}$$

Secondly, log-linearize to get

$$y_t = y_t^* + \frac{\omega_\xi}{\sigma} s_t - \eta\xi \ , \tag{39}$$

where $\omega_\xi \equiv 1 + \alpha(2-\alpha)(\sigma\eta - 1) - \sigma\xi > 0$.[13] Thirdly, replace the terms of trade by consumption,

$$c_t = \Phi'_\alpha y_t + (1-\Phi'_\alpha) y_t^* \ , \quad \Phi'_\alpha \equiv \frac{1-\alpha}{\omega_\xi} > 0 \ . \tag{40}$$

And fourthly, take the consumers' Euler equation and replace consumption with (40). The result of this procedure is the following dynamic equation for domestic output:

$$y_t = E_t\{y_{t+1}\} - \frac{\omega_\xi}{\sigma}(r_t - E_t\{\pi_{H,t+1}\} - \rho) + (\omega_\xi - 1)E_t\{\Delta y_{t+1}^*\} \ . \tag{41}$$

Net exports will be denoted as $nx_t \equiv (\frac{1}{Y}(Y_t - \frac{P_t}{P_{H,t}}C_t)$, which is approximately:

$$nx_t = y_t - c_t - \alpha s_t = (1-\Phi'_\alpha)(y_t - y_t^*) - \alpha s_t = \frac{\alpha\Lambda - \sigma\xi}{\omega_\xi}(y_t - y_t^*) \ , \tag{42}$$

where $\Lambda \equiv (2-\alpha)(\sigma\eta - 1) + (1-\sigma)$. The inflation dynamics in the small open economy and in the world economy are given by

$$\pi_{H,t} = \beta E_t\{\pi_{H,t+1}\} + \lambda(mc_t + \mu) \quad \text{and} \quad \pi_t^* = \beta E_t\{\pi_{t+1}^*\} + \lambda(mc_t^* + \mu) \ , \tag{43}$$

[13] The constant $\eta\xi$ can be neglected for correlations and impulse responses.

where $\lambda \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta}$. To get a representation for output in terms of deviation from the steady state, remember from section 2.2.2 that - as $MC_t^n = MC_t P_{H,t}$ - the (log) real marginal costs of the small open and the world economy are

$$mc_t = -\nu + w_t - a_t - p_{H,t} \quad \text{and} \quad mc_t^* = -\nu^* + w_t^* - a_t^* - p_t^* \ , \tag{44}$$

where the parameters $\nu = -\log(1-\tau)$ and $\nu^* = -\log(1-\tau^*)$ refer to the employment subsidies to rule out market power distortions. Together with the output supply (29), the consumer's intratemporal optimality condition (23), the first equation in (17) and (39) to substitute out s_t this can be rewritten just in terms of output and a productivity process:

$$mc_t = -\nu + \left(\frac{\sigma}{\omega_\xi} + \varphi\right) y_t + \sigma\left(1 - \frac{1}{\omega_\xi}\right) y_t^* - (1+\varphi)a_t + \xi\left(\frac{\sigma\eta}{\omega_\xi} - \frac{1}{\sigma}\right) \ , \tag{45}$$

$$mc_t^* = -\nu^* + (\sigma + \varphi)y_t^* - (1+\varphi)a_t^* \ . \tag{46}$$

To use the conventional notation in terms of a gap, the output gap shall be defined as deviation from its natural level, which would occur under flexible prices and thereby constant marginal costs $mc_t = mc_t^* = -\mu$.[14] Thus, we have $\tilde{y}_t \equiv y_t - \overline{y}_t$ and analogously $\tilde{y}_t^* \equiv y_t^* - \overline{y}_t^*$, where the natural levels are given by

$$\overline{y}_t = \Omega_\xi + \Gamma_\xi a_t + \Theta_\xi y_t^* \quad \text{and} \quad \overline{y}_t^* = \Omega_0 + \Gamma_0 a_t^* \tag{47}$$

with the use of (45). Here, $\Omega_\xi \equiv \frac{\omega_\xi(\nu - \mu - \xi\left(\frac{\sigma\eta}{\omega_\xi} - \frac{1}{\sigma}\right))}{\sigma + \omega_\xi\varphi}$, $\Gamma_\xi \equiv \frac{\omega_\xi(1+\varphi)}{\sigma+\omega_\xi\varphi}$, $\Theta_\xi \equiv \frac{\sigma(1-\omega_\xi)}{\sigma+\omega_\xi\varphi}$, $\Omega_0 \equiv \frac{\nu^*-\mu}{\sigma+\varphi}$ and $\Gamma_0 \equiv \frac{1+\varphi}{\sigma+\varphi}$. [15] Solving (45) for output and inserting in the definition of the output gap twice, at the actual and at the natural level, we get an equation relating marginal costs to the output gap for each small open and world economy. After inserting this result in (43), we get an equation for both economies, linking inflation and output gap

$$\pi_{H,t} = \beta E_t\{\pi_{H,t+1}\} + \kappa_\xi \tilde{y}_t \ , \tag{48}$$

$$\pi_t^* = \beta E_t\{\pi_{t+1}^*\} + \kappa_0 \tilde{y}_t^* \ , \tag{49}$$

where $\kappa_\xi \equiv \lambda\left(\frac{\sigma}{\omega_\xi} + \varphi\right)$ and $\kappa_0 \equiv \lambda(\sigma + \varphi)$. These two equations are representatives of the New Keynesian Phillips curve (NKPC) mentioned before.[16]

[14] On this special definition of an output gap in comparison with the usual "detrended output" see Galí (2001), pp. 12-13.

[15] To circumvent the necessity to program a solution strategy that includes constant terms we neglect the last term for the Matlab® program such that the constants drop out of the equations.

[16] See GM (2002), pp. 13-14.

Applying (41) to the small open economy's NKPC we get

$$\tilde{y}_t = E_t\{\tilde{y}_{t+1}\} - \frac{\omega_\xi}{\sigma}(r_t - E_t\{\pi_{H,t+1}\} - \overline{rr}'_t) \tag{50}$$

with $\overline{rr}'_t \equiv \rho - \frac{\sigma(1+\varphi)(1-\rho_a)}{\sigma+\omega_\xi\varphi}a_t - \varphi\Theta_\xi E_t\{\Delta y^*_{t+1}\}$, and for the world economy an IS-type equation is derived with the help of (37) as

$$\tilde{y}^*_t = E_t\{\tilde{y}^*_{t+1}\} - \frac{1}{\sigma}(r^*_t - E_t\{\pi^*_{t+1}\} - \overline{rr}^*_t) \ , \tag{51}$$

where $\overline{rr}^*_t \equiv -\sigma(1-\rho^*_a)\Gamma_0 a^*_t + \rho$. The $\overline{rr}$-terms are the natural rates of interest in the small open and the world economy, respectively, which would prevail under completely flexible prices.
Together with rules for monetary policy given in the previous sections, the model is now complete.

3 Results

3.1 Parameter Values

The parameter values chosen as a benchmark are given in table 1. Mostly, the values were chosen in accordance with those of the Galí and Monacelli model, with some exemptions. The first one applies to the productivity shock. Although it is not quite easy to estimate the standard deviation of a productivity shock when the production function lacks capital, there are some models of this kind on the field. As one example there is a cash-credit good model by Chari, Christiano, and Kehoe (1995), whose technology shock follows the same Markov chain for the model with and without capital.[17] The model by Schmitt-Grohé and Uribe (2001) refers to the previous model and translates the features of the technology process in the usual vocabulary: for annualized data, they take 0.0229 as standard deviation of the technology shock and 0.82 as its autocorrelation.[18] McCallum and Nelson (2001) call the lack of capital typical for the new open-economy macro literature and explain it as presuming investment and capital to be exogenous, with the capital stock being fixed.[19] They calibrate their model on the basis of Cooley and Prescott (1995), with the standard technology shock variance $\sigma^2_\epsilon = (0.007)^2$ and $\rho_a = 0.95$ as the autocorrelation of technology.[20] We will follow this line, which is used throughout the Cooley volume. For the correlation of productivity as well as for the degree of openness, the Galí and Monacelli

[17] Chari, Christiano, and Kehoe (1995), pp. 368-369 and 378.
[18] Schmitt-Grohé and Uribe (2001), pp. 10 and 12.
[19] McCallum and Nelson (2001), pp. 3-4.
[20] McCallum and Nelson (2001), table 1 on p. 9.

