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

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Executive Summary

In this paper, we analyze the quantitative features of a New Keynesian Open Economy Model as an example of its class. We focus especially on six puzzles in international macroeconomics explained by Obstfeld and Rogoff (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.

We find that the *small open economy* model by Galí and Monacelli (2002) can easily explain puzzles (1) and (3) with the help of a "degree of openness" parameter, which can be seen as closely related to a home bias in preferences parameter as mentioned in Obstfeld and Rogoff (2000*b*). The results for the investment-savings puzzle, addressed according to Obstfeld and Rogoff through the relation between the current account and the real interest rate, depend on the monetary policy assumed for the small open economy, with only domestic inflation targeting being able to reproduce the negative relation between net exports and the real interest rate in the basic calibration. Apart from the exchange rate persistence the model cannot reproduce puzzles (4) to (6).

The introduction of trade costs leads to an improvement 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) still depends on the monetary policy chosen, it is now possible to address also the last three puzzles. For 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, we need a high risk aversion as do Chari et al. (2001) in their model. Second, trade costs have to be more than 50 percent. Third, the import share on GDP (the model's parameter α) has to be low, according to 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"). Fourth, the international correlation of productivity has to be not more than about 50 percent, as again holds for the "G3". 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.

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Chapter 1

Introduction

Can the New Keynesian Open Economy Models explain the "Six Major Puzzles in International Macroeconomics", as documented in Obstfeld and Rogoff (2000*b*)?
This question is the motivation of our analysis. As we are at the beginning, we should define what is meant by that kind of models and by the six puzzles. In the introduction of the first "New Keynesian Economics" volume, N. Gregory Mankiw and David Romer give two questions that a New Keynesian will answer with an "emphatic yes":

> Does the theory violate the classical dichotomy? Does it posit that fluctuations in nominal variables like the money supply influence fluctuations in real variables like output and employment?
>
> Does the theory assume that real market imperfections in the economy are crucial for understanding economic fluctuations? Are such considerations as imperfect competition, imperfect information, and rigidity in relative prices central to the theory?[1]

Thus, a model with sticky prices and imperfect competition at its core can be called New Keynesian. If it furthermore includes more than one country, with at least one country influencing the other, it can be called an Open Economy Model. And if it also takes stock of the developments in dynamic, stochastic general equilibrium models that researchers have made, and even uses the "language" in which these models are written, it can truly be called a New Keynesian Open Economy Model.
What are "The Six Major Puzzles in International Macroeconomics", as Obstfeld and Rogoff (2000*b*) formulate?

Consumers particularly like buying products that were made in their home country. Why is that? Shouldn't we rather see full diversification in consumption? The fact that we do not see this outcome has been given the

[1] Mankiw and Romer (1991), p. 2.

name home bias in trade (Puzzle 1). When the residents of one country decide to save more, will this imply that investment in that country rises by the same degree? They could invest abroad, e.g., if the interest rate is higher there. But, in fact investments and savings are highly correlated, as Feldstein and Horioka (1980) found out: the Feldstein-Horioka puzzle (Puzzle 2). Taking the home country's market share in the world equity market as the natural rate at which agents should hold home equity to fully diversify their risk, we observe a distinct and puzzling home bias in equity portfolio: individuals tend to buy much more domestic than foreign equity (Puzzle 3). As another question of risk sharing, suppose you live near a big river and you know that a flood might hurt you. Since you like to consume roughly the same amount of goods every week, you would like to share your risk with others abroad to be able to smooth consumption. But the strange empirical finding is that consumption is internationally not very much correlated, even less than output: the international consumption correlation puzzle (Puzzle 4). We know how many Euros we have to take with us to go out for dinner in Berlin. But we do not know whether this amount of money, exchanged in Real, is enough to eat out in Rio de Janeiro. Since this uncertainty holds for the whole consumption basket, and since a difference in prices across countries does not vanish very fast, we have a purchasing power parity (PPP) puzzle: the real exchange rate is *a*) volatile and *b*) very persistent (Puzzle 5). Finally, the real exchange rate seems to be disconnected from basically any other macroeconomic aggregate in that it has *a*) a singularly high volatility and *b*) near zero correlations with nearly all other variables: the exchange rate disconnect puzzle (Puzzle 6).

These six puzzles will be addressed with the help of a New Keynesian Open Economy Model to see whether or not the model, and thereby perhaps the whole class of models, can reproduce the puzzling data – as well as some other features a good model should have. We see that puzzles one to three and 5*b*) can be reconciled quite well by the model, whereas puzzles four and six cannot.

To get improvements in these cases, we introduce trade costs, as Obstfeld and Rogoff (2000*b*) propose in their paper. We then explore how far trade costs can improve the properties of the model and how robust the obtained results are. We find out that it is in principle possible to solve all puzzles except the near zero correlations of the real exchange rate. But it is not possible to solve them all simultaneously. And the solutions of the international consumption correlation puzzle and to the exchange rate volatility are not very robust, have some counterfactual correlation properties, and need parameter values that are (up to now) not standard.
At the end, we summarize what we have found and draw a conclusion.

Chapter 2

The Six Major Puzzles in International Macroeconomics

Closed economies are unknown in real life. Every economy interacts with its neighbors, and in the era of globalization with a rising degree. Since the international interactions between economies become more and more important, there is a necessity to have models that can help to analyze these features. The extension of common closed economy macroeconomic models to so called *open economy* models has lead to many new insights, but at the same time to new challenges. The usual type of model consists of two economies interacting with each other. Sometimes the interaction is mutual, sometimes one very large economy is hardly influenced by another small economy. In both cases, economists have to deal with a doubled vector of the usual macroeconomic variables. Moreover, new variables, defined by a composition of each country's vector of variables have to be added: net exports, nominal and real exchange rates, the terms of trade. Observing the real time series data – most economists use data of the major economies in North America and Europe after World War II or after the Bretton Woods system – and its variances, cross- and autocorrelations, one can compare them to the values expected from standard theory extended to the two country case. To some extent this gives rise to confirmation of theory, to some extent it does not. Especially the latter cases increase the knowledge of how economies work and interact; so attention is drawn to them.

In an overview article, Obstfeld and Rogoff (2000*b*) reviewed six cases, where the data does not confirm theory, or – the other way round – theory cannot thoroughly explain the data. As Engel (2000) mentions in a comment to this article, some of these cases are closely intertwined such that they could be referred to as a single problem. But for clarity reasons, and to be

able to address and distinguish each single problem we stick to the Obstfeld and Rogoff (2000*b*) nomenclature. They state the following “Six Major Puzzles in International Macroeconomics”:
Puzzle 1: People consume much more home products than products from abroad. Puzzle 2: Savings and investment are closely correlated, as if the economies were closed. Puzzle 3: People invest mostly in domestic assets rather than distributing wealth equally. Puzzle 4: Despite the possibility of risk sharing, consumption is not highly correlated across countries. Puzzle 5: The real exchange rate is highly persistent. Puzzle 6: Both, nominal and real exchange rates are highly volatile. They are not significantly correlated with other macroeconomic variables. In the following, these puzzles will be laid out in detail and compared to similar findings by others.

2.1 The Home Bias in Trade Puzzle

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.[1]

2.2 The Feldstein-Horioka Puzzle

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 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

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

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.

2.3 The Home Bias in Equity Portfolio Puzzle

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.[2] 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.[3] 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.

2.4 The Low International Consumption Correlation Puzzle

A typical individual likes to consume an equal amount of goods every period, resulting in a smooth consumption function. Thus, she seeks to minimize the effects of idiosyncratic risk on income: pooling risk with others reduces the burden of a sudden negative surprise, inter-individually as well as internationally. 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.[4] 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[5] is internationally less correlated than output. They call this puzzle "the consumption/output/productivity anomaly, or the quantity anomaly".[6]

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

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

[4] Obstfeld and Rogoff (1996), p. 291; data from 1973 to 1993.

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

[6] Backus, Kehoe and Kydland (1995), p. 343.

2.5 The Purchasing Power Parity Puzzle

> The central puzzle in international business cycles is that fluctuations in real exchange rates are volatile and persistent.[7]

To understand how negative these features of the real exchange rate are for standard economic thinking, let us start with basic ideas. At first glance a theorist may argue that a product should sell at the same price (in some base currency) all over the world: just exchange your money to the local currency, remember the exchange rate and you will know the price of all the worldwide common products. Formally, the price of a good in one currency equals its price in another currency, times the nominal exchange rate:
$P_{i,t} = P^*_{i,t}\mathcal{E}_t$.
The failure of this Law of One Price (LOP) can be easily shown: the standard textbook example is a certain food sold in standardized stores around the world.[8] Aggregating over all prices to get a price index, one can apply the same argument to the aggregate. The theory of absolute Purchasing Power Parity (PPP) is based on the Law of One Price. It states that the real exchange rate is equal to unity or tends to unity in the long run:
$\mathcal{Q}_t = (P^*_t\mathcal{E}_t)/P_t = 1$.
Clearly, there are some costs influencing this relation: one has to pay the bank to exchange the money, or the McDonald's gimmicks have to be shipped to Malaysia (or from Malaysia to us). Allowing for market frictions like transport costs etc., relative PPP states that changes in price levels of different countries level off at least after some time of convergence. Inspite of evidence for relative PPP in the long run, it remains unclear why the real exchange rate is highly persistent. The autocorrelation of the real exchange rate $\mathrm{Corr}(\log(\mathcal{Q}_t), \log(\mathcal{Q}_{t-1}))$ is about 0.85.[9] Though there are some differences in the absolute value of the autocorrelation due to the periodicity of the underlying data,[10] 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.[11] 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.

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[7]Chari et al. (2001), p. 35.

[8]In 1998 the price for a Big Mac was ranging between 1.16 USD in Malaysia and 3.87 USD in Switzerland, compared to 2.56 USD in its home country; see Krugman and Obstfeld (2000*b*), p. 409, as well as Mankiw (2001), pp. 675-676. More sophisticated textbooks also compare some other goods, e.g., Burda and Wyplosz (1997), p. 208.

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

[10]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.

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

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?"[12] The causes for the high persistence of the real exchange rate have not found a thorough explanation, yet.

2.6 The Exchange Rate Disconnect Puzzle

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 for the volatility of other macroeconomic variables."[13] 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,[14] 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.[15] 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.

[12] Rogoff (1996), p. 647.
[13] Devereux and Engel (2002), p. 4.
[14] See e.g. Obstfeld and Rogoff (1996), pp. 622-624.
[15] Obstfeld and Rogoff (1996), p. 624.

Chapter 3

New Keynesian Open Economy Models

New Keynesian or – as Goodfriend and King (2001) call them – New Neoclassical Synthesis models combine the Keynesian thinking of incomplete markets and nominal rigidities with the "positive technology shock" which Real Business Cycle theory and its foundation of macroeconomics in microeconomic decision taking was for all economists. In the words of Clarida, Galí and Gertler (1999):

> In particular, we wish to make clear that we adopt the Keynesian approach of stressing nominal price rigidities, but at the same time base our analysis on frameworks that incorporate the recent methodological advances in macroeconomic modeling (hence the term "New").[1]

The expansion of micro-founded sticky prices models to the open economy case is rather young. Its beginnings are seen in Svensson and van Wijnbergen (1989) or even in Obstfeld and Rogoff (1995).[2] The main building block of New Keynesian open economy models is a forward looking type of a Phillips curve, determining current inflation by expected future inflation and some function of current output. This aggregate relation is referred to as "New Keynesian Phillips Curve" (NKPC).[3] The modeling of sticky prices in many papers follows Calvo (1983), who explained his approach to capture the fact of noncontinuous, non-synchronous price changes by the assumption "that each price-setter (or firm) is allowed to change his price whenever a random signal is 'lit up'."[4] While the so called Calvo pricing clearly lacks the statement of the firms' rationale to change prices, like it is given in the

[1] Clarida, Galí and Gertler (1999), p. 1662.

[2] See Lane (2000) for a survey of this literature, although with more attention to monetary policy shocks. Another survey article is written by Sarno (2000).

[3] See Woodford (2002), chapter 3, pp. 51-52.

[4] Calvo (1983), p. 383.

"menu costs" approach, it has the strong advantage of being easy to handle: "aggregating the decision rules of firms that are setting prices on a staggered basis is cumbersome."[5] In the following, a model built by Galí and Monacelli will be laid out as an example of New Keynesian Open Economy Models. To justify our model choice, we refer to McCallum and Nelson (2001), who call the Galí and Monacelli model a "standard" model that they use as a benchmark with which to compare their own model.[6]

3.1 The Galí and Monacelli (2002) Model

The model by Jordi Galí and Tommaso Monacelli was first presented in 1999 and recently published under the title "Monetary Policy and Exchange Rate Volatility in a Small Open Economy".[7] Although it focuses on the implications of different monetary policies, it nonetheless inhibits all major features of this class of models.

3.1.1 Households

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:

$$E_0 \sum_{t=0}^{\infty} \beta^t [U(C_t) - V(N_t)] \ , \tag{3.1}$$

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

$$C_t = \left[(1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \ . \tag{3.2}$$

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

[5] Clarida, Galí and Gertler (1999), p. 1666; see also King and Wolman (1996), p. 10. For a critique on this kind of staggering structure see Blanchard and Fischer (1989), p. 399, as well as Chari et al. (2001), p. 36: "Simply assuming that firms cannot change their prices [...] is somewhat unappealing."

[6] McCallum and Nelson (2001), p. 10.

[7] The earlier version under the title "Optimal Monetary Policy and Exchange Rate Volatility in a Small Open Economy" differed from the 2002 version as to the policy rules analyzed: in 1999 there were an optimal rule, a Taylor rule and an exchange rate peg, whereas the 2002 version has Domestic inflation targeting (which is optimal under some assumptions), CPI inflation targeting (which corresponds to a Taylor rule without reaction to output changes) and a peg. Furthermore, the 2002 version provides a section on welfare.

η is the elasticity of substitution between domestic and foreign goods. The budget constraint for each period t is

$$\int_0^1 [P_{H,t}(i)C_{H,t}(i) + P_{F,t}(i)C_{F,t}(i)]di + E_t\{Q_{t,t+1}D_{t+1}\} \leq D_t + W_t N_t + T_t \ , \tag{3.3}$$

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.

3.1.2 Some Identities

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

$$P_t \equiv [(1-\alpha)P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta}]^{\frac{1}{1-\eta}} \ , \tag{3.4}$$

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

$$P_{j,t} \equiv \left(\int_0^1 P_{j,t}(i)^{1-\varepsilon} di\right)^{\frac{1}{1-\varepsilon}} \quad \forall j \in \{H, F\} \ . \tag{3.5}$$

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 $\pi_{H,t} \equiv \log(P_{H,t}) - \log(P_{H,t-1})$.[8] For the world economy it follows from above that $\pi_{F,t}^* = \pi_t^*$.
Three exchange rates will be used in the model: the (log) *terms of trade* s_t, defined as the price of foreign goods in terms of home goods, given by

$$s_t = \log(\mathcal{S}_t) \equiv \log(P_{F,t}) - \log(P_{H,t}) = p_{F,t} - p_{H,t} \ , \tag{3.6}$$

the (log) *nominal exchange rate* e_t as the price of foreign currency in terms of home currency,

$$e_t = \log(\mathcal{E}_t) \equiv \log(P_{F,t}) - \log(P_{F,t}^*) = p_{F,t} - p_{F,t}^* \ , \tag{3.7}$$

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

and the (log) *real exchange rate* q_t, obtained through division by the price levels,

$$q_t = \log(\mathcal{Q}_t) \equiv e_t + \log(P_t^*) - \log(P_t) = e_t + p_t^* - p_t \ . \tag{3.8}$$

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 (3.4)as

$$p_t = p_{H,t} + \alpha s_t \quad \text{and, following from that,} \quad q_t = (1-\alpha)s_t \ . \tag{3.9}$$

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

$$r_t - r_t^* = E_t\{\Delta e_{t+1}\} \ . \tag{3.10}$$

3.1.3 Firms

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

$$y_t = n_t + a_t \ . \tag{3.11}$$

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 $MC_t^n = (1-\tau)W_t/A_t$. Since firms have market power in this model, prices are set higher than marginal costs, with a markup. 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. So firms set their prices in such a way that for the expected duration of the price the current value is maximized. As shown in appendix A.1, the log-linear price setting rule is

$$\overline{p}_{H,t} = \mu + (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k E_t\{mc_{t+k}^n\} \ , \tag{3.12}$$

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] Firms in the rest of the world face an analogous situation; their productivity evolves according to $\log(A_t^*) = a_t^* = \rho_a^* a_{t-1}^* + \epsilon_t^*$.

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

3.2 Analysis

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:

$$C_{j,t}(i) = \left(\frac{P_{j,t}(i)}{P_{j,t}}\right)^{-\varepsilon} C_{j,t} \quad \forall j \in \{H, F\} \tag{3.13}$$

within each country, and for total consumption:

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \quad \text{and} \quad C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t \ . \tag{3.14}$$

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

$$C_t^{\sigma} N_t^{\varphi} = \frac{W_t}{P_t} \tag{3.15}$$

and a typical Euler equation:

$$\beta R_t E_t\left(\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{P_t}{P_{t+1}}\right)\right) = 1 \ . \tag{3.16}$$

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

$$w_t - p_t = \sigma c_t + \varphi n_t \quad \text{and} \quad c_t = E_t\{c_{t+1}\} - \frac{1}{\sigma}(r_t - E_t\{\pi_{t+1}\} - \rho) \ . \tag{3.17}$$

It should be noted that, as we only took logarithms, β in (3.16) still remains, whereas in a log-linearization around the steady state β and, thereby, ρ drop out of the equation.[10] Nevertheless, in a situation close to the steady state this term is negligible. Equation (3.16) and its world analog[11] can be combined and iterated to get a relation for consumption in both economies:

$$C_t = \vartheta C_t^* \mathcal{Q}_t^{\frac{1}{\sigma}} \ , \tag{3.18}$$

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

$$c_t = c_t^* + \left(\frac{1-\alpha}{\sigma}\right) s_t \ . \tag{3.19}$$

[10] 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.

[11] 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.

3.2.1 Equilibrium

Since the "rest of the world", or in short, the world economy, is very huge, the influence of the small open economy's products on consumption in the world economy is thought of as negligible. So we can denote market clearing in the world economy by $y_t^* = c_t{}^*$. As the consumption Euler equation (3.17) symmetrically holds for the world economy, we can use it to get

$$y_t^* = E_t\{y_{t+1}^*\} - \frac{1}{\sigma}(r_t^* - E_t\{\pi_{t+1}^*\} - \rho) \ . \tag{3.20}$$

For the small open economy, an analog can be achieved in four steps, whose details are given in appendix A.2: first, relate domestic output to world output and the terms of trade,

$$Y_t = \vartheta Y_t^* \mathcal{S}_t^{\eta} \left((1-\alpha)\mathcal{Q}_t^{\frac{1}{\sigma}-\eta} + \alpha \right) \ . \tag{3.21}$$

Secondly, log-linearize to get

$$y_t = y_t^* + \frac{\omega_\alpha}{\sigma} s_t \ , \tag{3.22}$$

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

$$c_t = \Phi_\alpha y_t + (1-\Phi_\alpha) y_t^* \ , \quad \Phi_\alpha \equiv \frac{1-\alpha}{\omega_\alpha} > 0 \ . \tag{3.23}$$

And fourthly, take the consumers' Euler equation and replace consumption with (3.23). The result of this procedure is the following dynamic equation for domestic output:

$$y_t = E_t\{y_{t+1}\} - \frac{\omega_\alpha}{\sigma}(r_t - E_t\{\pi_{H,t+1}\} - \rho) + (\omega_\alpha - 1)E_t\{\Delta y_{t+1}^*\} \ . \tag{3.24}$$

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:

$$nx_t = y_t - c_t - \alpha s_t = (1-\Phi_\alpha)(y_t - y_t^*) - \alpha s_t = \frac{\alpha\Lambda}{\omega_\alpha}(y_t - y_t^*) \ , \tag{3.25}$$

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

$$\pi_{H,t} = \beta E_t\{\pi_{H,t+1}\} + \lambda(mc_t + \mu) \quad \text{and} \quad \pi_t^* = \beta E_t\{\pi_{t+1}^*\} + \lambda(mc_t^* + \mu) \ , \tag{3.26}$$

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 3.1.3 that - as

$MC_t^n = MC_t P_{H,t}$ - the (log) real marginal costs of the small open and the world economy are

$$mc_t = -\nu + w_t - a_t - p_{H,t} \quad \text{and} \quad mc_t^* = -\nu^* + w_t^* - a_t^* - p_t^* \ , \qquad (3.27)$$

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 (3.11), the consumer's intratemporal optimality condition (3.17), the first equation in (3.9) and (3.22) to substitute out s_t this can be rewritten just in terms of output and a productivity process:

$$mc_t = -\nu + \left(\frac{\sigma}{\omega_\alpha} + \varphi\right) y_t + \sigma \left(1 - \frac{1}{\omega_\alpha}\right) y_t^* - (1+\varphi) a_t \ , \qquad (3.28)$$

$$mc_t^* = -\nu^* + (\sigma + \varphi) y_t^* - (1+\varphi) a_t^* \ . \qquad (3.29)$$

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 $mc_t = mc_t^* = -\mu$.[12] 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

$$\overline{y}_t = \Omega_\alpha + \Gamma_\alpha a_t + \Theta_\alpha y_t^* \quad \text{and} \quad \overline{y}_t^* = \Omega_0 + \Gamma_0 a_t^* \qquad (3.30)$$

with the use of (3.28). Here, $\Omega_\alpha \equiv \frac{\omega_\alpha(\nu-\mu)}{\sigma+\omega_\alpha\varphi}$, $\Gamma_\alpha \equiv \frac{\omega_\alpha(1+\varphi)}{\sigma+\omega_\alpha\varphi}$, $\Theta_\alpha \equiv \frac{\sigma(1-\omega_\alpha)}{\sigma+\omega_\alpha\varphi}$, $\Omega_0 \equiv \frac{\nu^*-\mu}{\sigma+\varphi}$ and $\Gamma_0 \equiv \frac{1+\varphi}{\sigma+\varphi}$.[13] Solving (3.28) 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 (3.26), we get an equation for both economies, linking inflation and output gap

$$\pi_{H,t} = \beta E_t\{\pi_{H,t+1}\} + \kappa_\alpha \tilde{y}_t \ , \qquad (3.31)$$

$$\pi_t^* = \beta E_t\{\pi_{t+1}^*\} + \kappa_0 \tilde{y}_t^* \ , \qquad (3.32)$$

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

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

[13] For the implementation of the model in Matlab®, it should be noted that Ω_α is equal to zero for $\nu = \mu$ and Ω_0 for $\nu^* = \mu$. Since the fiscal authority will be assumed to act optimally, it will rule out the distortions through market power. As Galí and Monacelli (2002), pp. 22-23, show, this implies $\nu^* = \mu$ for the world and $\nu = \mu + \log(1-\alpha)$ for the small open economy. 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.

before.[14] Applying (3.24) to the small open economy's NKPC we get

$$\tilde{y}_t = E_t\{\tilde{y}_{t+1}\} - \frac{\omega_\alpha}{\sigma}(r_t - E_t\{\pi_{H,t+1}\} - \overline{rr}_t) \tag{3.33}$$

with $\overline{rr}_t \equiv \rho - \frac{\sigma(1+\varphi)(1-\rho_a)}{\sigma+\omega_\alpha\varphi} a_t - \varphi\Theta_\alpha E_t\{\Delta y^*_{t+1}\}$, and for the world economy the NKPC is derived with the help of (3.20) as

$$\tilde{y}^*_t = E_t\{\tilde{y}^*_{t+1}\} - \frac{1}{\sigma}(r^*_t - E_t\{\pi^*_{t+1}\} - \overline{rr}^*_t) \ , \tag{3.34}$$

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 a rule for monetary policy the model is now complete.

3.2.2 Monetary Policy Rules

Throughout the analysis we assume the monetary policy of the world economy to be optimal. Therefore, we have a fully stable world output gap and world inflation rate. So we can set them to zero: $\tilde{y}^*_t = \pi^*_t = 0$.
This drives the world interest in (3.32) to its natural level, such that we get

$$r^*_t = \rho - \sigma(1-\rho^*_a)\Gamma_0 a^*_t \ . \tag{3.35}$$

The authority for monetary policy in the small open economy may choose between three kinds of policy: it could aim at stabilizing the domestic goods inflation, in short domestic inflation targeting (DIT), it could aim at stabilizing CPI inflation (CIT) or it could become a member of a monetary union with the "rest of the world", i.e., it could peg the exchange rate to the world currency (PEG). It is assumed that the authority can act credibly, in a way expectations of the consumers are in line with the policy goal.

Domestic Inflation Targeting

With zero domestic inflation for all periods, $\pi_{H,t} = 0 \quad \forall\, t$, there is no output gap in the small economy. So from (3.33) it follows that the interest rate is at its natural level, i.e.,

$$r_t = \overline{rr}_t \quad \forall\, t \ . \tag{3.36}$$

From the definitions of the exchange rates and the *terms of trade* it follows that

$$e_t = s_t = \frac{1}{1-\alpha} q_t = \frac{\sigma(1+\varphi)}{\sigma+\omega_\alpha\varphi}(a_t - a^*_t) \ , \tag{3.37}$$

[14] See Galí and Monacelli (2002), pp. 13-14.

where the last equality comes from (3.22) and (3.30). Since domestic and world prices are constant, it follows from (3.9) that the domestic CPI price level is given by

$$p_t = \alpha e_t = \frac{\alpha\sigma(1+\varphi)}{\sigma+\omega_\alpha\varphi}(a_t - a_t^*) \ . \tag{3.38}$$

To be able to calculate impulse responses using (3.36) as policy rule one has to cope with the problem of indeterminacy: inserting (3.36) in (3.33), 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 (3.36), where we 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.[15]

CPI Inflation Targeting

Stabilizing the consumer price index means seeking to have $\pi_t = 0 \quad \forall\, t$. Setting $p_t = p_t^* = 0$, which will not change the results qualitatively, we get

$$p_{H,t} = -\alpha s_t \ . \tag{3.39}$$

This result can be used with (3.22) and (3.28) to derive a second order stochastic difference equation in $p_{H,t}$:

$$\gamma_c p_{H,t} = p_{H,t-1} + \beta E_t\{p_{H,t+1}\} - \lambda(1+\varphi)(a_t - a_t^*) \ , \tag{3.40}$$

with $\gamma_c \equiv 1+\beta+\frac{\lambda}{\alpha}(1+\frac{\varphi\omega_\alpha}{\sigma})$. Assuming equality between the autocorrelation of domestic and world productivity shock,[16] the difference equation has the solution

$$p_{H,t} = \xi_c p_{H,t-1} - \zeta_c(a_t - a_t^*) \ , \tag{3.41}$$

where ξ and ζ remain to be explained: $\xi_c \equiv \frac{1}{2\beta}(\gamma_c - \sqrt{\gamma_c^2 - 4\beta})$, $\zeta_c = \frac{\lambda\xi_c(1+\varphi)}{(1-\xi_c\beta\rho_a)}$. For the remaining variables of interest it follows from (3.9) and the definitions before that

$$e_t = q_t = -\frac{1-\alpha}{\alpha} p_{H,t} \ . \tag{3.42}$$

An Exchange Rate Peg

An exchange rate peg is in this model equal to a monetary union, where the small open economy completely follows the monetary policy of the world economy. The monetary policy authority uses its only instrument, the interest rate, to have the nominal exchange rate constant (for simplicity, it can be set to zero). This implies that the domestic interest rate one-to-one

[15] See Galí (2001), pp. 22-23. In fact, the restrictions for positive ϕ_π and ϕ_y have to be such that $\kappa_\alpha(\phi_\pi - 1) + (1-\beta)\phi_y > 0$.

[16] This will also be assumed later on in the impulse responses.

follows the world interest rate. For the price levels, the real exchange rate and the terms of trade we get the relations

$$p_t = -q_t = (1-\alpha)p_{H,t} = -(1-\alpha)s_t \ , \tag{3.43}$$

which follows again from (3.9) and the definitions before. $p_{H,t}$ is derived in the same way as in the CIT case via

$$\gamma_e p_{H,t} = p_{H,t-1} + \beta E_t\{p_{H,t+1}\} - \lambda(1+\varphi)(a_t - a_t^*) \ , \tag{3.44}$$

and has a very similar stationary representation given by

$$p_{H,t} = \xi_e p_{H,t-1} - \zeta_e(a_t - a_t^*) \ , \tag{3.45}$$

now with $\gamma_e \equiv 1 + \beta + \lambda(1 + \frac{\varphi\omega_\alpha}{\sigma})$,[17] $\xi_c \equiv \frac{1}{2\beta}(\gamma_e - \sqrt{\gamma_e^2 - 4\beta})$ and $\zeta_e = \frac{\lambda\xi_e(1+\varphi)}{(1-\xi_e\beta\rho_a)}$.

3.2.3 Calibration and Implementation

To calibrate the model there are two possible routes we could take. The first one is to use the parameter values given by Galí and Monacelli (2002, pp. 18-19), to see if we implemented the model in the right way. On the second route we look for the parameter values most probable and maybe use some more standard parameter values than Galí and Monacelli (2002), especially for the productivity processes. On this route we can be more sure that the results of our quantitative investigation are not biased by the chosen parameter values. We will sketch where the first route leads to, and then proceed on the second.

Galí and Monacelli (2002) set the standard deviation of productivity such that output varies with $\sigma_y = 2\%$.[18] As we read their paper, they use unfiltered series, so using their calibration given in table B.7 in the appendix, and switching off the Hodrick-Prescott filter (by setting `DO_HP_FILTER=0`) in the Matlab® program replicates their results.[19] This is already done in the file `GM_final.m` on the CD-ROM in appendix D.

To follow the second route, we will make some slight changes. 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

[17] I.e., γ_e is a bit smaller than γ_c because of the missing coefficient α in the denominator.

[18] See Galí and Monacelli (2002), p. 19.

[19] See Galí and Monacelli (2002), table 1 (for both shocks) and figure 1, as well as Galí and Monacelli (1999), figures 1, 2, and 5 to 8. Note, though, that there is a mistake in figure 1 of the (2002) version, where the real exchange rate impulse response for CIT is too high: it should behave as its nominal counterpart, according to (3.42).

the model with and without capital.[20] 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.[21] 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.[22] They calibrate their model on the basis of Cooley and Prescott (1995), with the standard technology shock variance $\sigma_\epsilon^2 = (0.007)^2$ and $\rho_a = 0.95$ as the autocorrelation of technology.[23] 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 values, which are aimed to reflect Canadian data,[24] will be held up.[25] 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 3.1.3. Also the Calvo sticky price parameter value of 0.75, i.e., price changes on average every year, are quite standard.[26] 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 Galí and Monacelli (2002, p. 18), who set η equal to unity, nor is it in line with Obstfeld and Rogoff (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 will come to this problem again in the sensitivity analysis in section 6.2.