Table 1: Benchmark Parameter Values

Parameter	Value	Explanation
		Preferences
β	0.987	Discount factor
η	1.50	Elasticity of substitution between domestic and foreign goods
ε	6.00	Elasticity of substitution among goods within each category
σ	1.00	Constant of relative risk aversion, inverse of the intertemporal rate of substitution
φ	3.00	Inverse of labor supply elasticity
α	0.40	Degree of openness of the small open economy, share of imports in domestic consumption
α^*	0.001	Degree of openness of the world economy
Ξ	0.25	Trade costs
		Technology
Θ	0.75	Percentage of domestic firms which cannot (re)set prices in period t
Θ^*	0.75	Percentage of firms in the world economy which cannot (re)set prices in period t
μ	0.182	Log of the gross steady state markup
		Processes
σ_ϵ	0.007	Standard deviation of domestic and world productivity shock
ρ_a	0.95	Autocorrelation of domestic productivity AR(1) process
ρ_a^*	0.95	Autocorrelation of world productivity AR(1) process
ρ_{a,a^*}	0.77	Correlation of productivity shocks

Notes: The degree of openness of the world economy α^* is according to GM (2002, pp. 9 and 28) "assumed to be negligible", but distinct from zero. The value of Θ corresponds to an average time of four quarters between a change of prices.

values, which are aimed to reflect Canadian data,[21] will be held up.[22] The net steady state markup μ of roughly 20 percent over marginal costs is consistent with the findings of Rotemberg and Woodford (1995, pp. 260-261) as well as Schmitt-Grohé and Uribe (2001, p. 11). With μ fixed we have already set the elasticity of substitution between different firms within a country ε through $\mu = \log(\varepsilon) - \log(\varepsilon - 1)$ from section 2.2.2. Also the Calvo sticky price parameter value of 0.75, i.e., price changes on average every year, are quite standard.[23] The (quarterly) discount factor β is set to 0.987 according to Cooley and Prescott (1995, p. 21). The elasticity of substitution between domestic and foreign goods η will take a value of 1.5 according to Backus et al. (1995, pp. 346-347) – note that this is neither in line with GM (2002, p. 18), who set η equal to unity, nor is it in line with OR (2000*b*, p. 7), who model only one good per country and therefore use the elasticity between the domestic and the foreign good to construct the steady state markup. Thus, they find η to take a value of about six. We refer to this problem in the sensitivity analysis in section 4.2.

The remaining parameters, i.e., the labor supply elasticity $1/\varphi$ and the intertemporal rate of substitution $1/\sigma$, are difficult to determine: for the labor supply elasticity $1/\varphi$, Benigno (2001, p. 25) proposes a value of 0.67, whereas Blanchard and Fischer (1989) report a low value between 0 and 0.45.[24] Yun (1996) calibrates his model with $1/\varphi = 1/4$ and $1/\sigma = 1$. Erceg et al. (2000, p. 299) use 1.5 for σ, Cochrane calls values between one and two standard,[25] Chari et al. (2001, p. 16) choose a high value of $\sigma = 5$. Since there is not too much evidence on the exact degree of these parameters, we will stick to the values attributed by GM (2002), i.e., $1/\varphi = 1/3$ and $\sigma = 1$ and try out the effects of different values in the sensitivity analysis in sections 4.4 and 4.3. Finally, trade costs are set to 25 percent, the value Obstfeld and Rogoff choose as their "baseline".[26]

3.2 Implementation

To calculate moments, impulse responses and simulations the model was solved using Uhlig (1995). A basic model version in output gaps and inflation works with the use of (48),(49) and (50) together with the two productivity

[21] See GM (2002), p. 20.

[22] Compare Backus et al. (1995), who in table 11.2 on p. 336 report 0.75 for the international productivity correlation, Burda and Wyplosz (1997), table 11.2 on p. 275 for degrees of openness of different economies and blocks, and OECD (2002) for the import shares in GDP, where for Canada in 2001 0.32 instead of 0.4 percent is reported.

[23] See Romer (1996), pp. 293-294 for a microeconomic evidence survey.

[24] See Blanchard and Fischer (1989), chapters 7 and 8, especially pp. 338-342 and 388.

[25] Cochrane (1997), p. 15. The asset pricing literature yields for even higher values to explain the equity premium puzzle.

[26] OR (2000*b*), p. 6.

processes and the monetary policy rules. We use a model with 20 variables.[27] In the following, results of the model are presented with a focus on the effect of trade costs. The (sometimes implicit) alternative model is one with zero trade costs.[28]

3.3 Standard Deviations and Correlations

The results of the augmented model are shown in table 2. For the standard deviations we see that the major influence of trade costs is on the volatility of net exports. Compared to the zero trade costs case, their standard deviation declines from 0.16 to 0.02 percent because of the trade-reducing costs. This results to a smaller extent in a decrease of domestic output volatility since domestic output is equal to domestic consumption plus net exports.[29] Some slight increases in volatility can be realized for domestic consumption, CPI prices, CPI inflation and the domestic interest rates. The exchange rates' volatility rises by 20 percent, for the nominal exchange rate and the terms of trade (the real exchange rate) from 0.51 to 0.61 percent, and for the real exchange rate from 0.30 to 0.37 percent.

For domestic consumption, the correlation pattern with domestic output is higher in the model with trade costs compared to the one without. This is balanced with a lower correlation of net exports. The exchange rates are less correlated with output (0.34 instead of 0.38 percent). The co-movement of both countries' output rises from 0.74 to 0.77 percent.

[27]These are: π_H, π^*, y^*, r, $\tilde{y}^*$, p, p_H, nx, r^*, π, e, q, c, c^*, y, y^*, s, r^{CPI}, a, a^*. The unsystematic order is partly a result of the ordering principle for the Matlab program.

[28]Further tables and figures for this case as well as for the case of alternative monetary policies can be obtained from the author upon request.

[29]See (42) and the definition of net exports given right before (42).

Table 2: Business Cycle in the DIT-Model with Trade Costs $\Xi = 0.25$

Variable	SD %	Cross-Correlation of Output with:										
		x_{t-5}	x_{t-4}	x_{t-3}	x_{t-2}	x_{t-1}	x_t	x_{t+1}	x_{t+2}	x_{t+3}	x_{t+4}	x_{t+5}
Domestic output	0.9277	-0.02	0.11	0.27	0.47	0.71	1.00	0.71	0.47	0.27	0.11	-0.02
Domestic output gap	0.0000	-0.02	0.11	0.27	0.47	0.71	1.00	0.71	0.47	0.27	0.11	-0.02
World output	0.9260	-0.02	0.08	0.21	0.36	0.55	0.77	0.55	0.36	0.21	0.08	-0.02
Domestic consumption	0.8728	-0.02	0.10	0.26	0.45	0.68	0.96	0.68	0.45	0.26	0.10	-0.02
Net exports	0.0198	-0.01	0.04	0.09	0.16	0.24	0.34	0.24	0.16	0.09	0.04	-0.01
Domestic CPI price level	0.2453	-0.01	0.04	0.09	0.16	0.24	0.34	0.24	0.16	0.09	0.04	-0.01
Domestic goods price level	0.0000	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Domestic CPI inflation	0.1862	0.04	0.06	0.07	0.09	0.11	0.13	-0.13	-0.11	-0.09	-0.07	-0.06
Domestic goods inflation	0.0000	0.02	-0.11	-0.27	-0.47	-0.71	-1.00	-0.71	-0.47	-0.27	-0.11	0.02
Nominal exchange rate	0.6132	-0.01	0.04	0.09	0.16	0.24	0.34	0.24	0.16	0.09	0.04	-0.01
Real exchange rate	0.3679	-0.01	0.04	0.09	0.16	0.24	0.34	0.24	0.16	0.09	0.04	-0.01
Terms of trade	0.6132	-0.01	0.04	0.09	0.16	0.24	0.34	0.24	0.16	0.09	0.04	-0.01
Domestic interest rate	0.0461	0.02	-0.11	-0.27	-0.47	-0.71	-1.00	-0.71	-0.47	-0.27	-0.11	0.02
Dom. real CPI interest rate	0.1972	-0.04	-0.08	-0.13	-0.20	-0.27	-0.36	-0.04	-0.01	0.02	0.04	0.06
World interest rate	0.0463	0.02	-0.08	-0.21	-0.36	-0.55	-0.77	-0.55	-0.36	-0.21	-0.08	0.02
Domestic productivity	0.9260	-0.02	0.11	0.27	0.47	0.71	1.00	0.71	0.47	0.27	0.11	-0.02
World productivity	0.9260	-0.02	0.08	0.21	0.36	0.55	0.77	0.55	0.36	0.21	0.08	-0.02

Notes: SD: Standard deviation. NaN: Not a number; the variable does not vary at all. The data comes from HP-filtered, frequency domain based calculation of moments. Since the model is built up without capital and the small open economy's influence on the rest of the world is negligible, world consumption equals world output and behaves identically, so only world output is shown above.

3.4 Impulse Responses

As shown in figure 1, the existence of trade costs has the expected influence on the impact of both shocks on domestic consumption and net exports. Compared to the case without trade costs, a shock has a stronger result in the country of its appearance and a weaker one in the other country, i.e., a domestic productivity shock leads to an increase in domestic consumption of 0.6 percent instead of 0.5 in the case without trade costs, and to an increase in net exports of only 0.02 percent instead of 0.22. A one percent increase in world productivity leads to an increase in domestic consumption of only 0.4 percent compared to 0.5 without trade costs. Net exports hardly react in the trade costs setting, although they fell about 0.25 percent in the basic model without trade costs.

The impacts of both shocks on CPI prices and inflation is larger with trade costs with 0.38 percent instead of 0.32 percent. The same holds for the exchange rates, which become about 20 percent more volatile in the trade costs model.[30]

3.5 The Trade Costs Model and the Six Puzzles

3.5.1 Home Bias in Trade

In an Arrow-Debreu world of complete international markets without any barriers on trade, one would suspect that an equal amount of products should be traded across international and intra-national borders, such that borders do not matter for trade. In reality, we see that there is significantly less trade across international borders, i.e., domestic products are preferred. This was pointed out especially by John McCallum (1995) for the example of the U.S. and Canada. McCallum found 22 times less trade across the border than across interstate borders in Canada or in the U.S. In a more careful study, Anderson and van Wincoop (2001) argue that borders reduce trade between industrialized countries by 29 percent or, in the case of U.S. - Canadian trade, by 44 percent.[31]

The share of consumption allocated to imported goods α is set exogenously in the model. It also measures the degree of openness of the small open economy: the more imports, the more open the economy.[32] In the same way, α^* measures the share of imports on world consumption and the degree of openness of the world economy. Using the household's two optimal consumption shares given in (20) to replace total consumption C_t, one gets

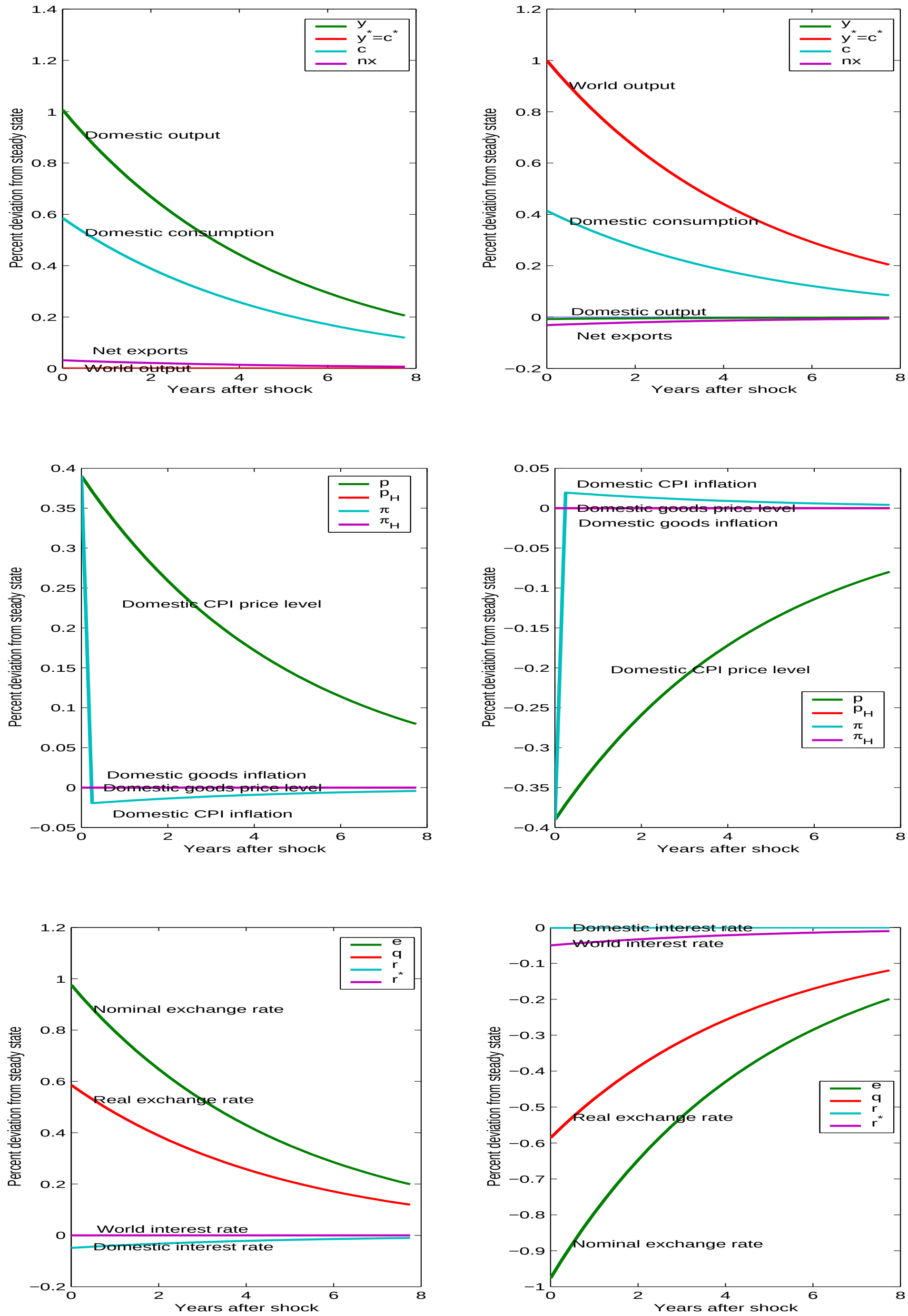
[30] Impact of the nominal exchange rate on both shocks ± 0.95 % instead of ± 0.8 %, of the real exchange rate ± 0.6 % instead of ± 0.5 %.

[31] Anderson and van Wincoop (2001), p. 2.

[32] Both interpretations hold exactly only in the steady state when domestic and foreign price index are equal. See GM (2002), p. 4.

Figure 1: Impulse Responses of the DIT-Model with Trade Costs

Shock to Domestic Productivity | Shock to World Productivity



a consumption share ratio:

$$\frac{C_{H,t}}{C_{F,t}} = \frac{1-\alpha}{\alpha} \left(\frac{P_{H,t}}{P_{F,t}} \right)^{-\eta} . \tag{52}$$

Multiplying the price ratio gives the ratio of expenditures on home goods relative to the expenditures on foreign goods:

$$\frac{P_{H,t} C_{H,t}}{P_{F,t} C_{F,t}} = \frac{1-\alpha}{\alpha} \left(\frac{P_{H,t}}{P_{F,t}} \right)^{1-\eta} . \tag{53}$$

For the world economy, a similar equation includes the nominal exchange rate and thereby trade costs. The world representative household's optimal expenditure share is:

$$\frac{\mathcal{E}_t P^*_{H,t} C^*_{H,t}}{\mathcal{E}_t P^*_{F,t} C^*_{F,t}} = \frac{\alpha^*}{1-\alpha^*} \left(\frac{\mathcal{E}_t P^*_{H,t}}{\mathcal{E}_t P^*_{F,t}} \right)^{1-\eta} , \tag{54}$$

which can be denoted in terms of domestic currency as

$$\frac{P_{H,t} C^*_{H,t}}{(1-\Xi)^2 P_{F,t} C^*_{F,t}} = \frac{\alpha^*}{1-\alpha^*} \left(\frac{P_{H,t}}{(1-\Xi)^2 P_{F,t}} \right)^{1-\eta} , \tag{55}$$

or simpler

$$\frac{P_{H,t} C^*_{H,t}}{P_{F,t} C^*_{F,t}} = \frac{\alpha^*}{1-\alpha^*} (1-\Xi)^{2\eta} \left(\frac{P_{H,t}}{P_{F,t}} \right)^{1-\eta} . \tag{56}$$

This implies a strong home bias for the world economy: with the basic calibration[33] we get a relation of 1/2368, i.e., a household in the world economy allocates around 2300 times more expenditure on home than on foreign products. The combination of home bias in preferences and trade costs apparently explains any home bias one could think of.