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.[27] Yun (1996) calibrates his model with $1/\varphi = 1/4$ and $1/\sigma = 1$. Erceg

[20] Chari, Christiano, and Kehoe (1995), pp. 368-369 and 378.

[21] Schmitt-Grohé and Uribe (2001), pp. 10 and 12.

[22] McCallum and Nelson (2001), pp. 3-4.

[23] McCallum and Nelson (2001), table 1 on p. 9.

[24] See Galí and Monacelli (2002), p. 20.

[25] 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.

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

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

et al. (2000, p. 299) use 1.5 for σ, Cochrane calls values between one and two standard,[28] 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 Galí and Monacelli (2002), i.e., $1/\varphi = 1/3$ and $\sigma = 1$ and try out the effects of different values in the sensitivity analysis in sections 6.4 and 6.3. The parameterization chosen as a benchmark is given in table 3.1.

To calculate moments, impulse responses and simulations the model was implemented in the Matlab® Toolkit program as documented in Uhlig (1995). A basic model version in output gaps and inflation works with the use of (3.31),(3.32) and (3.33) together with the two productivity processes given in section 3.1.3. The model with 20 variables (π_H, π^*, y^*, r, $\tilde{y}^*$, p, p_H, nx, r^*, π, e, q, c, c^*, y, y^*, s, r^{CPI}, a, a^*)[29] is obtained with the following equations (or known facts), given in the used order:[30]

- For Domestic Inflation Targeting (DIT):
  (3.35), the definition of π_t, (3.37) twice for e_t and q_t, (3.23), the identity of world output and world consumption, both equations in (3.30) in connection with the definitions of the output gaps given before, (3.6), the definition of the real (CPI) interest rate r_t^{CPI}, (3.32), (3.34), (3.31), (3.33), (3.36) in connection with the definition of the natural rate of interest and (3.34), (3.38), the fact that domestic price changes are zero for DIT, and (3.25), together with the two productivity processes.

- For CPI Inflation Targeting (CIT):
  (3.35), the fact that CPI inflation is equal to zero for CIT, (3.42) twice, (3.23), the identity of world output and world consumption, both equations in (3.30) in connection with the definitions of the output gaps given before, (3.6), the definition of the real (CPI) interest rate r_t^{CPI}, (3.32), (3.34), (3.31), (3.33), the definition of the domestic goods inflation, the fact that the CPI price index can be normalized to zero, (3.41), and (3.25), together with the two productivity processes.

- For the Exchange Rate Peg (PEG):
  (3.35), (3.43) in differences to relate π_t and $\pi_{H,t}$, the fact that the nominal exchange rate changes are equal to zero for the peg, (3.43) for the real exchange rate, (3.23), the identity of world output and world consumption, both equations in (3.30) in connection with the definitions of the output gaps given before, (3.6), the definition of

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

[29] The unsystematic order is partly a result of the ordering principle for the Toolkit: first, the endogenous state variables are given, then the “other endogenous variables”, and finally the stochastic processes.

[30] The exact way of implementation is given in the Matlab® code in appendix C.1.

Table 3.1: 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
		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 Galí and Monacelli (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.

the real (CPI) interest rate r_t^{CPI}, (3.32), (3.34), (3.31), (3.33), the definition of the domestic goods inflation, the relation between p_t and $p_{H,t}$ from (3.43), (3.45), and (3.25), together with the two productivity processes.

The – maybe a bit strange looking – order of the equations has its explanation in the Toolkit procedure as explained in Uhlig (1995). First, the non-expectational equations are given, followed by the equations conditional on date t and the equations for the stochastic processes.[31] Some modifications of the equations were necessary to get rid of constant terms, since this solution method is not intended to cope with them. The (log) discount factor ρ in (3.17) and further on usually drops out of the Euler equation through log-linearization, so it is neglected here; the same applies to the Ω-constants in (3.30).[32]

3.3 Results

There are several paths to analyze the features of the model. We will begin with a comparison of the model's standard deviations, autocorrelations and cross-correlations with output, and the international co-movements with some data of the major OECD countries.[33] The results of the model, implemented in the file `GM_basic.m`, are given in three tables: table 3.2 for the domestic inflation targeting policy is given below, being representative of many cases. The results for CPI targeting and the exchange rate peg are given in tables B.3 and B.4 in the appendix. Then we draw attention to the effects of each of the two productivity impulses on the economies and thereby at the international co-movement of major macroeconomic variables. The impulse responses are again given in three figures, where the one for domestic inflation targeting is given in the text, while the other two are in the appendix.

3.3.1 Standard Deviations

Throughout the model's variables, we do not get enough volatility with the parameter values given in table 3.1. The volatility of domestic output, as given in table 3.2 for the DIT policy, table B.3 for CPI targeting (CIT), and table B.4 for the monetary union,[34] 0.94 percent, world output is with 0.93 percent only slightly less volatile. Domestic consumption as well as domestic

[31] In fact, for the implementation some endogenous variables had to be "redeclared" to be state variables, and some equations dated t and $t-1$ had to be "redeclared" to be expectational equations to have a system solvable with the Toolkit; see Uhlig (2002), p. 38, especially note 10 for that procedure.

[32] See the footnotes in the relevant sections 3.2 and 3.2.1 for further comments.

[33] If not mentioned, we will refer to HP-filtered data, as it is done in Backus et al. (1995).

[34] A comparison of all models' standard deviations is given in table B.1 in appendix B.1.

productivity are a bit less volatile. While the relative volatility of output, technology and consumption is confirmed by the data, the absolute value of the volatility is too low: between 1970:I and 1990:II output volatility was between 1.01 for Europe and 1.92 for the U.S., whereas consumption and technology varied between 0.8 and 1.7 percent.[35] Net exports are usually less volatile than output, for the U.S. nearly a quarter, for Europe half as volatile. The model's result of 0.16 is therefore too low. The values are nearly constant over all three policies – only the output gap rises from a DIT to a PEG policy, as explained in Galí and Monacelli (2002, p. 20).

The variability of the nominal variables clearly depends on the kind of monetary policy assumed for the small open economy. Nonetheless there is some overall result that the model's nominal variables are not enough volatile: the consumer price index varies between zero (CIT) and 0.23 (PEG) percent, compared to something between 1.09 (Germany) and 2.27 (UK) percent in the data.[36] Inflation of all consumer goods as well as of domestic goods varies between zero (π_H in the DIT case, π for CIT) and 0.19 (π_H, PEG) percent in the model compared to 0.57 percent in U.S. post-war data or 0.70 percent in post Bretton Woods data for the "G3" called countries Japan, Germany and the United Kingdom.[37]

The nominal exchange rate as well as its real opposite are quantitatively perhaps the biggest failure of the model: the data show a volatility between six and nine percent,[38] the model at most a twelfth of it (nominal exchange rate for DIT). Comparing the results of the three policies, we see the correct pattern of the data: the real exchange rate is less volatile when the nominal exchange rate is fixed, in our model 0.23 percent in the PEG situation, compared to 0.26 (0.30) for a CIT (DIT) policy. Empirically this was shown in a study by Mussa (1986).[39] The nominal interest rate varies for both economies and for all policies between 0.04 and 0.07 percent compared to 0.46 for the G3 and 1.29 percent for the U.S. one month treasury bond rate.[40] The volatility of the domestic real (CPI) interest rate is slightly higher (up to 0.16 percent), but still too low compared to the data. Clearly, there are some disturbances missing in the model.

[35] Backus et al. (1995), p. 334.

[36] See Kollmann (2001), p. 254; data for 1973:I till 1994:IV. For the U.S., the CPI varied about 1.43 percent between 1954:I and 1991:II; see Cooley and Hansen (1995), p. 180.

[37] Cooley and Hansen (1995), p. 180, Kollmann (2002), table 4.

[38] Chari et al. (2001), table 1.

[39] A good survey of Mussa's findings is Dornbusch and Giovannini (1990), pp. 1251-1256, a recent application Monacelli (2000).

[40] Kollmann (2001), p. 254; Cooley and Hansen (1995), p. 181.

Table 3.2: Business Cycle in the Domestic Inflation Targeting Model

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	0.9405	-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	0.01	-0.04	-0.11	-0.19	-0.29	-0.40	-0.29	-0.19	-0.11	-0.04	0.01
World output	0.9260	-0.02	0.08	0.20	0.35	0.53	0.74	0.53	0.35	0.20	0.08	-0.02
Domestic consumption	0.8712	-0.02	0.10	0.25	0.43	0.66	0.92	0.66	0.43	0.25	0.10	-0.02
Net exports	0.1621	-0.01	0.04	0.10	0.18	0.27	0.38	0.27	0.18	0.10	0.04	-0.01
Domestic CPI price level	0.2026	-0.01	0.04	0.10	0.18	0.27	0.38	0.27	0.18	0.10	0.04	-0.01
Domestic goods price level	0.0000	0.01	-0.04	-0.10	-0.18	-0.27	-0.38	-0.27	-0.18	-0.10	-0.04	0.01
Domestic CPI inflation	0.1538	0.05	0.06	0.08	0.10	0.12	0.14	-0.14	-0.12	-0.10	-0.08	-0.06
Domestic goods inflation	0.0000	-0.01	0.05	0.12	0.20	0.31	0.44	0.31	0.20	0.12	0.05	-0.01
Nominal exchange rate	0.5065	-0.01	0.04	0.10	0.18	0.27	0.38	0.27	0.18	0.10	0.04	-0.01
Real exchange rate	0.3039	-0.01	0.04	0.10	0.18	0.27	0.38	0.27	0.18	0.10	0.04	-0.01
Terms of trade	0.5065	-0.01	0.04	0.10	0.18	0.27	0.38	0.27	0.18	0.10	0.04	-0.01
Domestic interest rate	0.0446	0.02	-0.10	-0.26	-0.46	-0.70	-0.99	-0.70	-0.46	-0.26	-0.10	0.02
Dom. real CPI interest rate	0.1636	-0.04	-0.09	-0.15	-0.22	-0.30	-0.40	-0.06	-0.01	0.02	0.05	0.07
World interest rate	0.0463	0.02	-0.08	-0.20	-0.35	-0.53	-0.74	-0.53	-0.35	-0.20	-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	0.20	0.35	0.53	0.74	0.53	0.35	0.20	0.08	-0.02

Notes: SD: Standard deviation. 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.

3.3.2 Auto- and Cross-Correlations

Concerning the correlation structure, the data is well replicated for the real variables, but the model has quite a lot of problems with the co-movements of nominal variables with output. Especially the interest rate behavior is not confirmed by the data. Model output is equally autocorrelated in the small open economy as well as in the world economy: a value of 0.71 for the first lag seems reasonable, although a bit low, compared to 0.85 for the U.S. or 0.78 for the G3.[41] The persistence pattern for more leads and lags is identical to the data,[42] approaching negative values after a five periods' distance. Consumption seems to be less correlated with current output, but more autocorrelated at higher lags in the data, while the correlation of productivity with output in the model as well as in the data is close to unity.[43] The correlation behavior of the nominal variables in the model is very much dependent on the policy rule chosen: for the consumer price index, only the peg delivers the negative correlation with output seen in the data; the result for the DIT policy is qualitatively wrong.[44] For the CPI inflation the PEG model is qualitatively wrong[45] and the DIT model is right, but quantitatively too low (0.14 percent). For the exchange rates' correlations the three sub-models have the following properties: they predict the high co-movement of nominal and real exchange rate with each other.[46] Their autocorrelations are all positive and quite close to the data: DIT delivers 0.71, CIT 0.84 and the PEG 0.88,[47] compared to something between 0.78 and 0.85 in the data.[48] A model deficiency is the contemporaneous correlation with output: coefficients of 0.34 to 0.38 are not seen in the data, which shows the puzzling "disconnect".[49] For the interest all the three models are completely wrong. The strong negative correlation of the interest rate with output clearly diverges from the slightly positive correlation with output in the data.[50]

[41] Backus et al. (1995), p. 334; Kollmann (2001), p. 254.

[42] Cooley and Hansen (1995), p. 181.

[43] Backus et al. (1995), p. 334.

[44] PEG: -0.34, CIT: 0 due to stabilization, DIT: 0.38, compared to -0.52 for the U.S. and -0.50 for the G3; Cooley and Hansen (1995), p. 180, Kollmann (2001), p. 254.

[45] -0.24 instead of 0.34 percent in the data; see Cooley and Hansen (1995), p. 180.

[46] From the covariance matrices calculated by the program, one gets $\text{Corr}(e_t, q_t) = \text{Cov}(e_t, q_t)/\sqrt{\text{Var}(e_t)\text{Var}(q_t)}$ equal to unity for DIT and CIT, while the result for the nominal exchange rate stabilizing peg cannot be calculated ($\text{Var}(e_t) = 0$). The data says 0.99 (Chari et al. (2001), table 1).

[47] The results can be delivered with the command `au1mat_fil(x,x)/varvec_fil(x,1)` in the Matlab® Command Window, where `x` stands for the position of the variable in the `HP_SELECT` vector.

[48] Chari et al. (2001), table 1, Kollmann (2001), p. 254.

[49] Correlation with output in the G3 countries: -0.07 for the nominal and -0.01 for the real (U.S.-dollar) exchange rate; see Kollmann (2001), p. 254.

[50] The U.S. one month treasury bill correlation with GDP is 0.40, the G3 short term rates' GDP-correlation 0.14; Cooley and Hansen (1995), p. 180, Kollmann (2001), p. 254.

International Correlations

Galí and Monacelli have set the correlation of domestic and foreign (world) productivity to 0.77 to match Canada-U.S. data for productivity as well as for output, since both correlation coefficients are nearly the same.[51] With our calibration this implies a correlation of 0.74 between domestic and foreign output. Compared to other country combinations the value is quite high: U.S.-German output is correlated with a coefficient of 0.66, U.S.-U.K. output with 0.55.[52] For consumption, table B.2 in the appendix shows that $\mathrm{Corr}(c_t, c_t^*) = \mathrm{Cov}(c_t, c_t^*)/\sqrt{\mathrm{Var}(c_t)\mathrm{Var}(c_t^*)} = 0.95$ for the DIT case.[53] This is not true for the data, neither as absolute value nor relative to output: in the data, Backus et al. report values between -0.19 for U.S.-Australian and 0.51 for U.S.-European consumption, while compared to output, correlation of consumption (and productivity) is always lower – the "quantity anomaly" or the low international consumption correlation puzzle.[54] The interest rates in the model are highly correlated with each other for every policy rule. The nominal variables and their international correlations will not be explored in great detail since the model clearly simplifies by setting the world inflation as well as the world output gap equal to zero for all times, diminishing the possibility of calculating correlations.

3.3.3 Impulse Responses

The responses for the model's main variables to a one percent deviation impulse of domestic and world productivity, respectively, provide some visual impression of the model's pros and cons.[55] Figure 3.1 shows the responses for optimal monetary policy in both economies, which is in this model domestic inflation targeting. We take this sub-model as benchmark. The results for CPI inflation targeting and the peg are given in figures B.1 and B.2, respectively.

Domestic Productivity Shock

A sudden rise in domestic productivity leads to an even larger rise in domestic output, used for rising net exports and for a smaller rise in domestic consumption, which is due to the exogenously set consumption share of foreign goods, but could also be explained by consumption smoothing. World

[51] Galí and Monacelli (2002), p. 19; compare Backus et al. (1995), p. 336.

[52] See Backus et al. (1995), p. 336.

[53] In the program, the relevant numbers can be found in the covariance matrix `covmat_fil`, which is ordered as the variables in the vector `HP_SELECT`.

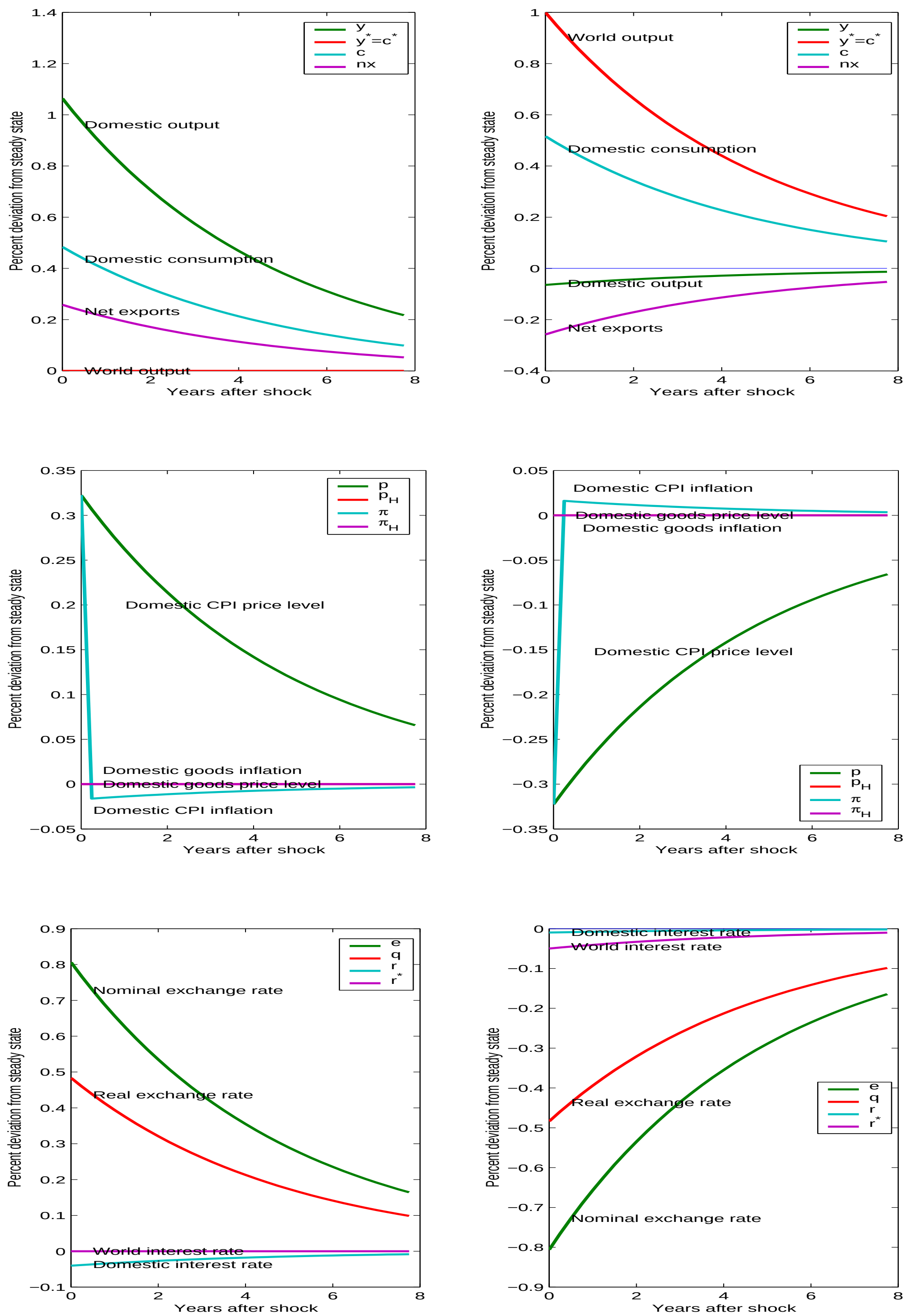
[54] See Backus et al. (1995), pp. 336 and 343 as well as section 2.4 above.

[55] As far as we understand the procedure, the Toolkit calculates forecast error impulse responses. Compared to orthogonalized impulse responses, this procedure has difficulties in a situation in which both shocks appear contemporaneously; see Lütkepohl (1991), pp. 34-56, especially p. 48.

Figure 3.1: Impulse Responses of the Domestic Inflation Targeting Model

Shock to Domestic Productivity

Shock to World Productivity



output and consumption is not affected – the small open economy is just too small. The reactions of the nominal variables depend on the monetary policy conducted: for DIT, the domestic price level and its changes shall not move, so the domestic currency becomes much more valuable: the exchange rates rise sharply. Thereby foreign goods get more expensive, which means a slowly declining CPI price level and a very short term positive reaction in the CPI inflation. Domestic interest slightly falls, world interest is unaffected. For CPI targeting, domestic goods prices show the expected and quite persistent fall, whereas CPI prices are stabilized. It follows from 3.42 that both nominal and real exchange rate are identical; as in the DIT case they experience an appreciation, but to a less extent. Domestic interest rises slightly for half a year, then falls till it reaches its steady state level. For CIT- and PEG-policies the responses to a domestic productivity shock are qualitatively the same, as shown in the left column of figure B.1 (CIT) and figure B.2 (PEG). A difference is that in the PEG case because of nominal exchange rate stabilizing the exchange rate channel is less and the prices channel much more volatile, where the CPI price level is now free to move nearly parallel, though to less extent, with its domestic goods counterpart. As always world interest is not affected for the peg, as well as domestic (nominal) interest – inflation freely moves such that there is no necessity to adjust nominal interest.

World Productivity Shock

The real variables reaction to a positive shock to world productivity is policy independent: world output (and consumption) rises to the same amount as productivity, consumption in the small open economy only to a slightly smaller percentage than the extent of its openness. Because of the imported consumption goods net exports become negative. And since foreign goods become cheaper through the exchange rate appreciation, domestic output is lowered slightly. Since the world monetary policy authority aims to stabilize world inflation, it lowers the world interest rate. Under a DIT, prices in the small open economy sharply fall at the beginning due to cheaper production in the rest of the world, then they rise very slowly. Under CPI targeting, domestic prices have to rise in order to compensate for the cheaper imports. This is caused by a sharp short-term contraction in the domestic interest rate. Under the PEG, the fixed nominal exchange rate forces the domestic monetary authority to follow the world interest rate rule. The decline in the interest rate in the presence of the domestic output contraction leads to rising prices in the small open economy, implying positive but falling inflation rates.

Chapter 4

The Model and the Six Puzzles

Having analyzed the main features of the model, we may return to the "Six Puzzles". A close view on the model's features with respect to these puzzles leads to a mixed result.

4.1 Home Bias in Trade

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.[1] 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 (3.14) to replace total consumption C_t, one gets a consumption share ratio:

$$\frac{C_{H,t}}{C_{F,t}} = \frac{1-\alpha}{\alpha}\left(\frac{P_{H,t}}{P_{F,t}}\right)^{-\eta} \quad . \tag{4.1}$$

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

$$\frac{P_{H,t}C_{H,t}}{P_{F,t}C_{F,t}} = \frac{1-\alpha}{\alpha}\left(\frac{P_{H,t}}{P_{F,t}}\right)^{1-\eta} \quad . \tag{4.2}$$

The same is true for the world economy which imports $C^*_{H,t}$ and produces itself $C^*_{F,t}$. The world's analog to (3.14) in terms of domestic currency, using

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

the nominal exchange rate equation $P_{j,t} = \mathcal{E}_t P^*_{j,t} \quad \forall j \in \{H, F\}$, leads to

$$\frac{\mathcal{E}_t P^*_{H,t} C^*_{H,t}}{\mathcal{E}_t P^*_{F,t} C^*_{F,t}} = \frac{P_{H,t} C^*_{H,t}}{P_{F,t} C^*_{F,t}} = \frac{\alpha^*}{1-\alpha^*} \left(\frac{P_{H,t}}{P_{F,t}} \right)^{1-\eta} = \frac{\alpha^*}{1-\alpha^*} \left(\frac{\mathcal{E}_t P^*_{H,t}}{\mathcal{E}_t P^*_{F,t}} \right)^{1-\eta} . \tag{4.3}$$

Assuming the ratio of price indices equal to one as in the steady state, the consumption ratios can be easily calculated. Under the basic calibration with $\alpha = 0.4$, $\alpha^* = 0.001$ and $\eta = 1.5$, the consumption expenditure ratios are

$$\frac{P_{H,t} C^*_{H,t}}{P_{F,t} C^*_{F,t}} = \frac{1-0.4}{0.4} = 1.5 \tag{4.4}$$

for the small open economy and

$$\frac{P_{F,t} C_{F,t}}{P_{H,t} C_{H,t}} = \frac{1-0.001}{0.001} = 999 \tag{4.5}$$

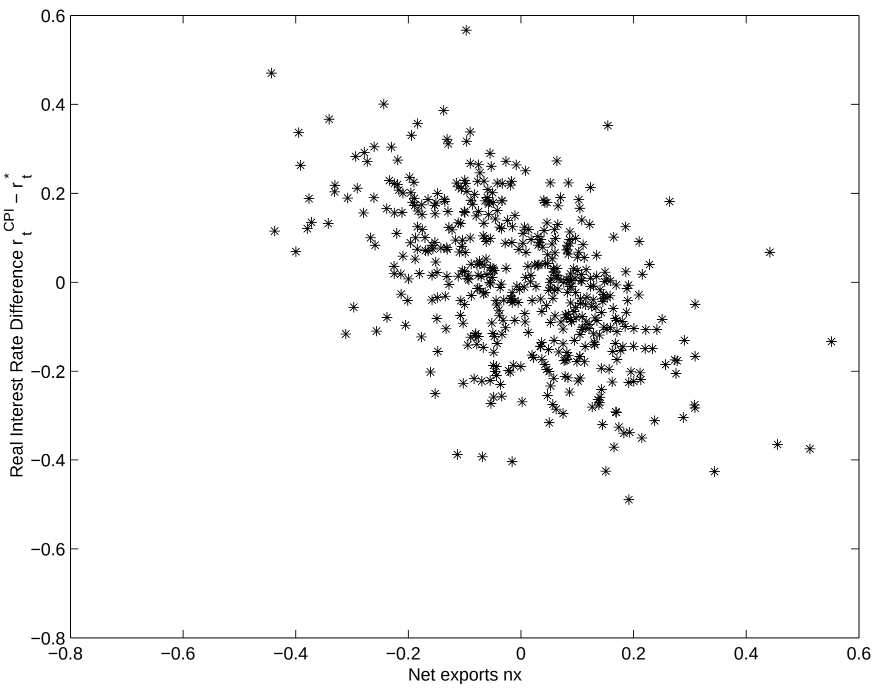
for the world economy. Thus, this puzzle can be easily "solved" exogenously, but a thorough explanation is missing. While Galí and Monacelli have set α such that the small open economy's degree of openness fits the Canadian share of imports relative to GDP,[2] Obstfeld and Rogoff suggest a parameter similar to $\alpha/(1-\alpha)$ in the utility function to capture a "home bias in preferences".[3] This interpretation of α solves the first puzzle insofar as it assumes additional utility from something like patriotism. The difficulty is that α now plays a twofold role: on the one hand it displays the degree of openness (in the steady state) which is a policy variable, on the other hand it builds the preference parameter $\alpha/(1-\alpha)$, referring to the household's utility function. It would be preferable to separate these two functions of α.

4.2 Feldstein-Horioka

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.[4] 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"[5]

[2] Galí and Monacelli (2002), p. 19.
[3] Obstfeld and Rogoff (2000*b*), p. 9.
[4] An attempt to include capital in the model is shown in section A.3 in the appendix.
[5] Jeanne (2000), p. 393.

Figure 4.1: Effect of Net Exports on the Interest Rate Difference



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. A look at figure 4.1 from a model simulation over 500 periods suggests that the Feldstein-Horioka puzzle is solved by the model: net exports are positive for the domestic real interest rate lower than its world counterpart. Therefore, there is a clear negative relation between a current account surplus and the real interest spread. The calculated correlation coefficient for $\alpha = 0.4$ is about $\text{Corr}(nx_t, r_t^{\text{CPI}} - r_t^*) = -0.54$ for a DIT-policy.[6] Though we can say that this puzzle is solved indirectly in this little model, this result holds only for DIT and is not stable across different monetary polices in the model. Under CPI targeting and for an exchange rate peg the result is reverted: the CIT coefficient is about 0.4, the PEG coefficient about 0.6.

[6] The results can be obtained by the command `corrcoef(sim_xyz(8,:), (sim_xyz(18,:)-sim_xyz(9,:)))` with the standard ordering of the variables. The domestic real interest rate is $r_t^{\text{CPI}} = r_t - \pi_t$, the world interest rate r_t^* is real, since $\pi_t^* = 0 \quad \forall t$.

4.3 Home Bias in Equity Portfolio

The way this puzzle can be addressed in a model without money and capital is quite simple: the consumption share of domestic goods equals the equity share of domestic goods.[7] 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,

$$\frac{1}{P_{H,t}}\frac{\partial U}{\partial C_{H,t}} = \frac{1}{\mathcal{E}_t P^*_{H,t}}\frac{\partial U^*}{\partial C^*_{H,t}} \ . \tag{4.6}$$

This is under the given utility function

$$\frac{1}{P_{H,t}}\ C_t^{\frac{1}{\eta}-\sigma}(1-\alpha)^{\frac{1}{\eta}}C_{H,t}^{\frac{-1}{\eta}} = \frac{1}{\mathcal{E}_t P^*_{H,t}}\ C_t^{*\frac{1}{\eta}-\sigma}\alpha^{*\frac{1}{\eta}}C_{H,t}^{*\frac{-1}{\eta}}\ , \tag{4.7}$$

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

$$\frac{1}{P_{F,t}}\ C_t^{\frac{1}{\eta}-\sigma}\alpha^{\frac{1}{\eta}}C_{F,t}^{\frac{-1}{\eta}} = \frac{1}{\mathcal{E}_t P^*_{F,t}}\ C_t^{*\frac{1}{\eta}-\sigma}(1-\alpha^*)^{\frac{1}{\eta}}C_{F,t}^{*\frac{-1}{\eta}}\ . \tag{4.8}$$

Market clearing for home and foreign products implies

$$Y_{H,t} = C_{H,t} + C^*_{H,t} \quad \text{and} \quad Y_{F,t} = C^*_{F,t} + C_{F,t}\ . \tag{4.9}$$

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 Galí and Monacelli (2002). This means that C_t and C^*_t drop out of the equations. Together with $P_{j,t} = \mathcal{E}_t P^*_{j,t} \quad \forall j \in \{H,F\}$, which holds under the law of one price assumed for this model, equations (4.7) and (4.8) simplify to

$$(1-\alpha)^{\frac{1}{\eta}}C_{H,t}^{\frac{-1}{\eta}} = \alpha^{*\frac{1}{\eta}}C_{H,t}^{*\frac{-1}{\eta}} \quad \text{and} \quad \alpha^{\frac{1}{\eta}}C_{F,t}^{\frac{-1}{\eta}} = (1-\alpha^*)^{\frac{1}{\eta}}C_{F,t}^{*\frac{-1}{\eta}}\ . \tag{4.10}$$

With (4.9) and (4.10) one can evaluate the four equity- as well as consumption shares $X_{H,t}$, $X_{F,t}$, $X^*_{F,t}$ and $X^*_{H,t}$ as functions of $Y_{H,t}$ or $Y^*_{F,t}$, depending only on the home bias in preferences parameters $\alpha/(1-\alpha)$ and $\alpha^*/(1-\alpha^*)$:

$$X_{H,t} = C_{H,t} = \frac{1}{1+\frac{\alpha^*}{1-\alpha}}Y_{H,t}\ , \tag{4.11}$$

$$X^*_{H,t} = C^*_{H,t} = \frac{1}{1+\frac{1-\alpha}{\alpha^*}}Y_{H,t}\ , \tag{4.12}$$

[7] The way this topic is dealt with is a direct application of Obstfeld and Rogoff (2000*b*), pp. 22-28. Since they have included trade costs in their model, consumption and equity shares differ slightly.

$$X_{F,t} = C_{F,t} = \frac{1}{1 + \frac{1-\alpha^*}{\alpha}} Y^*_{F,t} \ , \tag{4.13}$$

$$X^*_{F,t} = C^*_{F,t} = \frac{1}{1 + \frac{\alpha}{1-\alpha^*}} Y^*_{F,t} \ . \tag{4.14}$$

With $\alpha = 0.4$ and $\alpha^* = 0.001$ this implies that both economies show a distinct home bias in equity portfolio: in the small open economy more than 99 percent of the equity is held by residents, whereas in the world economy the residents still have a home portfolio share of 71 percent.[8] This result is quantitatively very good, compared to the values presented in section 2.3. It is less so when taking into account that in the data smaller countries tend to be less biased in their equity portfolios than big countries.[9] This feature of the data is not modeled correctly, but in line with the model of Obstfeld and Rogoff: the same wrong result can be found in table 4 of Obstfeld and Rogoff (2000*b*), where the home country gets bigger from the left to the right, whereas the home bias c_H gets smaller. Without the assumption $\sigma\eta = 1$ the results do not change essentially.[10]

4.4 International Consumption Correlation

As seen in the last part of section 3.3.2, this puzzle – the "quantity anomaly" in the words of Backus et al. (1995) – is not solved in the model. The model fails to reproduce the confusing data. Instead of a lower correlation for consumption than for output, in the model for all three policies consumption is more correlated with 0.95 than output with 0.74.[11] This result is in line with the benchmark model as well as nearly all variations of Backus et al. (1995): the only exception there is a case with autarky, lacking trade in goods and assets and with only technology shocks linked across countries. Under autarky, consumption correlation is lowered to 0.56, but this is still higher than the corresponding output correlation, which is 0.08.[12]

4.5 Purchasing Power Parity

The puzzling persistence of the real exchange rate is well replicated in the model. The autocorrelation of the exchange rate ranges from 0.71 for DIT to 0.88 for a PEG. This means that the half time is less than one and

[8] With the law of one price holding, share prices are equal in both economies.