3.5.2 Investment-Savings

If one supposes that capital can move freely across countries and people are free to invest their money wherever they want, one would suspect that rising savings in one economy did not necessarily imply a rising investment in the same country. The savings could also be directed to some other countries, leaving investments in the first country constant or even reducing it – if conditions for investment are temporarily better abroad. With this in mind one would expect a rather low correlation between savings and investment in open economies with free capital movements. Instead, the data shows a high positive correlation: Feldstein and Horioka (1980) found a coefficient of 0.89 for 16 OECD countries between 1960 and 1974. A

[33] $\alpha = 0.4$, $\alpha^* = 0.001$ and $\eta = 1.5$, and $\xi = 0.25$.

regression for a 22 OECD country sample between 1982-91 by Obstfeld and Rogoff (1996, p. 162) results in a coefficient of 0.62, while the latest regression by the same authors (Obstfeld and Rogoff 2000*b*, table 1) for the 24 OECD countries between 1990-97 yields 0.60. Although there is decreasing trend, the absolute value of the correlation coefficient is still large.

The Galí and Monacelli model lacks the introduction of capital. Thus, one might think the high investment-savings correlation puzzle of Feldstein and Horioka (1980) cannot be addressed yet. However, it can, but not directly: theory predicts the correlation of national savings and investment to be low since savings will be invested in the country with the highest rate of return and not necessarily in the home country. If the world real interest rate is higher than the domestic counterpart, one would expect the current account to be positive because of the exported savings. On the other hand: if domestic interest rises relative to the world interest, i.e., "the rate at which domestic agents can substitute their consumption intertemporally"[34] gets better, domestic agents will consume more in the current period, such that net exports become negative. Thus, a linear negative relation between the current account and the real interest rate difference can be seen as an analog to the high investment-savings correlation seen in the data.

The model analyzed shows a correlation coefficient between these variables of -0.49, comared to -0.54 for the case without trade costs.[35] This range of values is quite stable, even for changes to the OR (2000*b*) value for the elasticity of substitution between domestic and foreign goods, $\eta = 6$, and trade costs up to 75 percent.

3.5.3 Home Bias in Equity Portfolio

U.S. Americans hold about 90 percent of their equity wealth in the U.S. stock market. However, both the U.S. and the Canadian equity market capitalization account for less then half of the world's equity market capitalization.[36] Japan shows a similar pattern, with 95 percent of equity held in the home stock market. Other countries like the U.K. and Germany are less "biased": between 15 and 24 percent of these countries' equity wealth is invested in foreign stock markets.[37] Compared to the relative size of their stock markets these numbers still show a significant home bias. With this findings the standard assumption of complete risk diversification is difficult to maintain.

The way this puzzle can be addressed in a model without money and

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[34] Jeanne (2000), p. 393.

[35] $\text{Corr}(nx_t, r_t^{\text{CPI}} - r_t^*) = -0.49$, where the domestic real interest rate is $r_t^{\text{CPI}} = r_t - \pi_t$, and the world interest rate r_t^* is real, since $\pi_t^* = 0 \quad \forall t$.

[36] Tesar and Werner (1998), pp. 293 and 296; data for 1996.

[37] Tesar and Werner (1998), pp. 298-300; data for 1996. For an overview see also OR (1996), pp. 304-306.

capital is the following: the consumption share of domestic goods equals the equity share of domestic goods.[38] So the calculation of the portfolio share dedicated to the foreign country is straightforward: since security markets are supposed to be complete, the ratio of marginal utility of domestic goods consumption to the domestic goods price should be equal in both countries,

$$\frac{1}{P_{H,t}}\frac{\partial U}{\partial C_{H,t}} = \frac{1}{\mathcal{E}_t P^*_{H,t}}\frac{\partial U^*}{\partial C^*_{H,t}} \ . \tag{57}$$

This is under the given utility function

$$\frac{1}{P_{H,t}}\ C_t^{\frac{1}{\eta}-\sigma}(1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{-1}{\eta}} = \frac{1}{\mathcal{E}_t P^*_{H,t}}\ C_t^{*\frac{1}{\eta}-\sigma}\alpha^{*\frac{1}{\eta}} C_{H,t}^{*\frac{-1}{\eta}}\ , \tag{58}$$

where $\mathcal{E}_t$ stands for the nominal exchange rate in levels. The same argument applies to the foreign good, so equality in both countries results in

$$\frac{1}{P_{F,t}}\ C_t^{\frac{1}{\eta}-\sigma}\alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{-1}{\eta}} = \frac{1}{\mathcal{E}_t P^*_{F,t}}\ C_t^{*\frac{1}{\eta}-\sigma}(1-\alpha^*)^{\frac{1}{\eta}} C_{F,t}^{*\frac{-1}{\eta}}\ . \tag{59}$$

Market clearing for home and foreign products implies:

$$Y_{H,t} = C_{H,t} + \frac{1}{1-\Xi}C^*_{H,t} \quad \text{and} \quad Y_{F,t} = C^*_{F,t} + \frac{1}{1-\Xi}C_{F,t}\ . \tag{60}$$

To make the calculations easier, we focus on the special case for which $\frac{1}{\eta} = \sigma$ holds, e.g. $\sigma = \eta = 1$ as in the calibration of GM (2002). This means that C_t and C_t^* drop out of the equations. One can use (11) and (12) together with (58) to get an equation for the home good:

$$(1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{-1}{\eta}} = \alpha^{*\frac{1}{\eta}}(1-\Xi) C_{H,t}^{*\frac{-1}{\eta}}\ , \tag{61}$$

and we can use (11) with (59) for the foreign good equation:

$$\alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{-1}{\eta}} = (1-\alpha^*)^{\frac{1}{\eta}}\frac{1}{1-\Xi} C_{F,t}^{*\frac{-1}{\eta}}\ . \tag{62}$$

Applying the market clearing conditions given in (60), we can get four consumption share and four equity portfolio share equations:

$$X_{H,t} = C_{H,t} = \frac{1}{1+\frac{\alpha^*}{1-\alpha}(1-\Xi)^{\eta-1}}Y_{H,t}\ , \tag{63}$$

$$(1-\Xi)X^*_{H,t} = C^*_{H,t} = \frac{\frac{\alpha^*}{1-\alpha}(1-\Xi)^{\eta}}{1+\frac{\alpha^*}{1-\alpha}(1-\Xi)^{\eta-1}}Y_{H,t}\ , \tag{64}$$

$$(1-\Xi)X_{F,t} = C_{F,t} = \frac{\frac{\alpha}{1-\alpha^*}(1-\Xi)^{\eta}}{1+\frac{\alpha}{1-\alpha^*}(1-\Xi)^{\eta-1}}Y^*_{F,t}\ , \tag{65}$$

$$X^*_{F,t} = C^*_{F,t} = \frac{1}{1+\frac{\alpha}{1-\alpha^*}(1-\Xi)^{\eta-1}}Y^*_{F,t}\ . \tag{66}$$

[38] The way this topic is dealt with is a direct application of OR (2000*b*), pp. 22-28.

The difference in consumption and equity portfolio shares for the imported goods, i.e., $C_{F,t}$ and $C^*_{H,t}$, is due to trade costs: for consumption, these goods have to be traded with costs, and so there remain only $(1 - \Xi)$ percent in the destination country, whereas equity portfolio can be traded without any costs.
With the GM (2002) calibration $\alpha = 0.4$, $\alpha^* = 0.001$ and $\eta = 1$, the equity portfolio shares do not change compared to the situation without trade costs, since the trade costs always vanish due to their exponent $(\eta - 1)$. According to Cochrane (1997), values between $\sigma = 1$ and $\sigma = 2$ are standard for the constant of relative risk aversion.[39] For the elasticity of substitution between domestic and foreign goods, Chari et al. (2001) report values between one and two.[40] Obstfeld and Rogoff argue in favor of a much higher value: they cite studies with values up to 21 in some sectors, with a mean around six.[41] All studies suggest that both σ and η are not smaller than one, so within the simple case $\sigma\eta = 1$ there is no choice to deviate from $\sigma = \eta = 1$. Without that restriction this small model is not solvable, since in contrast to the Obstfeld and Rogoff model,[42] symmetry does not hold for the extended Galí and Monacelli model.