[9] Tesar and Werner (1998), pp. 298-299.

[10] See table 4 in Obstfeld and Rogoff (2000*b*) for a comparison.

[11] See section 3.3.2.

[12] See Backus et al. (1995), tables 11.4B and 11.8B, figure 11.3 and pp. 342-343.

a half years, between 16 months under a PEG and six moths for DIT.[13] Compared to the HP-filtered quarterly data reported in Chari et al. (2001) and Kollmann (2001), the value of 0.734 is quite acceptable, though a bit lower than the average of 0.83 in Chari et al. and 0.78 in Kollmann.[14] On the whole one can say that the persistence part of the puzzle is solved. However, the high volatility dimension of the puzzle is not explained. As seen in section 3.3.1, both exchange rates have a standard deviation too low by a factor of twelve. The "real exchange rate – consumption anomaly" Chari et al. (2001, pp. 2-3) find in their model is not seen here, i.e., the high and positive correlation of both variables. In our model the correlation of the real exchange rate with domestic consumption is nearly zero.[15]

4.6 Exchange Rate Disconnect

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 sub-models are set up, the real exchange rate is identical to the CPI price level for domestic inflation targeting, to the negative of the domestic goods price level for CPI targeting and – with opposite sign – to both of them for an exchange rate peg. 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.[16] Also along the second dimension the model does not fit the data: the volatility of both real and nominal exchange rates is with 0.2 to 0.5 percent by far smaller than the 6 to 9 percent reported in most datasets.[17]

[13]Via $0.88^x = 0.5$ the half-time is calculated e.g. as $\frac{\log(0.5)}{\log(0.88)} = 5.42$, which with quarterly data implies 1.36 years or slightly more than 16 months for the PEG.

[14]The very high persistence of the real exchange rate – based on monthly data – with a half-time of about three years reported in Obstfeld and Rogoff (2000*b*), p. 35, is not shown in the model, be it due to HP-filtering or to the periodicity of the data.

[15]$\text{Corr}(q_t, c_t) = \text{Cov}(q_t, c_t)/(\text{Std}(q_t) * \text{Std}(c_t)) = -0.003/(0.3039 * 0.8712) = -0.0113$ for the DIT-model.

[16]See McCallum and Nelson (2001), pp. 15-21, for correlations from annual and quarterly data, as well as the correlation in the Galí and Monacelli model which they looked at. For the Galí and Monacelli model correlations see also the first column of table 5.2 below.

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

Chapter 5

Including Trade Costs

5.1 Why Trade Costs?

There are various ways to extend the model. Kollmann (2001) and Erceg et al. (2000) include sticky wages and different shocks, Betts and Devereux (1996, 2000) use local currency pricing, various authors model influences of both economies on each other in a two country model.[1] To address some of the six puzzles, several paths have been used:

- The main source to explain the observed home bias in trade are costs of international trade, such as tariffs, transportation costs or prohibitive regulations. Apart from that, one can suppose a preference parameter for domestic goods in the utility function.

- For the high correlation between savings and investment, at least four apsects have been proposed: 1. political influence to avoid current-account imbalances, 2. near steady state situations for developed economies with only small deviations in the savings plans, 3. corporate saving through retained earnings, and 4. the life-cycle theory of consumption.[2]

- Informational asymmetries, cultural and linguistic barriers, and differences in national tax systems and regulations have been suggested as reasons for the home bias in equity portfolio.[3] Obstfeld and Rogoff also offer nontradables and small utility gains to diversification.[4]

- For the low consumption correlation, Backus and Smith (1993) come up with nontradables to solve this puzzle, but this route is criticized

[1] Bacchetta and van Wincoop (2000), Benigno (2001), Benigno and Benigno (2000), e.g.

[2] See Obstfeld and Rogoff (1996), pp. 162-163.

[3] See Jeanne (2000), p. 391.

[4] Obstfeld and Rogoff (1996), pp. 303-329.

by various authors, since the data does not show different results for tradables and nontradables.[5] Chari et al. (2001) use a sticky price model with capital accumulation and highly correlated national monetary shocks to get the low consumption correlation.[6]

- According to the seminar paper by Rogoff (1996), the main avenues to explain the PPP puzzle are transportation costs such as tariffs and nontariff barriers, nontraded components in goods, and price discrimination across different markets – the so-called pricing-to-market.[7] The integration of nontradables into models was proposed for example by Backus and Smith (1993), but recently this avenue is becoming less popular: critique comes from Chari et al. (2001), who show that the difference between traded and nontraded goods prices can account only for two percent of the real exchange variability. Furthermore, Engel (1999) shows that real exchange rates built on nontraded goods price indices do not differ significantly from those built on traded goods price indices. A critique on pricing-to-market in the form of local currency pricing based on statistical evidence can be found in Obstfeld and Rogoff (2000*a*), who suggest the additional introduction of wage rigidity to be helpful.

- For exchange rate disconnect there are only few answers up to now. One way to deal with this puzzle is to subsume it under asset price riddles and call for a general solution of the ingredients of the observed asset price behavior.[8] Another way might be a model with "trade costs, [...] monopoly, and pricing to market in local currency."[9]

Since costs of trade generally appear in the list above, they will be included in the model. Another possible change of the model, the introduction of capital and thereby of a strong intertemporal link, has been tried – it is reported in section A.3 in the appendix. So far the model did quite well in explaining puzzles one to three and partly five. Thus, the focus of introducing trade costs will be on the puzzles still unsolved.

5.2 General Notes on Trade Costs

Costs of trade – the main source of explanation for the six puzzles in the Obstfeld and Rogoff (2000*b*) paper – appear in many different forms. The most obvious are tariffs and transportation costs. Still there are less obvious

[5] See Obstfeld and Rogoff (2000*b*), n. 28 on p. 29.

[6] See Chari et al. (2001), pp. 2 and 22, as well as table 6; see also Obstfeld and Rogoff (2000*b*), n. 30 on p. 32.

[7] Rogoff (1996), pp. 653-654.

[8] See Obstfeld and Rogoff (1996), pp. 625-626, Jeanne (2002), pp. 398-402.

[9] See Obstfeld and Rogoff (2000*b*), p. 41.

examples such as costs of delay, translation costs or costs for bribing, just to mention a few nontariff barriers. It is a difficult to measure which size these costs can take: estimates begin with about three percent and range up to 30 percent if clearly nontradable goods are included.[10] The argument used here is that nontradable goods are regarded as goods with trade costs too high for profitable export. In agreement with this argument even higher trade costs may be appropriate.[11]

The basic idea underlying trade costs is the following. Suppose one is at a beach on a hot summer day and longs for ice-cream. The next dealer is about five hundred meters away from one's location. Going there, buying and hurrying back to one's towel certainly may satisfy one's wish, but as certain it results in less ice-cream than in the case of the dealer selling right at one's towel. If the market for ice-cream at beaches was compatible, the trade costs one has should result in a lower price. Denoting the price at the seller's – as far away as the stars – P_F^* and the price right at one's feet P_F, one would suspect trade costs Ξ to reduce P_F because of the ice-cream lost on the way:

$$P_F = P_F^*/(1 - \Xi) \ . \tag{5.1}$$

While one can make the model a bit more complicated, the idea remains simple.[12] In the following, trade costs are included in the model economy laid out in section 3.1. Then, the changed model is analyzed and its results are shown and compared with the six puzzles.

5.3 The Galí and Monacelli Model with Trade Costs

To include trade costs Ξ in the Galí and Monacelli (2002) model, (5.1) has to be enlarged for the nominal exchange rate $\mathcal{E}_t$:

$$P_{F,t} = \mathcal{E}_t P_{F,t}^*/(1 - \Xi) \ . \tag{5.2}$$

Of course, apart from the beach of the example given above, the index F refers to a good of the world economy, whereas the asterisk denotes the foreign price. Similarly, a home good has to sell cheaper abroad:

$$P_{H,t} = \mathcal{E}_t P_{H,t}^*(1 - \Xi) \ . \tag{5.3}$$

Log-linearizing (5.2) and (5.3) results with the definition $\xi \equiv -\log(1 - \Xi)$ in

$$p_{F,t} = e_t + p_{F,t}^* + \xi \tag{5.4}$$

$$p_{H,t} = e_t + p_{H,t}^* - \xi \ . \tag{5.5}$$

[10]See Obstfeld and Rogoff (2000*b*), pp. 8 and 58, as well as Rogoff (1996), p. 653.

[11]For a deeper understanding of this point see Obstfeld (2000), pp. 12-14.

[12]These lines for intuition are closely related to Obstfeld and Rogoff (2000*b*), p. 5.

For the (log) terms of trade s_t and the (log) real exchange rate q_t this implies some changes compared to section 3.1.2:

$$s_t = p_{F,t} - p_{H,t} = e_t + p^*_{F,t} + \xi - p_{H,t} = e_t + p^*_t + \xi - p_{H,t} \ , \qquad (5.6)$$

since $p^*_{F,t} = p^*_t$ as $\lim_{\alpha^* \to 0}$, and

$$q_t = e_t + p^*_t - p_t = s_t - \xi + p_{H,t} - p_t = (1-\alpha)s_t - \xi \ . \qquad (5.7)$$

Trade costs have no influence on the firms' decisions of price setting.

5.4 Model Analysis with Trade Costs

Maximizing the household's utility function (3.1) as before results in the optimality condition (3.14). This, together with its world opposite under competitive markets results in an equation relating the consumption ratios of the two economies in the steady state:

$$\frac{C_{H,t}}{C_{F,t}} = \frac{1-\alpha}{\alpha}\frac{1-\alpha^*}{\alpha^*}(1-\Xi)^{-2\eta}\frac{C^*_{H,t}}{C^*_{F,t}} \ , \qquad (5.8)$$

where α^* is the world economy's share of imports, which is assumed to be close to zero. We see that equality of the consumption ratios holds for $\alpha = \alpha^* = 0.5$ and $\Xi = 0$. The relation of consumption ratios depends on the home bias in preferences, the trade costs and the elasticity of substitution between home and foreign goods, η. The next change compared to the basic Galí and Monacelli model[13] appears in (3.22): as the (log) trade costs enter a particular form of the real exchange rate, the parameter ω_α has to be replaced for $\omega_\xi = \omega_\alpha - \sigma\xi$, such that (3.22) becomes

$$y_t = y^*_t + \frac{\omega_\xi}{\sigma}s_t - \eta\xi \ . \qquad (5.9)$$

Since this central equation has changed, all further equations change in the same way, with ω_α being replaced by ω_ξ, whereas the constant $-\eta\xi$ can be neglected for impulse responses and correlations. Accordingly, Φ_α in (3.23) changes to $\Phi'_\alpha \equiv \frac{1-\alpha}{\omega_\xi}$, again neglecting the additional constant. Domestic output dynamics become

$$y_t = E_t\{y_{t+1}\} - \frac{\omega_\xi}{\sigma}(r_t - E_t\{\pi_{H,t+1}\} - \rho) + (\omega_\xi - 1)E_t\{\Delta y^*_{t+1}\} \ , \qquad (5.10)$$

the net exports up to a constant change into

$$nx_t = y_t - c_t - \alpha s_t = (1-\Phi'_\alpha)(y_t - y^*_t) - \alpha s_t = \frac{\alpha\Lambda - \sigma\xi}{\omega_\xi}(y_t - y^*_t) \ . \qquad (5.11)$$

[13] As explained in section 3.2.3, additional constant terms are neglected for the computer calculation. Thus, constant trade costs terms are left out of the log-linearized equations; see Galí and Monacelli (2002), p. 6 for an identical treatment.

The usual change from ω_α to ω_ξ applies to four more equations for the small open economy: to the domestic marginal costs in (3.28), the domestic natural output level in (3.30), the New Keynesian Phillips Curve (3.31) and to the IS-type equation (3.33). The resulting equations are

$$mc_t = -\nu + \left(\frac{\sigma}{\omega_\xi} + \varphi\right) y_t + \sigma\left(1 - \frac{1}{\omega_\xi}\right) y_t^* - (1+\varphi)a_t + \xi\left(\frac{\sigma\eta}{\omega_\xi} - \frac{1}{\sigma}\right) \ , \tag{5.12}$$

$$\overline{y}_t = \Omega_\xi + \Gamma_\xi a_t + \Theta_\xi y_t^* \ , \tag{5.13}$$

where

$$\Omega_\xi \equiv \frac{\omega_\xi(\nu - \mu - \xi\left(\frac{\sigma\eta}{\omega_\xi} - \frac{1}{\sigma}\right))}{\sigma + \omega_\xi\varphi} \ , \quad \Gamma_\xi \equiv \frac{\omega_\xi(1+\varphi)}{\sigma + \omega_\xi\varphi} \ , \quad \Theta_\xi \equiv \frac{\sigma(1-\omega_\xi)}{\sigma + \omega_\xi\varphi} \ ,$$

$$\pi_{H,t} = \beta E_t\{\pi_{H,t+1}\} + \kappa_\xi \tilde{y}_t \ , \quad \kappa_\xi \equiv \lambda\left(\frac{\sigma}{\omega_\xi} + \varphi\right) \ , \tag{5.14}$$

$$\tilde{y}_t = E_t\{\tilde{y}_{t+1}\} - \frac{\omega_\xi}{\sigma}(r_t - E_t\{\pi_{H,t+1}\} - \overline{rr}'_t) \ , \tag{5.15}$$

with

$$\overline{rr}'_t \equiv \rho - \frac{\sigma(1+\varphi)(1-\rho_a)}{\sigma + \omega_\xi\varphi} a_t - \varphi\Theta_\xi E_t\{\Delta y_{t+1}^*\} \ .$$

Note that the constants will be neglected for computer calculations.

5.4.1 Monetary Policy Rules

Trade costs lead to changes in monetary policy rules as follows.

Domestic Inflation Targeting

A domestic inflation targeting policy with trade costs mathematically shows only small changes compared to the one without. The main equations derived in the DIT part of section 3.2.2, i.e., (3.36), (3.37) and (3.38), change as follows:

$$r_t = \overline{rr}'_t \quad \forall\, t \ , \tag{5.16}$$

$$e_t = s_t = \frac{1}{1-\alpha} q_t = \frac{\sigma(1+\varphi)}{\sigma + \omega_\xi\varphi}(a_t - a_t^*) \ , \tag{5.17}$$

$$p_t = \alpha e_t = \frac{\alpha\sigma(1+\varphi)}{\sigma + \omega_\xi\varphi}(a_t - a_t^*) \ . \tag{5.18}$$

CPI Inflation Targeting

Under CPI targeting, the trade costs influence the rule through the use of (5.9) instead of (3.22) and (5.12) instead of (3.28). The dynamics of the domestic price level are therefore

$$\gamma_c' p_{H,t} = p_{H,t-1} + \beta E_t\{p_{H,t}\} - \lambda(1+\varphi)(a_t - a_t^*) \ , \tag{5.19}$$

with $\gamma_c' \equiv 1 + \beta + \frac{\lambda}{\alpha}(1 + \frac{\varphi\omega_\xi}{\sigma})$. This implies

$$p_{H,t} = \xi_c' p_{H,t-1} - \zeta_c'(a_t - a_t^*) \ , \tag{5.20}$$

where $\xi_c' \equiv \frac{1}{2\beta}(\gamma_c' - \sqrt{\gamma_c'^2 - 4\beta})$, $\zeta_c' = \frac{\lambda\xi_c'(1+\varphi)}{(1-\xi_c'\beta\rho_a)}$.

An Exchange Rate Peg

Under the peg, the changes are quite similar to the ones for CIT. The domestic price level dynamics (3.44) change slightly into

$$\gamma_e' p_{H,t} = p_{H,t-1} + \beta E_t\{p_{H,t+1}\} - \lambda(1+\varphi)(a_t - a_t^*) \ , \tag{5.21}$$

which implies the following changes for the stationary representation (3.45)

$$p_{H,t} = \xi_e' p_{H,t-1} - \zeta_e'(a_t - a_t^*) \ , \tag{5.22}$$

with $\gamma_e' \equiv 1 + \beta + \lambda(1 + \frac{\varphi\omega_\xi}{\sigma})$, $\xi_c' \equiv \frac{1}{2\beta}(\gamma_e' - \sqrt{\gamma_e'^2 - 4\beta})$ and $\zeta_e' \equiv \frac{\lambda\xi_e'(1+\varphi)}{(1-\xi_e'\beta\rho_a)}$.

5.5 Results with Trade Costs

Looking at the results with trade costs, we will focus on the model with a domestic inflation targeting (DIT) policy in the small open economy. Trade costs will be set to 25 percent, the value Obstfeld and Rogoff choose as their "baseline".[14]

5.5.1 Standard Deviations and Correlations

The results of the augmented model are shown in table 5.1, a comparison of the standard deviations for all policies with and without trade costs is given in table B.1 in the appendix. For the standard deviations we see that the major influence of trade costs is on the volatility of net exports. 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 in principle equal to domestic consumption plus net exports.[15] Some slight increases in volatility can be

[14] Obstfeld and Rogoff (2000*b*), p. 6.

[15] See (3.25) and the definition of net exports given right before (3.25).

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 benchmark model analyzed before. 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. For the CPI targeting policy, table B.5 in the appendix shows similar results with the exception of prices, where now the domestic goods price index and the same inflation become more volatile through trade costs. For the exchange rate peg, table B.6 in the appendix shows that both price indices and inflations have higher standard deviations compared to the PEG-model without trade costs as presented in table B.4.[16]

[16]See Galí and Monacelli (2002), pp. 18-20, for an assessment of the changes in output gap volatility.

Table 5.1: Business Cycle in the DIT-Model with Trade Costs $\Xi = 0.25$

		Cross-Correlation of Output with:										
Variable	SD %	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.

5.5.2 Impulse Responses

As shown in figure 5.1 for the DIT-model, the existence of trade costs has the expected influence on the impact of both shocks on domestic consumption and net exports. A shock has now 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.[17] 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.[18]

Under CIT- and PEG- policies, figures B.3 for CIT and B.4 for PEG factually show the same results as DIT model with trade costs when compared to their counterparts without trade costs.[19] Trade costs increase the response of domestic consumption to a domestic productivity shock and decrease its response to a world productivity shock. They reduce the response of the net exports to both shocks. Besides, they increase the response of the domestic nominal variables, and of the exchange rates on both productivity shocks.

5.6 The Trade Costs Model and the Six Puzzles

5.6.1 Home Bias in Trade

As the law of one price no longer holds, the nominal exchange rate is influenced by trade costs as in (5.2) and (5.3). For the world representative household's optimal expenditure share[20] this leads to the following changes:

$$\frac{\mathcal{E}_t P^*_{H,t} C^*_{H,t}}{\mathcal{E}_t P^*_{F,t} C^*_{F,t}} = \frac{\alpha^*}{1-\alpha^*} \left(\frac{\mathcal{E}_t P^*_{H,t}}{\mathcal{E}_t P^*_{F,t}} \right)^{1-\eta} , \tag{5.23}$$

[17] The comparison is made between the DIT-model without trade costs as in figure 3.1 and the DIT-model with trade costs as in figure 5.1.

[18] 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 %.

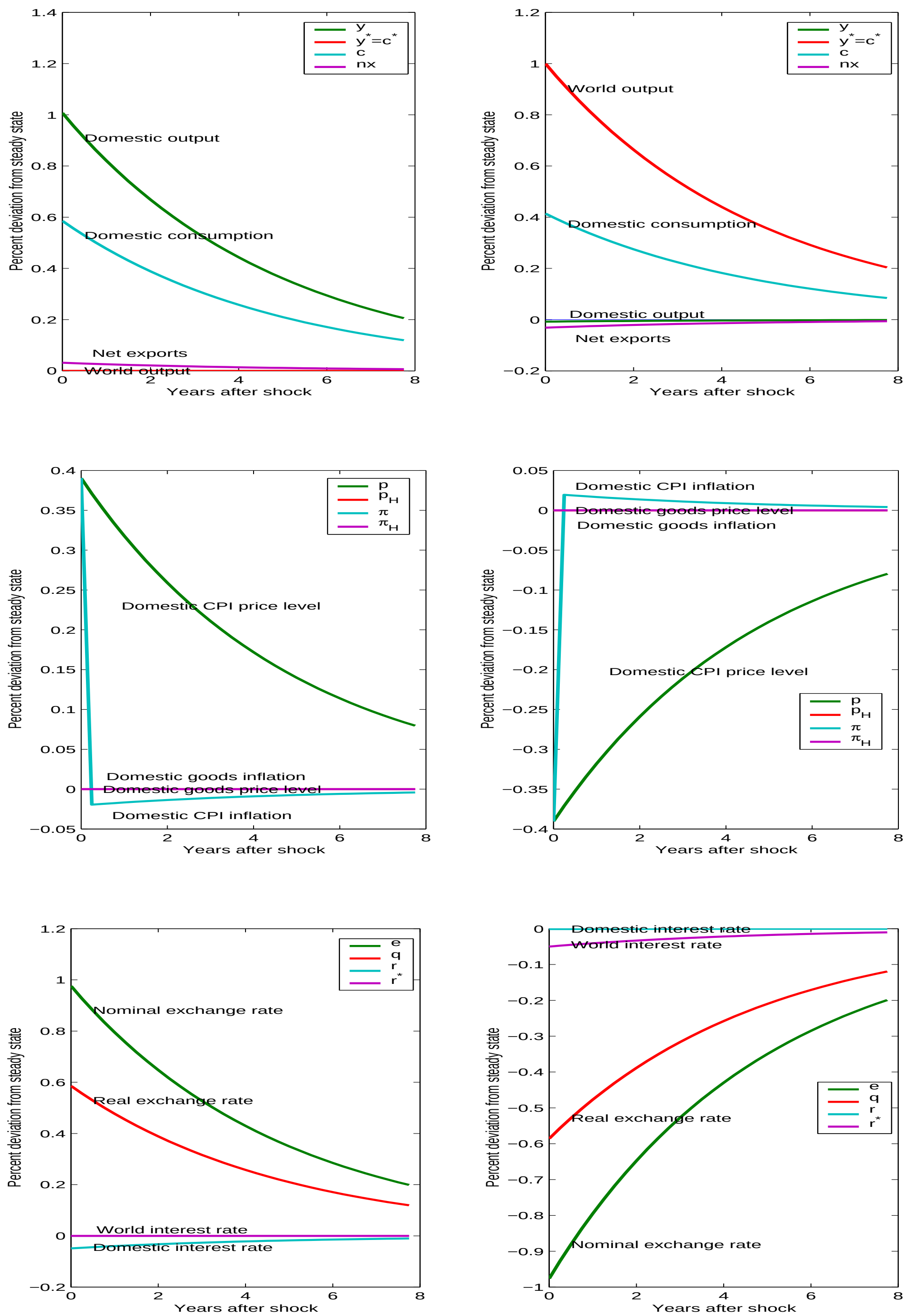
[19] I.e., figures B.1 and B.2, all given in the appendix.

[20] See equation (4.3) from the previous section on the home bias in trade puzzle, section 4.1.

Figure 5.1: Impulse Responses of the DIT-Model with Trade Costs

Shock to Domestic Productivity

Shock to World Productivity



which can be denoted in terms of domestic currency as

$$\frac{P_{H,t}C^*_{H,t}}{(1-\Xi)^2 P_{F,t}C^*_{F,t}} = \frac{\alpha^*}{1-\alpha^*}\left(\frac{P_{H,t}}{(1-\Xi)^2 P_{F,t}}\right)^{1-\eta} \quad , \tag{5.24}$$

or simpler

$$\frac{P_{H,t}C^*_{H,t}}{P_{F,t}C^*_{F,t}} = \frac{\alpha^*}{1-\alpha^*}(1-\Xi)^{2\eta}\left(\frac{P_{H,t}}{P_{F,t}}\right)^{1-\eta} \quad . \tag{5.25}$$

This implies an even stronger home bias for the world economy: with the basic calibration[21] and with 25 percent trade costs 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.

5.6.2 Investment-Savings

Here, we consider the high correlation of investment and savings first mentioned by Feldstein and Horioka, addressed through a relation between net exports and the real interest rate spread as in section 4.2. The correlation changes slightly into the right direction for the benchmark case with trade costs of 25 percent with DIT and elasticity of substitution between domestic and foreign goods of 1.5. The correlation coefficient now becomes -0.49 instead of -0.54. This range of values is quite stable, even for changes to the Obstfeld and Rogoff (2000*b*) value for the elasticity of substitution between domestic and foreign goods, $\eta = 6$, and trade costs up to 75 percent. For the other two policies, the strange different signs remain. The CIT coefficient in the benchmark trade costs model becomes 0.48 instead of 0.4 before, the PEG coefficient stays around 0.6. Thus, there are no significant changes to be realized from the introduction of trade costs for these policies.

5.6.3 Home Bias in Equity Portfolio

Compared to the previous section on home bias in equity portfolio (section 4.3), trade costs slightly change the picture. The market clearing conditions in (4.9) alter to

$$Y_{H,t} = C_{H,t} + \frac{1}{1-\Xi}C^*_{H,t} \quad \text{and} \quad Y_{F,t} = C^*_{F,t} + \frac{1}{1-\Xi}C_{F,t} \ . \tag{5.26}$$

Also due to trade costs, $P_{j,t} = \mathcal{E}_t P^*_{j,t} \quad \forall j \in \{H, F\}$ has to be replaced by (5.2) and (5.3). In the simple case, where $\sigma\eta = 1$, we can use (5.3) together with the still valid (4.7) to get an equation for the home good:

$$(1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{-1}{\eta}} = {\alpha^*}^{\frac{1}{\eta}}(1-\Xi) {C^*_{H,t}}^{\frac{-1}{\eta}} \quad , \tag{5.27}$$

[21] $\alpha = 0.4$, $\alpha^* = 0.001$ and $\eta = 1.5$.

and we can use (5.2) with (4.8) for the foreign good equation:

$$\alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{-1}{\eta}} = (1-\alpha^*)^{\frac{1}{\eta}} \frac{1}{1-\Xi} C_{F,t}^{*\frac{-1}{\eta}} \ . \tag{5.28}$$

Applying the market clearing conditions given in (5.26), we can get four consumption share and four equity portfolio share equations:

$$X_{H,t} = C_{H,t} = \frac{1}{1+\frac{\alpha^*}{1-\alpha}(1-\Xi)^{\eta-1}} Y_{H,t} \ , \tag{5.29}$$

$$(1-\Xi)X_{H,t}^* = C_{H,t}^* = \frac{\frac{\alpha^*}{1-\alpha}(1-\Xi)^{\eta}}{1+\frac{\alpha^*}{1-\alpha}(1-\Xi)^{\eta-1}} Y_{H,t} \ , \tag{5.30}$$

$$(1-\Xi)X_{F,t} = C_{F,t} = \frac{\frac{\alpha}{1-\alpha^*}(1-\Xi)^{\eta}}{1+\frac{\alpha}{1-\alpha^*}(1-\Xi)^{\eta-1}} Y_{F,t}^* \ , \tag{5.31}$$

$$X_{F,t}^* = C_{F,t}^* = \frac{1}{1+\frac{\alpha}{1-\alpha^*}(1-\Xi)^{\eta-1}} Y_{F,t}^* \ . \tag{5.32}$$

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 Galí and Monacelli (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.[22] For the elasticity of substitution between domestic and foreign goods, Chari et al. (2001) report values between one and two.[23] 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.[24] 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,[25] symmetry does not hold for the extended Galí and Monacelli (2002) model.

[22]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.

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

[24]Obstfeld and Rogoff (2000*b*), p. 7.

[25]Obstfeld and Rogoff (2000*b*), pp. 22-26.

5.6.4 Low International Consumption Correlation

In the DIT case, $\mathrm{Corr}(c_t, c_t^*) = 0.92$, whereas $\mathrm{Corr}(y_t, y_t^*) = 0.77$ for the benchmark trade costs $\Xi = 0.25$. That implies a movement in the right direction: output correlation rises, whereas consumption correlation declines. For higher values of the trade costs the correlations converge: $\Xi = 0.35$ results in $\mathrm{Corr}(c_t, c_t^*) = 0.90$ and $\mathrm{Corr}(y_t, y_t^*) = 0.78$, $\Xi = 0.55$ in $\mathrm{Corr}(c_t, c_t^*) = 0.80$ and $\mathrm{Corr}(y_t, y_t^*) = 0.84$. 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.[26] 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 $\mathrm{Corr}(c_t, c_t^*) = 0.20$ and $\mathrm{Corr}(y_t, y_t^*) = 0.53$, and $\Xi = 0.45$, $\rho_{a,a^*} = 0.5$ and $\alpha = 0.3$ results in $\mathrm{Corr}(c_t, c_t^*) = 0.54$ and $\mathrm{Corr}(y_t, y_t^*) = 0.59$. 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,[27] 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 $\mathrm{Corr}(c_t, c_t^*) = 0.46$ and $\mathrm{Corr}(y_t, y_t^*) = 0.54$.