3.5.4 Low International Consumption Correlation

If risk were pooled internationally, the changes in consumption would be closely correlated across countries. However, this is not the case. Consumption is even less correlated than output: compared to the world growth rate, the correlation of consumption growth in the OECD countries lies somewhere between 0.27 for Italy and 0.63 for Germany. At the same time, output correlations are nearly always higher, between 0.42 for Japan and 0.70 for Canada and Germany.[43] Backus, Kehoe and Kydland (1995, tables 1 and 2) have slightly different numbers but the same findings. Apart from that, they come to the result that productivity[44] is internationally less correlated than output. They call this puzzle "the consumption/output/productivity

[39] See also Backus et al. (1995), table 11.3, p. 338, and Kollmann (2001), p. 252, who use a value of two, or Chari et al. (2001), p. 16, who need a value of 5 in their model to generate an enough volatile real exchange rate. Cochrane (1997) along with a good deal of the asset pricing literature would need a very high value of risk aversion – up to $\sigma = 250$ – to match their observations in the stock market, but this usually contradicts the logic of the intertemporal rate of substitution, which is the inverse of σ; See Cochrane (1997), pp. 15 - 18.

[40] Chari et al. (2001), p. 17. Compare to Backus et al. (1995), p. 347, who choose $\eta = 1.5$.

[41] OR (2000*b*), p. 7.

[42] OR (2000*b*), pp. 22-26.

[43] OR (1996), p. 291; data from 1973 to 1993.

[44] Productivity is measured by the Solow residual z of a standard Cobb-Douglas production function $Y_t = Z_t K_t^{\theta} N_t^{1-\theta}$.

anomaly, or the quantity anomaly".[45] This puzzle – the "quantity anomaly" in the words of Backus et al. (1995) – is not solved in the benchmark model. The model implies a correlation of $\text{Corr}(c_t, c_t^*) = 0.92$, whereas $\text{Corr}(y_t, y_t^*) = 0.77$. But relative to the zero trade costs case, where $\text{Corr}(c_t, c_t^*) = 0.95$ and $\text{Corr}(y_t, y_t^*) = 0.74$, this implies a movement in the right direction: output correlation rises, whereas consumption correlation declines. For higher values of the trade costs the correlations even converge: $\Xi = 0.35$ results in $\text{Corr}(c_t, c_t^*) = 0.90$ and $\text{Corr}(y_t, y_t^*) = 0.78$, $\Xi = 0.55$ in $\text{Corr}(c_t, c_t^*) = 0.80$ and $\text{Corr}(y_t, y_t^*) = 0.84$. We see that the relation is reverted and thus matches the data, though with quite high trade costs. To reduce the absolute value of the correlation, one could reduce the correlation of the productivity shocks ρ_{a,a^*}. A reduction from 0.77 to 0.66 (while $\Xi = 0.25$) leads to a correlation coefficient of 0.70 for consumption and 0.76 for output, which shows that the direction is right, but there are still some problems with the absolute values. Backus et al. (1995, table 11.2) report a slightly higher productivity correlation compared to consumption correlation for OECD economies, whereas here consumption correlation is higher than productivity correlation.

A combination of trade costs $\Xi = 0.45$ and productivity correlation $\rho_{a,a^*} = 0.7$, leads to correlation coefficients of 0.81 for output and 0.70 for consumption, which quite well reproduces the U.S.-Canadian data.[46] The problem in this setting is that output correlation is reduced by a smaller productivity correlation or a higher elasticity of substitution between domestic and foreign goods, whereas consumption correlation rises if the elasticity falls. We suppose that this outcome might be an effect of the simplifying assumption that world output and world consumption are identical, and, consequently, consumption smoothing cannot show up.

If we use high trade costs, a low international productivity correlation *and* a low degree of openness in the small economy, then it is possible to reproduce the data. For example, choosing $\Xi = 0.5$, $\rho_{a,a^*} = 0.35$ and $\alpha = 0.24$ results in $\text{Corr}(c_t, c_t^*) = 0.20$ and $\text{Corr}(y_t, y_t^*) = 0.53$, and $\Xi = 0.45$, $\rho_{a,a^*} = 0.5$ and $\alpha = 0.3$ results in $\text{Corr}(c_t, c_t^*) = 0.54$ and $\text{Corr}(y_t, y_t^*) = 0.59$. A low degree of openness is also able to reproduce a lower consumption correlation with our benchmark trade costs $\Xi = 0.25$: setting $\alpha = 0.1$, which is a bit more than the import share on GDP in Japan,[47] and $\rho_{a,a^*} = 0.5$, which is about the mean of the productivity correlations reported in Backus et al. (1995, p. 336), we get $\text{Corr}(c_t, c_t^*) = 0.46$ and $\text{Corr}(y_t, y_t^*) = 0.54$.

[45] Backus, Kehoe and Kydland (1995), p. 343.
[46] See Backus et al. (1995), p. 336, table 11.2.
[47] See OECD (2002), p. 272.

3.5.5 Purchasing Power Parity

The autocorrelation of the real exchange rate $\text{Corr}(\log(\mathcal{Q}_t), \log(\mathcal{Q}_{t-1}))$ is about 0.85.[48] Though there are some differences in the absolute value of the autocorrelation due to the periodicity of the underlying data,[49] the high degree of autocorrelation is puzzling. Standard deviations of exchange rates are relatively large: usually they amount to about eight percent, which is up to six times higher than output deviations.[50] Since there is a lot of variation in the nominal as well as in the real exchange rate, a strong and rapid reaction to shocks would be possible. Therefore, Rogoff (1996) puts the PPP puzzle question as follows: "How can one reconcile the enormous short-term volatility of real exchange rates with the extremely slow rate at which shocks appear to damp out?"[51] While the puzzling persistence of the real exchange rate is not too badly replicated in the model with $\text{Corr}(\log(\mathcal{Q}_t), \log(\mathcal{Q}_{t-1})) = 0.71$, the volatility dimension is clearly not replicated in the model. The influence of trade costs on the standard deviation of the real exchange rate as shown in table 3 qualitatively moves the model in the right direction: the benchmark trade costs of 25 percent raise the volatility of the real exchange rate by 7 basis points or more than 20 percent from 0.30 to 0.37. Though this number is still by far too low compared to the data, trade costs improve the model in this respect. The last column of table 3 reveals that a high elasticity of substitution has a negative effect on exchange rate volatility. As products become more like substitutes internationally, a change in relative product prices has a larger effect. This reduces exchange rate volatility. For the autocorrelation the picture is different: trade costs do not have an influence in this respect.

3.5.6 Exchange Rate Disconnect

Another fact concerning the real, but also to the nominal exchange rate is the missing of a strong connection to any other macroeconomic variable. This feature can be examined from two points of view: *a*) a connection could be seen if the high volatility of exchange rates would have an effect on the volatility of some other macroeconomic variable. In this respect, the disconnect shows up in a situation in which, "while exchange rate volatility is ultimately tied to volatility in the fundamental shocks to the economy, the exchange rate can display extremely high volatility without any implications

[48] See the survey article for this puzzle by Rogoff (1996).

[49] Obstfeld and Rogoff (2000*b*), p. 35, report values between 0.97 and 0.99 for monthly data, but 0.85 (1996), p. 623, for annual data. Chari et al. (2001), table 1, report values between 0.77 and 0.86 for logged, Hodrick-Prescott (HP)-filtered European post-Bretton Woods data relative to the U.S. Dollar, Kollmann (2001), p. 254, gives nearly the same results for Japan, Germany and the UK.

[50] See Chari et al. (2001), table 2, or Kollmann (2001), p. 254.

[51] Rogoff (1996), p. 647.

for the volatility of other macroeconomic variables."[52] As Flood and Rose (1995) show, moving from floating to fixed exchange rates or into the other direction does not influence the volatility of other macroeconomic variables. *b*) The disconnect is also a question of correlations between the exchange rate and other variables such as output or prices. Kollmann (2001, p. 254) reports correlations with domestic GDP between -0.21 and 0.15 for Japanese, German and UK post-Bretton Woods data, on average -0.07 for the nominal and -0.01 for the real exchange rate. While theory (but less evidence) may relate the real exchange rate to the real interest rate,[53] especially the nominal exchange rate seems to be out of the sphere of influence of any other variable: to model it as a random walk results in better models than any structural approach.[54] According to Jeanne (2000, p. 402) it is not clear whether the low correlations help to explain the high volatility: if the low correlations should leave us thinking of exchange rate volatility in the same way as of asset price volatility, the exchange rate volatility problem just comes up in the broader asset price volatility puzzle.

The two dimensions of this puzzle, the singularly high volatility of the exchange rate and the low correlation with other macroeconomic variables, are both not found in the model. As the model is set up, the real exchange rate is identical to the CPI price level and therefore perfectly correlated with the latter. From our point of view this is clearly a model deficiency. As McCallum and Nelson (2001) report, the empirical correlation of the inflation rate and the exchange rate is low, whereas the model predicts a high contemporaneous correlation.[55] Also along the second dimension the model does not fit the data: the volatility of both real and nominal exchange rates is with 0.37 and 0.61 percent by far smaller than the 6 to 9 percent reported in most datasets.[56]. Still, table 3 shows that increasing trade costs also increases the real (nominal) exchange rate standard deviation from 0.30 (0.51) percent in the model without trade costs to 0.37 (0.61) percent in the model with 25 percent trade costs. For higher trade costs, the results are more precise: for $\eta = 1.5$ and $\Xi = 0.40$ we get $\sigma_q = 0.44$ and $\sigma_e = 0.73$. If the substitutability between domestic and foreign goods η is set to 6, and trade costs $\Xi = 0.25$, as in the OR (2000*b*) calibration, the standard deviations again fall down to 0.20 (0.12) percent.[57] The results for the second dimension, i.e., the correlation of exchange rates with fundamentals,

[52] Devereux and Engel (2002), p. 4.

[53] See e.g. Obstfeld and Rogoff (1996), pp. 622-624.

[54] Obstfeld and Rogoff (1996), p. 624.

[55] See McCallum and Nelson (2001), pp. 15-21, for correlations from annual and quarterly data, as well as the correlation in the GM (1999) model which they looked at. For the GM model correlations see also the first column of table 3 below.

[56] E.g., Chari et al. (2001) and Kollmann (2001).

[57] The same results apply if the substitutability between different goods from one country is lowered to unity.

are also reported in table 3.[58] In particular, notice that trade costs reduce the co-movement with domestic output and do not have a relevant negative influence on the already low correlation with domestic consumption. On the other hand, trade costs lead to a rise in the correlation with the domestic nominal and real interest rates. The comparison with the OR (2000*b*) calibration in the last column of table 3 shows that the results are highly dependent on the chosen value for the elasticity of substitution between domestic and foreign goods: if both goods are substitutes, the correlation of the real exchange rate with domestic output increases while it becomes negative with domestic consumption.

4 Sensitivity Analysis and Discussion

To get an impression of the robustness of main results, we will test the benchmark domestic inflation targeting model with trade costs along five dimensions. First, we change the U.S.-Canadian setup of Galí and Monacelli to a setup which can be compared with the U.S. and U.K., or the U.S. and Italy. A second change refers to the elasticity of substitution between domestic and foreign goods. Here, we use the high value of Obstfeld and Rogoff. Third, we explore a setup with very risk-averse individuals, similar to the parameter value Chari et al. (2001) use in their model. In section four, we focus on labor supply elasticity. In the first version of their model, GM (1999) calibrated the labor supply to be of unit elasticity. In consequence, we examine the outcome of labor supply elasticity equal to a tenth of it – or if we use their first value one. The fifth modification refers to trade costs: we will investigate the effects of quite sizeable costs of trade. Section six specially addresses the real exchange rate volatility. We investigate if there is a combination of parameter values that results in the observed high volatility. The overall impression will be discussed in the final section.

4.1 Degree of Openness and Productivity Correlation: The U.K. instead of Canada

As mentioned in section 3, Galí and Monacelli construct their model such that it fits the data for Canada relative to the U.S. Especially, they set the correlation of Canadian productivity with U.S. productivity to 0.77 according to the data, and the degree of openness to the Canadian import share on GDP. The question which may arise is the following: do the results also hold for another setup? Therefore, we choose another relatively small country with its productivity correlation and degree of openness, to address this question. The U.K. and Italy are quite similar with respect to the two

[58] Since the nominal exchange rate nearly one to one co-moves with the real exchange rate, only the latter is given in the table.

Table 3: Exchange Rate Behavior in the DIT-Model with Trade Costs

	Trade Costs Ξ					
Variable v_t	0.00	0.10	0.20	0.25	0.40	"OR"
Standard Deviation in %						
Nominal exchange rate	0.51	0.54	0.59	0.61	0.73	0.12
Real exchange rate	0.30	0.32	0.35	0.37	0.44	0.20
Autocorrelation $\text{Corr}(v_t, v_{t-1})$						
Nominal exchange rate	———		0.7119		———	
Real exchange rate	———		0.7119		———	
Correlation with the Real Exchange Rate $\text{Corr}(v_t, q_t)$						
Domestic output	0.38	0.37	0.35	0.34	0.31	0.47
Domestic output gap	0.70	0.93	0.01	0.41	0.56	-0.23
World output	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34
Domestic consumption	-0.01	0.01	0.04	0.06	0.14	-0.22
Net exports	1.00	1.00	1.00	1.00	-1.00	1.00
Domestic CPI price level	1.00	1.00	1.00	1.00	1.00	1.00
Domestic goods price level	-1.00	NaN	-1.00	NaN	NaN	NaN
Domestic CPI inflation	0.38	0.38	0.38	0.38	0.38	0.38
Domestic goods inflation	-0.67	-0.95	0.00	-0.40	0.57	0.34
Nominal exchange rate	1.00	1.00	1.00	1.00	1.00	1.00
Terms of trade	1.00	1.00	1.00	1.00	1.00	1.00
Domestic interest rate	-0.22	-0.25	-0.30	-0.32	-0.43	0.13
Dom. real CPI interest rate	-0.42	-0.42	-0.43	-0.43	-0.45	-0.23
World interest rate	0.34	0.34	0.34	0.34	0.34	0.34
Domestic productivity	0.34	0.34	0.34	0.34	0.34	0.34
World productivity	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34

Notes: "OR": Calibration of OR (2000*b*), i.e., $\Xi = 0.25$ and the elasticity of substitution between domestic and foreign goods $\eta = 6$ instead of 1.5 in our calibration or 1.0 in GM (2002). NaN: Not a number; the variable does not vary at all or the calculation is impossible. The data comes from HP-filtered, frequency domain based calculation of moments. As before, world consumption is identical with world output.

dimensions mentioned. Both have the same productivity correlation with U.S. productivity (0.35),[59] and both have roughly the same import share of slightly more than 20 percent.[60] The implications of this setup are shown in the fifth column of table 4. In particular, both exchange rates become about twice as volatile.[61] The less open the economy, the more volatile the exchange rate: this is exactly what Hau (2001) finds in his (partly) empirical study and what OR (2000*a*) also see in their traded-nontraded goods model.[62] Net exports are now negatively correlated with output as in the data, but counter-factually positively with the real interest rate. So we see that this setup takes a big step to solve puzzle 5 (PPP), but (with DIT) at the expense of puzzle two ($\text{Corr}(nx_t, r_t^{\text{CPI}})$)

4.2 Substitutability between Domestic and Foreign Goods

Jeanne (2000, p. 391) states that a high elasticity of substitution between domestic and foreign goods η is necessary for trade costs to have an influence. OR (2000*b*) report estimates of $\eta = 6$ in their paper. So why didn't we change to their value right from the introduction of trade costs? The difficulty is that they found their estimates partially on markups,[63] but in our model markups are connected with the elasticity of substitution between different goods of the home country (ε). If we only look at their "second pillar", i.e., estimates of the import demand elasticity with respect to prices, and choose a value of, e.g., six, then we have to explain our implicit assumption that foreign goods are as much substitutes as any other domestic good since $\eta = \varepsilon$. Engel raises exactly this question at the end of his comment on the "Six Puzzles" and proposes the intranational elasticity to be twice as high as the international.[64] Nonetheless, we test the $\eta = 6$, $\Xi = 0.25$ setup – the "baseline case"[65] – and hope that this setup leads to an improvement to solve the puzzles. But the insipid findings presented in the sixth column of table 4 do not show an overall improvement worth mentioning. The pros are more volatile net exports and consumption less correlated with output. The cons are less volatile and more output-correlated exchange rates. To put it positively: In a model with trade costs *and* a home bias in preferences we do not need high values for the elasticity of substitution η.

[59] See Backus et al. (1995), table 11.2 on p. 336.