5.6.5 Purchasing Power Parity

The influence of trade costs in the DIT-model on the standard deviation of the real exchange rate as shown in table 5.2 qualitatively moves the model in the right direction: the benchmark trade costs of 25 percent raise the

[26] See Backus et al. (1995), p. 336, table 11.2.
[27] See OECD (2002), p. 272.

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 5.2 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.

5.6.6 Exchange Rate Disconnect

The first dimension of the disconnect puzzle, the relation between exchange rate volatility and the volatility of other macroeconomic aggregates, has not changed very much. The standard deviation of both nominal and real exchange rate is still much lower than the standard deviations of the underlying productivity shocks, as table 5.1 shows. Nonetheless, trade costs have slightly increased the exchange rate volatility. The real (nominal) exchange rate standard deviation rises from 0.30 (0.51) percent in the basic model – as documented in table 3.2 – 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 Obstfeld and Rogoff (2000*b*) calibration, the standard deviations again fall down to 0.20 (0.12) percent.[28] The results for the second dimension, i.e., the correlation of exchange rates with fundamentals, are reported in table 5.2.[29] 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 Obstfeld and Rogoff (2000*b*) calibration in the last column of table 5.2 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.

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

[29]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 5.2: 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	"O-R"
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 Corr(v_t, v_{t-1})						
Nominal exchange rate	———		0.7119		———	
Real exchange rate	———		0.7119		———	
Correlation with the Real Exchange Rate 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: "O-R": Calibration of Obstfeld and Rogoff (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 Galí and Monacelli (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.

Chapter 6

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, Galí and Monacelli (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.

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

As mentioned in section 3.2.3, 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 dimensions mentioned. Both have the same productivity correlation with U.S. productivity (0.35),[1] and both have roughly the same import share of slightly more than 20 percent.[2] The implications of this setup are shown in the fifth column of table 6.1. In particular, both exchange rates become about twice as volatile.[3] 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 Obstfeld and Rogoff (2000*a*) also see in their traded-nontraded goods model.[4] Net exports are now negatively correlated with output as in the data, but counter-factually positively with the real interest rate.[5] So we see that this setup takes a big step to solve puzzle 5 (PPP), but (with DIT) at the expense of puzzle two ($\mathrm{Corr}(nx_t, r_t^{\mathrm{CPI}})$)

6.2 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. Obstfeld and Rogoff (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,[6] 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.[7] Nonetheless, we test the $\eta = 6$, $\Xi = 0.25$ setup – the "baseline case"[8] – and hope that this setup leads to an improvement to solve the puzzles. But the insipid findings presented in the sixth column of table 6.1 do not show an overall improvement worth mentioning. The pros are more volatile net exports and consumption

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

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

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

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

[5] Note that this is not true with CIT and PEG, where the correlation coefficient becomes -0.48.

[6] See Obstfeld and Rogoff (2000*b*), p. 7.

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

[8] Obstfeld and Rogoff (2000*b*), p. 6.

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.

6.3 High Risk Aversion

Two values were quite unclear in section 3.2.3. 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 6.1 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.[9] 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.

6.4 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,[10] we will have a look at the labor supply elasticity in greater detail. As has been argued in section 3.2.3, 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?[11] 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 6.1.

[9] See section 4.6.

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

[11] Galí and Monacelli (1999), p. 13.

6.5 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.[12] 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 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,[13] we can increase the percentage of ice-cream that melts while one is returning to one's towel.[14] And if a critical voice throws in that ice-cream is tradable, we will calmly answer: true, but there *are* things hardly tradable, and if we do not want to artificially divide goods in tradables and nontradables, we have to face the generally high trade costs in our model, even if they are a bitter pill to swallow. For the sake of the argument, let us assume $\Xi = 0.5$, i.e., trade costs of 50 percent.[15] Implementing $\Xi = 0.4$ in the model yields results that are compactly presented in the ninth column of table 6.1. 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. But remembering the strange result in section 4.2, a look at the results for different monetary policy rules in the small open economy shows reverse results ($\mathrm{Corr}(nx_t, r_t^{\mathrm{CPI}}) = -0.56$) for CPI targeting and the peg.[16] So this critical outcome might change with a better, unifying assumption for monetary policy.

[12] 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.

[13] See section 5.2 and Obstfeld (2000).

[14] Remember the little story in section 5.2, close to the "iceberg" shipping costs explanation in Obstfeld and Rogoff (2000*b*), p. 5.

[15] 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.

[16] The correlation coefficients between net exports and the real interest rate spread, as used in the chapters before, are similar: -0.56 for CIT and -0.53 for PEG.

6.6 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*.[17] In the same manor, we choose the productivity correlation with U.S. productivity, as given in Backus et al. (1995).[18] With σ set as in section 6.3, 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 6.1, 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, net exports nearly perfectly positive. Furthermore, net exports are now positively correlated with the real interest rate, now for DIT as well as for PEG (0.59) – only the CIT result is negative (-0.70). 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 $\text{Corr}(q_t, c_t) = 0.92$ – a value not found in the data.[19] 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. We should decide very carefully which number to assume for Ξ!

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

[18] 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.

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

Table 6.1: Business Cycle Comparison of Different DIT-Model Parameterizations

Statistics and Variable	Data	Basic Model	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 Obstfeld and Rogoff (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.

6.7 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 Obstfeld and Rogoff (2000*b*). Instead, the result depends on *a*) the monetary policy in the small open economy, and *b*) the degree of openness or the value of the trade costs parameter Ξ. While we do not yet see the underlying principle for the changes for different monetary policies, the change in the sign in case *b*) 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 Obstfeld and Rogoff (2000*b*) paper. In section 5.6.4 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 6.3. 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.

Chapter 7

Summary and Conclusion

Can the New Keynesian Open Economy Models explain the Six Major Puzzles in International Macroeconomics, as documented in Obstfeld and Rogoff (2000*b*)? We have addressed this question on the basis of the model by Galí and Monacelli (2002). 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 difficult to interpret. Different monetary policies lead to a different sign in the coefficients for the correlation between net exports and the real interest rate spread – the "translation" of the investment-savings correlation proposed by Obstfeld and Rogoff (2000*b*). With a DIT policy this coefficient is negative as predicted and shown by Obstfeld and Rogoff,[1], with CIT and PEG it is positive. Thus, we *can* say that there is a strong relation linking net exports and the real interest rate, but for some monetary policy rules this relation contradicts the theory and the data.[2] 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" [3] 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.

With this knowledge, we introduced trade costs for a single, but strong reason: Obstfeld and Rogoff (2000*b*) supposed that a model with trade costs

[1] Obstfeld and Rogoff (2000*b*), pp. 13-20 and table 2 on p. 57.

[2] We do not dare to say that the CIT and PEG policies or the DIT policy were counterfactual, since the model assumption of a fixed capital stock and exogenous investment (see section 3.2.3) is quite strong – maybe results change in a different setting.

[3] Obstfeld and Rogoff (2000*b*), p. 33.

could solve all the puzzles and take away all the pain of macroeconomists coming from these six puzzles. With one exception: the volatility problem of the real exchange rate is not expected to be completely solved by trade costs. Having modified the model and analyzed the usual features, we intensely looked at the results, and got the following impression: trade costs change the model for the better, but in general not too much. The Feldstein-Horioka correlation coefficient becomes slightly more significant for DIT, but is still wrong for the other polices. 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 round and shows the right sign for CIT and PEG, but the wrong for DIT.[4] Clearly, some further investigation on this policy dependency would be of interest. 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 5.6.4 and in principle again in section 6.5, 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

[4]See sections 6.1 and 6.5.

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), Obstfeld and Rogoff (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.[5] 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 have to be included in this set, possibly also a friction to the law of one price: Devereux and Engel (2002) point out that a low exchange rate pass-through is necessary for a volatile but disconnected real exchange rate. Maybe this is a good way to proceed with our model to solve the "six puzzles". And if a solution to all of them is found, then for sure there are nine new puzzles for the three country models to be built in the future.

[5]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.

Bibliography

[1] Anderson, James E., and Eric van Wincoop (2001): "Gravity with Gravitas: A Solution to the Border Puzzle", National Bureau of Economic Research Working Paper 8079.

[2] Bacchetta, Philippe, and Eric van Wincoop (2000): "Does Exchange Rate Stability Increase Trade and Welfare?", *American Economic Review*, vol. 90, 1093-1109.

[3] Backus, David K., Patrick J. Kehoe and Finn E. Kydland (1995): "International Business Cycles: Theory and Evidence", in *Frontiers of Business Cycle Research*, edited by Thomas F. Cooley, Princeton, Princeton University Press.

[4] Backus, David K., and Gregor W. Smith (1993): "Consumption and Real Exchange Rates in Dynamic Economies with Non-traded Goods", *Journal of International Economics*, vol. 35, 297-316.

[5] Benigno, Pierpaolo (2001): "Optimal Monetary Policy in a Currency Area", mimeo, New York University.

[6] Benigno, Gianluca, and Pierpaolo Benigno (2000): "Price Stability as a Nash Equilibrium in Monetary Open-Economy Models", mimeo, Bank of England and New York University.

[7] Betts, Caroline, and Michael B. Devereux (1996): "The Exchange Rate in a Model of Pricing-to-Market", *European Economic Review*, vol. 40 (April), 1007-1021.

[8] Betts, Caroline, and Michael B. Devereux (2000): "Exchange Rate Dynamics in a Model of Pricing-to-Market", *Journal of International Economics*, vol. 50 (1), 215-244.

[9] Blanchard, Olivier, and Stanley Fischer (1989): *Lectures on Macroeconomics*, Cambridge, Mass., MIT Press.

[10] Burda, Michael C., and Charles Wyplosz (1997): *Macroeconomics: a European text*, Oxford, Oxford University Press.

[11] Calvo, Guillermo (1983): "Staggered Prices in a Utility Maximizing Framework", *Journal of Monetary Economics*, vol. 12, 383-398.

[12] Chari, V.V., Lawrence J. Christiano, and Patrick J. Kehoe (1995): "Policy Analysis in Business Cycle Models", in *Frontiers of Business Cycle Research*, edited by Thomas F. Cooley, Princeton, Princeton University Press.

[13] Chari, V.V., Patrick J. Kehoe, and Ellen R. McGrattan (1998): "Sticky Price Models of the Business Cycle: Can the Contract Multiplier Solve the Persistence Problem?", Research Department Staff Report 217/JV, Federal Reserve Bank of Minneapolis; also in *Econometrica*, vol. 68 (September 2000), 1151 - 1179.

[14] Chari, V.V., Patrick J. Kehoe, and Ellen R. McGrattan (2001): "Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates?", Research Department Staff Report 277, Federal Reserve Bank of Minneapolis; revised version of "Monetary Shocks and Real Exchange Rates in Sticky Price Models of International Business Cycles", National Bureau of Economic Research Working Paper 5876, 1997.

[15] Chiang, Alpha C. (1984): *Fundamental Methods of Mathematical Economics*, Auckland et al., McGraw-Hill.

[16] Clarida, Richard, Jordi Galí, and Mark Gertler (1999): "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature*, vol. 37, 1661-1707.

[17] Cochrane, John H. (1997): "Where is the market going? Uncertain facts and novel theories", *Economic Perspectives*, Nov./Dec., Federal Reserve Bank of Chicago.

[18] Cooley, Thomas F., and Gary D. Hansen (1995): "Money and the Business Cycle", in *Frontiers of Business Cycle Research*, edited by Thomas F. Cooley, Princeton, Princeton University Press.

[19] Cooley, Thomas F., and Edward C. Prescott (1995): "Economic Growth and Business Cycles", in *Frontiers of Business Cycle Research*, edited by Thomas F. Cooley, Princeton, Princeton University Press.

[20] Devereux, Michael B., and Charles Engel (2002): "Exchange Rate Pass-Through, Exchange Rate Volatility, and Exchange Rate Disconnect", mimeo.

[21] Dornbusch, Rudiger, and Alberto Giovannini (1990): "Monetary Policy in the Open Economy", in *Handbook of Monetary Economics*, vol. 2, edited by Benjamin M. Friedman, and Frank. H. Hahn, Amsterdam, Elsevier Science.

[22] Engel, Charles (1999): “Accounting for U.S. Real Exchange Rate Changes”, *Journal of Political Economy*, vol. 107 (June), 507-538.

[23] Engel, Charles (2000): “Comments on Obstfeld and Rogoff’s ’The Six Major Puzzles in International Macroeconomics: Is there a common cause?’”, National Bureau of Economic Research Working Paper 7818. (Also in *NBER Macroeconomics Annual 2000*, edited by Ben S. Bernanke, and Kenneth Rogoff, Cambridge, Mass., MIT Press, 403-411.)

[24] Erceg Christopher J., D.W. Henderson, and A.T. Levine (2000): “Optimal Monetary Policy with Staggered Wage and Price Contracts,” *Journal of Monetary Economics*, vol. 46, 281-313.

[25] Feldstein, Martin, and Charles Horioka (1980): “Domestic Savings and International Capital Flows”, *Economic Journal*, vol. 90 (June), 314-329.

[26] Flood, Robert P., and Andrew K. Rose (1995): “Fixing Exchange Rates. A Virtual Quest for Fundamentals”, *Journal of Monetary Economics*, vol. 36, 3-37.

[27] Galí, Jordi (2001): “New Perspectives on Monetary Policy, Inflation, and the Business Cycle”, forthcoming in *Advances in Economic Theory*, edited by L. Hansen, and S. Turnovsky, Cambridge, Mass., Cambridge University Press. (Also National Bureau of Economic Research Working Paper 8767).

[28] Galí, Jordi, and Tommaso Monacelli (1999): “Optimal Monetary Policy and Exchange Rate Volatility in a Small Open Economy”, mimeo, Universitat Pompeu Fabra.

[29] Galí, Jordi, and Tommaso Monacelli (2002): “Monetary Policy and Exchange Rate Volatility in a Small Open Economy”, National Bureau of Economic Research Working Paper 8905.

[30] Goodfriend, Marvin, and Robert G. King (2001): “The Case for Price Stability”, in *Why Price Stability?*, edited by A. Garcia-Herrero et al., Frankfurt am Main, European Central Bank.

[31] Hau, Harald (2001): “Real Exchange Rate Volatility and Economic Openness: Theory and Evidence”, *Journal of Money, Credit and Banking*, forthcoming.

[32] Jeanne, Olivier (2000): “Comment [on Obstfeld and Rogoff’s ’The Six Major Puzzles in International Macroeconomics: Is there a common cause?’]”, in *NBER Macroeconomics Annual 2000*, edited by Ben S.

Bernanke, and Kenneth Rogoff, Cambridge, Mass., MIT Press, 390-403.

[33] Kollmann, Robert (2001): "The Exchange Rate in a Dynamic Optimizing Current Account Model with Nominal Rigidities: A Quantitative Investigation," *Journal of International Economics* vol. 55, 243-262.

[34] Kollmann, Robert (2002): "Monetary Policy Rules in the Open Economy: Effects on Welfare and the Business Cycle", mimeo.

[35] Krugman, Paul R., and Maurice Obstfeld (2000): *International Economics: Theory and Policy*, Reading, Mass., Addison-Wesley.

[36] Lane, Philip R. (2000): "The New Open Economy Macroeconomics: A Survey", *Journal of International Economics*, vol. 54, 235-266.

[37] Lütkepohl, Helmut (1991): *Introduction to Multiple Time Series Analysis*, Berlin et al., Springer-Verlag.

[38] Mankiw, Gregory N. (2001): *Principles of Economics*, Fort Worth et al., Harcourt College Publishers.