[60] Italy: 21.2%, U.K.: 23.8%, see OECD (2002), "Imports of goods and services as percentage of GDP", data for 2001 (Italy: 2000).

[61] See GM (2002, figure 3) for similar findings, although without trade costs and with a different calibration.

[62] While Hau is quite convinced by this result, OR (2000*a*), p. 136, only admit that Hau's results "appear to support the hypothesis".

[63] See OR (2000*b*), p. 7.

[64] Engel (2000), p. 409.

[65] OR (2000*b*), p. 6.

4.3 High Risk Aversion

Two values were quite unclear in section 3. One is the risk aversion coefficient σ, which we have set to unity. But as we argued, this is the lower bound of the typical range for this parameter. A value of two is not untypical, and even five has found its advocates in Chari et al. (2001). What changes if we suppose risk averse individuals and set σ equal to five? As column seven of table 4 shows, risk aversion reduces consumption and thereby output volatility, at the expense of exchange rate volatility. This is good, since it helps to resolve the "volatility dimension" of the "disconnect" puzzle.[66] Also, risk aversion reduces the output-correlation of consumption to a reasonable value. But on the other side, the output-correlation of net exports and the exchange rates rises, such that the "correlation dimension" of the "disconnect" puzzle is not reproduced.

4.4 Labor Supply Elasticity

The second parameter whose value is not yet fixed in the literature is the elasticity of labor supply, in our model $1/\varphi$. Although we hardly focus on the labor market implications of this model, e.g., the correlation pattern of labor with output or the labor supply volatility,[67] we will have a look at the labor supply elasticity in greater detail. As has been argued in section 3, there is a general agreement that labor supply is inelastic, but the exact value is controversial. Blanchard and Fischer (1989, p. 341) report a range from zero to 0.45. What if we reduce the elasticity from 0.33 to 0.1? What if we raise it to unity, as in the first version of the Galí and Monacelli paper?[68] Both answers are: nothing happens! At least for the variables observed the results are stable for a wide range of labor supply elasticity, i.e., $1/\varphi \in [0.1; 1.0]$. Therefore, we present only the case of the low elasticity in column eight of table 4.

4.5 High Trade Costs

What is the amount of reasonable trade costs? Looking only at tariffs, the early U.S. history shows quite extraordinary values of more than 50 percent.[69] Today, tariffs usually account to less than 10 percent. So, this argumentation does not lead to the high number looked for in our experiment. Nontariff barriers are not assumed to take higher values in OECD

[66] See section 3.5.6.

[67] Chari et al. (2001), p. 22, state that sticky price models usually have counter-cyclical labor productivity – counter-factually.

[68] GM (1999), p. 13.

[69] Figure 35-11 in Samuelson and Nordhaus (1998), p. 708, shows tariffs in the United States from 1820 till 2000. Till 1833, and again between 1861 and 1870, tariffs about 50 percent were no exception.

countries, as long as we suppose bribery to be relatively rare. One has to stick to another argument to allow for really high values of Ξ: along the argument that nontradables are traded goods with prohibitively large trade costs,[70] we can possibly increase the percentage of trade costs quite a lot. For the sake of the argument, let us assume $\Xi = 0.5$, i.e., trade costs of 50 percent.[71] Implementing $\Xi = 0.4$ in the model yields results that are compactly presented in the ninth column of table 4. This parameterization is perhaps the most promising. We see more volatility in the nominal and real exchange rates as well as in the net exports, we see the negative output-correlation of net exports and reduced output-correlations of both exchange rates. And we see that the international consumption correlation is nearly as low as the international correlation of output. So this parameterization is on the right way to solve puzzles four ($\mathrm{Corr}(c_t, c_t^*)$), five (PPP) and six (disconnect). A drop of bitterness is the significantly positive correlation of net exports with the real interest rate.

4.6 Accounting for the Real Exchange Rate Volatility

As we have seen, the U.K. parameterization, high risk aversion, and high trade costs lead to an increase in exchange rate volatility. So what do we get if we put all the things together? As we chose a "G3"-average of Germany, Japan and the U.K. for the data, we now choose the degree of openness α according to the arithmetic average of the import shares of these three countries, which are 26, 8, and 24 percent according to the *Main Economic Indicators*.[72] In the same manor, we choose the productivity correlation with U.S. productivity, as given in Backus et al. (1995).[73] With σ set as in section 4.3, we end up with the following parameter values: $\alpha = 0.19$, $\rho_{a,a^*} = 0.53$, $\sigma = 5$. If we set trade costs Ξ to a value of 0.572, we can get exactly the real exchange rate volatility we see in the data, as the last column of table 4, labeled "G3+Risk+Trade", shows. The result for the volatility is good: volatility of output equals two percent, of consumption a bit less, of net exports more than twice as much, of the real exchange rate more than four times as much, for the nominal exchange rate a bit less than for the real exchange rate. We see also that nominal and real exchange rate are highly correlated with each other and that international output correlation is close to the data. But there are also model deficiencies. Consumption and both exchange rates are nearly perfectly negative correlated with output,

[70] See Obstfeld (2000).

[71] In the traded-nontraded goods thinking, this may come from prohibitive trade costs for nontraded goods of around 80 percent, and trade costs of 20 percent for traded goods. If nontraded goods account for 50 percent of total output, as supposed in Obstfeld and Rogoff (2000*b*), pp. 21-22, than average trade costs are 50 percent.

[72] See OECD (2002), data for 2001 (U.K.:2000).

[73] U.S.-productivity correlation with Germany 0.65, with Japan 0.58, with the U.K. 0.35; see Backus et al. (1995), p. 336.

net exports nearly perfectly positive. Furthermore, net exports are now positively correlated with the real interest rate. The negative international consumption correlation is also quite unusual: Backus et al. (1995, p. 336) report this outcome only once, for the relation between U.S. and Australian consumption. And, finally, we now have the same finding as Chari et al. (2001): the "consumption-real exchange rate anomaly", i.e., the correlation between the real exchange rate and consumption is now $\mathrm{Corr}(q_t, c_t) = 0.92$ – a value not found in the data.[74] Referring to the volatility, we have to object that the results are highly nonlinear in the trade costs: for $\Xi = 0.50$ the real exchange rate varies with 4.17 percent, for $\Xi = 0.55$ with 6.58 percent, for $\Xi = 0.60$ with 18.67 percent and for $\Xi = 0.62$ with 93.38 percent. Then the movement is reverted: $\Xi = 0.65$ results in 17.24 percent, $\Xi = 0.70$ in 5.35 percent, and $\Xi = 0.75$ in 2.95 percent.

[74] See Chari et al. (2001), p. 3.

Table 4: Business Cycle Comparison of Different DIT-Model Parameterizations

Statistics and Variable	Data	No Trade Costs	Trade Costs Model	Parameter Changes to the Trade Costs Model: $\alpha = 0.24$, $\rho_{a,a^*} = 0.35$	$\eta = 6$	$\sigma = 5$	$\varphi = 10$	$\Xi = 0.5$	"G3+Risk +Trade"
Standard Deviations in %									
Domestic output	1.52	0.94	0.93	0.91	0.98	0.61	0.93	0.90	2.10
Domestic consumption	1.45	0.87	0.87	0.83	0.89	0.44	0.87	0.90	1.31
Net exports	4.34	0.16	0.02	0.09	0.57	0.17	0.02	0.33	5.02
Nominal exchange rate	9.13	0.51	0.61	1.12	0.20	0.78	0.61	0.87	9.08
Real exchange rate	8.89	0.30	0.37	0.85	0.12	0.47	0.37	0.52	7.36
Autocorrelations Corr(v_t, v_{t-1})									
Domestic output	0.78	—	—	—	0.7119	—	—	—	—
Nominal exchange rate	0.80	—	—	—	0.7119	—	—	—	—
Real exchange rate	0.78	—	—	—	0.7119	—	—	—	—
Cross-Correlations with Domestic Output Corr(v_t, y_t)									
Domestic consumption	0.69	0.92	0.96	0.98	0.76	0.61	0.96	1.00	-0.87
Net exports	-0.29	0.38	0.34	-0.55	0.47	0.70	0.34	-0.26	0.98
Nominal exchange rate	-0.07	0.38	0.34	0.55	0.47	0.70	0.34	0.26	-0.98
Real exchange rate	-0.01	0.38	0.34	0.55	0.47	0.70	0.34	0.26	-0.98
International Correlations Corr(v_t, v_t^*)									
Output	0.61	0.74	0.77	0.37	0.68	0.44	0.77	0.82	0.64
Consumption	0.45	0.95	0.92	0.53	0.99	0.98	0.92	0.83	-0.19
Other Cross-Correlations									
Net exports – Dom. real interest	-0.18	-0.51	-0.41	0.48	-0.24	-0.33	-0.52	0.46	0.59
Nominal – Real exchange rate	0.97	1.00	1.00	1.00	0.96	0.99	0.99	1.00	1.00

Notes: **Parameters:** α: Degree of openness of the small open economy; ρ_{a,a^*}: International correlation of productivity shocks; η: Elasticity of substitution between domestic and foreign goods; σ: Coefficient of risk aversion; φ: Inverse of labor supply elasticity; Ξ: Trade costs; "G3+Risk+Trade": $\alpha = 0.19$ and $\rho_{a,a^*} = 0.53$ according to"G3" data, $\sigma = 5$ as in the risk averse case, and $\Xi = 0.572$. **Data:** arithmetic averages of logged, HP-filtered data of Germany, Japan and the U.K. (the "G3") relative to the U.S. from 1973:I till 1994:IV, as reported in Kollmann (2001, p. 254). Exceptions: The international correlations are based on logged, HP-filtered data from 1070:I till 1990:II, reported in Backus et al, (1995, p. 336), "G3"-averaged; the correlation between net exports and the domestic real interest rate is taken from OR (2000*b*, p. 57), based on annual data from 1978 till 1998 for 20 OECD countries. For comparison we report their "Specification 2", where the real interest rate is obtained by use of the contemporaneous CPI inflation. While we find it more intuitive to think of the relation between net exports and the real interest rate spread, we use this notation for comparison reasons (for the real interest spread, model results of 500 simulations are: -0.54, -0.49, 0.54, -0.51, -0.47, -0.51, 0.49, 0.59). The model data is obtained by HP-filtered, frequency domain based calculation of moments.

4.7 Discussion

We have seen that the basic model already does well in explaining the home biases in consumption and in equity portfolio with the help of a home bias in preferences parameter in the utility function. The introduced trade costs work in the same direction, so the question arises whether both arguments together result in too high biases. We suppose it is difficult to estimate a preference parameter or to test the hypothesis H_0: $\alpha > 0$ against H_1:$\alpha = 0$. And for the trade costs parameter Ξ "anything goes" if we argue that only traded goods exist – with more or less trade costs.

As the sensitivity analysis showed, we have no robust negative correlation of net exports with the domestic real interest rate or the real interest spread, as would be necessary to reproduce the findings of table two in OR (2000*b*). Instead, the result depends on the degree of openness or the value of the trade costs parameter Ξ. The change in the sign is due to the absolute degree of the frictions in international trade, defined as home bias in preferences parameter $\alpha/(1-\alpha)$, and trade costs Ξ.
To solve the international consumption correlation puzzle, the sensitivity analysis showed that essentially Ξ, α and ρ_{a,a^*} play the central roles. The (international) elasticity of substitution η is in this setup not that effective as one might think reading the OR (2000*b*) paper. In section 3.5.4 we saw the result we long for, but only in a setting that cannot be called conventional.

For the exchange rate puzzles we see that the two trade frictions ($\alpha/(1-\alpha)$ and Ξ), a low productivity correlation, and a high risk aversion can raise the volatility (the volatility dimension of the PPP puzzle), but only in the U.K. case and for high risk aversion the nominal exchange rate varies significantly more than the other macroeconomic variables (the volatility dimension of the "disconnect" puzzle). Interestingly, in the U.K. case the degree of openness α accounts for less exchange rate volatility as the productivity correlation ρ_{a,a^*}. For $\sigma = 5$ and productivity completely uncorrelated, the real exchange rate varies about 1.62 percent. Putting together these four pieces, one can get any volatility seen in the data, but with the wrong output correlation pattern we saw already in the risk averse parameterization of section 4.3. The autocorrelation of the exchange rates (the correlation dimension of the PPP puzzle) is not affected by any changes and stays at the quite acceptable value of the basic model. The results for the correlation dimension of the "disconnect" puzzle are poor: only for trade costs equal to 50 percent we see a sizeable reduction of correlation with output.

5 Summary and Conclusion

Can the New Keynesian Open Economy Models explain the Six Major Puzzles in International Macroeconomics, as documented in OR (2000*b*)? We have addressed this question on the basis of the model by GM (1999, 2002, 2003). We found that the model does well along the two home bias puzzles (in goods and in equity portfolio; puzzles 1 and 3) with the help of the degree of openness α, understood as a function of a home bias in preferences parameter. The result for the correlation of investment and savings observed by Feldstein and Horioka (1980; puzzle 2) is addressed only indirectly through the sign in the coefficient of the correlation between net exports and the real interest rate spread – as proposed by OR (2000*b*). This coefficient is negative as predicted and shown by Obstfeld and Rogoff,[75]. But still, we take this finding with a grain of scepticism.[76] The fourth puzzle, the low international consumption correlation, cannot be solved with the basic model, where consumption was nearly perfectly correlated in both economies. For the last two puzzles about "the real effects of a nominal variable" [77] we found that the model is able to produce exchange rate persistency that is consistent with the data. But it can neither reproduce the factual exchange rate volatility. Nor can it reproduce the clear "disconnect" with macroeconomic fundamentals.

The effect of trade costs on the model's behavior along the lines of the six puzzles is a positive one, but in general not that big. The Feldstein-Horioka correlation coefficient becomes slightly more significant. The international consumption correlation is reduced, but the coefficient is still beyond 0.9. The exchange rate behavior concerning the volatility and the correlation with output becomes better, but is not solved. A complete "disconnect" is far from being valid in this model.

We then explored the robustness of our findings – or, to put it in other words, we looked at some parameter values which might change the model for the better – or the worse. For the Feldstein-Horioka puzzle we found that our first result holds only as long as the frictions in international trade, i.e., the home bias in preferences and trade costs, do not get too large. For large frictions the result turns around and shows the wrong sign.[78] The low international consumption correlation remains difficult to address. In most of the settings, consumption is by far more correlated internationally than output. But as shown in section 3.5.4 and in principle again in section

[75] OR (2000*b*), pp. 13-20 and table 2 on p. 57.

[76] Using different monetary policy rules like CPI-inflation targeting or an exchange rate peg seems to reverse the result.

[77] OR (2000*b*), p. 33.

[78] See sections 4.1 and 4.5.

4.5, we found that it is possible to reproduce the low consumption correlation with either extremely high trade costs (more than 50 percent) and a moderate home bias in preferences, or with a large home bias in preferences ($\alpha/(1-\alpha=0.1)$, e.g.) and "moderate" trade costs of 25 percent. Whether this values are reasonable is still to proof.

The behavior of the exchange rates in this model crucially depends on four parameters. A high risk aversion coefficient leads to an increase in exchange rate volatility as in the model by Chari et al. (2001), but still the elasticity is not big enough. A low international correlation of productivity shocks and high trade costs have the same result. A low degree of openness α, along the argument by Hau (2001), that less open economies have higher exchange rate volatility, works in the same direction. Together these four ingredients can account for the observed high volatility of the real exchange rate. It is worth mentioning that in contrast to Chari et al. (2001) or Kollmann (2001) our model is only based on technology shocks as driving force. We did not include monetary shocks as Chari et al. (2001), shocks to the foreign price level or to the foreign interest rate as Kollmann (2001), shocks to the uncovered interest parity as Kollmann (2002), or demand shocks as Benigno and Benigno (2000) or Monacelli (2000). And we did not engage any frictions to the law of one price, as do Betts and Devereux (1996 and 2000), OR (2000*a*) or Monacelli (2002), to mention a few. But even if our underlying parameter values were reasonable, the exchange rate disconnect puzzle, especially its correlation dimension, cannot be solved in this setting.

So the answer to our question posed at the beginning has to be: New Keynesian Models – as far as it is possible to address a whole class of models with just one example – *can* explain the six puzzles.[79] But they cannot – yet – explain them simultaneously. And they have to use parameter values which are not always standard. But perhaps such parameter values could be avoided if there were something like a set of canonical frictions. We take the view that sticky prices as well as trade costs ought to be included in this set.

[79] Here we should note one exception: the low correlation of the real exchange rates cannot be found in this model. But there are models which state that they solve this puzzle; see e.g. Devereux and Engel (2002), which along the argument of Mankiw and Romer (1991) can be called without doubts a New Keynesian Model.

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