[39] Mankiw, Gregory N., and David Romer (1991): "Introduction", in *New Keynesian Economics*, vol. 1, *Imperfect Competition and Sticky Prices*, edited by Gregory N. Mankiw, and David Romer, Cambridge, Mass., MIT Press.

[40] McCallum, Bennet T., and Edward Nelson (2001): "Monetary Policy for an Open Economy: An Alternative Framework with Optimizing Agents and Sticky Prices", National Bureau of Economic Research Working Paper 8175.

[41] McCallum, John (1995): "National Borders Matter: Canada-U.S. Regional Trade Patterns", *American Economic Review*, vol. 85 (June), 615-623.

[42] Monacelli, Tommaso (2000): "Into the Mussa Puzzle: Monetary Policy Regimes and the Real Exchange Rate in a Small Open Economy", mimeo, Boston College.

[43] Monacelli, Tommaso (2002): "Monetary Policy in a Low Pass-Through Environment", mimeo, IGIER Bocconi and Boston College.

[44] Mussa, Michael (1986): "Nominal Exchange Rate Regimes and the Behavior of Real Exchange Rates: Evidence and Implications", *Carnegie-Rochester Series on Public Policy*, vol. 25, 117-214.

[45] Obstfeld, Maurice (2000): "International Macroeconomics: Beyond the Mundell-Flemming Model", *International Monetary Fund Staff Papers*, vol. 47 (Special Issue 2001), 1-39.

[46] Obstfeld, Maurice, and Kenneth Rogoff (1995): "Exchange Rate Dynamics Redux", *Journal of Political Economy*, vol. 103, 624-660.

[47] Obstfeld, Maurice, and Kenneth Rogoff (1996): *Foundadtions of International Macroeconomics*, Cambridge, Mass., MIT Press.

[48] Obstfeld, Maurice, and Kenneth Rogoff (2000*a*): "New Directions for Stochastic Open Economy Models", *Journal of International Economics*, vol. 50, 117-153.

[49] Obstfeld, Maurice, and Kenneth Rogoff (2000*b*): "The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?", National Bureau of Economic Research Working Paper 7777. (Also in *NBER Macroeconomics Annual 2000*, edited by Ben S. Bernanke, and Kenneth Rogoff, Cambridge, Mass., MIT Press, 339-390.)

[50] Organization for Economic Co-operation and Development (OECD) (2002): "Basic Structural Statistics", in *Main Economic Indicators*, August, 272-275.

[51] Rogoff, Kenneth (1996): "The Purchasing Power Parity Puzzle", *Journal of Economic Literature*, vol. 34 (June), 647-668.

[52] Romer, David (1996): *Advanced Macroeconomics*, New York et al., McGraw-Hill.

[53] Rotemberg, Julio J., and Michael Woodford (1995): "Dynamic General Equilibrium Models with Imperfectly Competitive Markets", in *Frontiers of Business Cycle Research*, edited by Thomas F. Cooley, Princeton, Princeton University Press.

[54] Samuelson, Paul A., and William D. Nordhaus (1998): *Economics*, 16th, international edition, Boston et al., Irwin/McGraw-Hill.

[55] Sarno, Lucio (2000): "Towards a New Paradigm in Open Economy Modeling: Where Do We Stand?", mimeo.

[56] Schmitt-Grohé, Stephanie, and Martín Uribe (2001): "Optimal Fiscal and Monetary Policy Under Sticky Prices", mimeo.

[57] Svensson, Lars, and Sweder van Wijnbergen (1989): "Excess Capacity, Monopolistic Competition and International Transmission of Monetary Disturbances", *Economic Journal*, vol. 99, 785-805.

[58] Taylor, John B. (1980): “Aggregate Dynamics and Staggered Contracts”, *Journal of Political Economy*, vol. 88, 1-23.

[59] Tesar, Linda L., and Ingrid M. Werner (1998): “The Internationalization of Securities Markets since the 1987 Crash”, in *Brookings-Wharton papers on Financial Services*, edited by Robert E. Litan, and Anthony M. Santomero, Washington, The Brookings Institution.

[60] Uhlig, Harald (1995): “A Toolkit for Analyzing Nonlinear Dynamic Stochastic Models easily,” in *Computational Methods for the Studies of Dynamic Economies*, edited by Ramon Marimon, and Andrew Scott, Oxford, Oxford University Press 1999, 30-61.

[61] Woodford, Michael (2002): *Interest and Prices: Foundations of a Theory of Monetary Policy*, in preparation for Princeton University Press.

[62] Yun, Tack (1996): “Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycles”, *Journal of Monetary Economics*, vol. 37, 345-370.

Appendix A

Mathematics

A.1 Price Setting

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.

$$\max_{\overline{P}_{H,t}} \sum_{k=0}^{\infty} \theta^k E_t\{Q_{t,t+k}[Y_{t+k}(\overline{P}_{H,t} - MC^n_{t+k})]\} \ , \tag{A.1}$$

$$\text{s.t.} \quad Y_{t+k} \leq \left(\frac{\overline{P}_{H,t}}{P_{H,t+k}}\right)^{-\varepsilon} (C_{H,t+k} + C^*_{H,t+k}) \ . \tag{A.2}$$

The according first order condition is

$$\sum_{k=0}^{\infty} \theta^k E_t\{Q_{t,t+k} Y_{t+k}(\overline{P}_{H,t} - \frac{\varepsilon}{\varepsilon - 1} MC^n_{t+k})\} = 0 \ . \tag{A.3}$$

Log-linearizing around the zero inflation, perfect foresight, balanced trade steady state and a lot of rearranging leads to

$$\overline{p}_{H,t} - p_{H,t-1} = \beta\theta E_t\{\overline{p}_{H,t+1} - p_{H,t}\} + \pi_{H,t} + (1-\beta\theta)(mc_t + \mu) \tag{A.4}$$

and can be transformed via $mc_t = mc^n_t - p_{H,t}$ and forward solving to get (3.12) in section 3.1.3. From the Calvo style price setting it follows immediately that

$$P_{H,t} \equiv [\theta P^{1-\varepsilon}_{H,t-1} + (1-\theta)\overline{p}^{1-\varepsilon}_{H,t}]^{\frac{1}{1-\varepsilon}} \ . \tag{A.5}$$

Log-linearizing this equation, combined with (A.4), gives rise to (3.26) in section 3.2.1.

A.2 Domestic Output Dynamics

Market clearing for domestic product i implies that it will be consumed at home or abroad: $Y_t(i) = C_{H,t}(i) + C^*_{H,t}(i)$. The equations for an optimal allocation (3.13) and (3.14), together with analogs for the world economy are used to rewrite this equation in terms of domestic and world consumption of all goods:

$$Y_t(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\varepsilon} \left[\left(\frac{P_{H,t}}{P_t}\right)^{-\eta}(1-\alpha)C_t + \left(\frac{P_{H,t}}{\mathcal{E}_t P^*_t}\right)^{-\eta}\alpha^* Y^*_t\right] , \quad \text{(A.6)}$$

where $P_{H,t}(i)/P_{H,t} = P^*_{H,t}(i)/P^*_{H,t}$ is assumed and $C^*_t = Y^*_t$ as in section 3.2.1 is used. With (3.18) C_t can be replaced by $\vartheta C^*_t \mathcal{Q}_t^{\frac{1}{\sigma}} = \vartheta Y^*_t \mathcal{Q}_t^{\frac{1}{\sigma}}$ to get:

$$Y_t(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\varepsilon} \vartheta Y^*_t \left[\left(\frac{P_{H,t}}{P_t}\right)^{-\eta}(1-\alpha)\mathcal{Q}_t^{\frac{1}{\sigma}} + \left(\frac{P_{H,t}}{\mathcal{E}_t P^*_t}\right)^{-\eta}\alpha\right] . \quad \text{(A.7)}$$

Since aggregate output is defined by $Y_t \equiv \left(\int_0^1 Y_t(i)^{1-\frac{1}{\varepsilon}} di\right)^{\frac{\varepsilon}{\varepsilon-1}}$, we can include (A.7) into this definition. Since the integral applies only to the numerator of the first factor $P_{H,t}(i)$, defined in (3.4), it can be easily simplified. Keeping in mind that $\frac{P_{H,t}}{P_t} = \frac{P_{H,t}\mathcal{Q}_t}{\mathcal{E}_t P^*_t}$ and $\frac{P_{H,t}}{\mathcal{E}_t P^*_t} = \mathcal{S}_t^{-1}$, the following equation – the same as (3.21) in the text – can be easily get:

$$Y_t = \vartheta Y^*_t \mathcal{S}^\eta_t \left((1-\alpha)\mathcal{Q}_t^{\frac{1}{\sigma}-\eta} + \alpha\right) . \quad \text{(A.8)}$$

Step two is log-linearization around the steady state denoted by a bar, following the principle $Y_t = \overline{Y}e^{y_t} \approx \overline{Y}(1+y_t)$:

$$Y_t = \vartheta Y^*_t \mathcal{S}^\eta_t (1-\alpha)\mathcal{Q}_t^{\frac{1}{\sigma}-\eta} + \vartheta Y^*_t \mathcal{S}^\eta_t \alpha , \quad \text{(A.9)}$$

which around the steady state is well approximated by

$$\overline{Y}(1+y_t) = \vartheta \overline{Y}^* \overline{\mathcal{S}}^\eta (1-\alpha)\overline{\mathcal{Q}}^{\frac{1}{\sigma}-\eta}(1+y^*_t+\eta s_t+(\frac{1}{\sigma}-\eta)q_t) + \vartheta \overline{Y}^* \overline{\mathcal{S}}^\eta \alpha(1+y^*_t \eta s_t) .$$

After dividing by the steady state $\overline{Y} = \vartheta \overline{Y}^*$ – since $\overline{\mathcal{S}} = \overline{\mathcal{Q}} = 1$ – this becomes

$$\begin{aligned}
1 + y_t &= (1-\alpha)(1 + y_t^* + \eta s_t + (\frac{1}{\sigma} - \eta)q_t) + \alpha(1 + y_t^* \eta s_t) \\
&= 1 + y_t^* + \eta s_t + (1-\alpha)(\frac{1}{\sigma} - \eta)q_t \\
&= 1 + y_t^* + s_t \left(\eta + (1-\alpha)^2(\frac{1}{\sigma} - \eta) \right) \\
&= 1 + y_t^* + s_t \frac{1}{\sigma} \left(\sigma\eta + (1-\alpha)^2(1 - \sigma\eta) \right) \\
&= 1 + y_t^* + s_t \frac{1}{\sigma} (\sigma\eta + 1 - 2\alpha + \alpha^2 - \sigma\eta + 2\alpha\sigma\eta - \alpha^2\sigma\eta) \\
&= 1 + y_t^* + s_t \frac{1}{\sigma} \left(1 + \alpha(-2 + \alpha + 2\sigma\eta - \alpha\sigma\eta)\right) \\
&= 1 + y_t^* + s_t \frac{1}{\sigma} \left(1 + \alpha(2-\alpha)(\sigma\eta - 1)\right) \ .
\end{aligned} \tag{A.10}$$

Subtracting the one on both sides of the equation results in (3.22) in the text:

$$y_t = y_t^* + \frac{\omega_\alpha}{\sigma} s_t \ , \quad \omega_\alpha \equiv 1 + \alpha(2-\alpha)(\sigma\eta - 1) \ > 0 \ . \tag{A.11}$$

As a third step, one can use (3.19) to substitute out s_t and get an equation for c_t as follows:

$$c_t = \Phi_\alpha y_t + (1 - \Phi_\alpha) y_t^* \ , \tag{A.12}$$

with the parameter defined as $\Phi_\alpha \equiv \frac{1-\alpha}{\omega_\alpha} > 0$.
In the fourth step, the consumer's Euler equation as given in (3.17) and the previous equations are combined with the first part of (3.9) in differences to obtains a kind of IS curve. The procedure is as follows: on the basis of the household's intertemporal optimality condition (3.17), insert (A.12) for c_t and c_{t+1} and $\pi_t = \pi_{H,t} + \alpha \Delta s_t$ from (3.9) leaded once for π_{t+1}. Second, use (A.11) to substitute out s_{t+1}. Then solve for y_t to obtain (3.24) in the text:

$$y_t = E_t\{y_{t+1}\} - \frac{\omega_\alpha}{\sigma}(r_t - E_t\{\pi_{H,t+1}\} - \rho) + (\omega_\alpha - 1)E_t\{\Delta y_{t+1}^*\} \ . \tag{A.13}$$

A.3 Capital – A Try

To be able to cope with puzzles two and three in a more direct way, one could think of enlarging the model for investment and capital. As Chari et al. (1998) point out, it might possibly be that, "while eliminating the intertemporal links of capital accumulation and interest-sensitive money demand makes developing analytical expressions easy, this procedure can be misleading."[1] In particular, the propagation of monetary shocks for staggered price setting crucially depends on intertemporal links. In a model without capital and interest-sensitive money demand, Chari et al. show a contract multiplier[2] of more than 20 compared to values of about unity in presence of intertemporal links.[3] Although monetary shocks are not assumed in this model, it is nonetheless a question whether capital may change results. The implementation of the intertemporal link through capital accumulation in the Galí and Monacelli (2002) model is begun in the following.

Adding capital to the model requires at first changes in the household's choice and in the firms' production function. The budget constraint of the representative household (3.3), which under optimal allocation simplifies from the integral over all goods' consumption expenditures to $P_t C_t$, now includes investment I_t and capital K_t:

$$P_t(C_t + I_t) + E_t\{Q_{t,t+1} D_{t+1}\} \leq D_t + W_t N_t + T_t + R_t K_{t-1} \ , \qquad \text{(A.14)}$$

where $R_t = 1 + r_t$ is the rental rate of capital and capital accumulation evolves according to:

$$K_t + \frac{1}{2}\phi(K_t K_{t-1})^2 K_{t-1}^{-1} = (1-\delta)K_{t-1} + I_t \ , \qquad \text{(A.15)}$$

with the second part on the left side being adjustment costs for capital which can be ignored by setting $\phi = 0$.[4] The new production function has the standard Cobb-Douglas form $Y_t(i) = A_t K_{t-1}^{\psi}(i) N_t^{1-\psi}(i)$, so instead of (3.11) aggregation and log-linearization gives

$$y_t = a_t + \psi k_{t-1} + (1-\psi) n_t \ . \qquad \text{(A.16)}$$

Cost minimization subject to the given production technology and the law of motion for capital (A.15) results in the nominal marginal costs

$$MC_t^n = A_t^{-1} R_t^{\psi} W_t^{1-\psi} \psi^{-\psi} (1-\psi)^{-(1-\psi)} \ . \qquad \text{(A.17)}$$

[1] Chari et al. (1998), p. 4 and pp. 19-22.

[2] Chari et al. (1998) call the result of staggered price setting in the words of Taylor (1980) "contract multiplier", capturing the fact that firms, when setting their prices for some periods, have to take into account the contracts other firms have made, such that a sudden influence to one contract multiplies in the economy.

[3] Chari et al. (1998), table 2.

[4] This modeling of capital follows Kollmann (2001, 2002), with a difference in the dating: as in Uhlig (1995), capital is dated "one period earlier".

Utility maximizing behavior of the representative household results in a second Euler equation besides (3.16), now via maximizing utility with respect to capital and after inserting its law of motion (A.15) in the budget constraint (A.14:

$$\beta E_t\left(\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{\frac{R_{t+1}}{P_{t+1}}+1-\delta+\frac{1}{2}\phi\left(1+\frac{K_{t+1}^2}{K_t^2}\right)}{1+\phi\frac{K_t-K_{t-1}}{K_{t-1}}}\right)=1\ . \tag{A.18}$$

So far adding capital seems easy. In the following, there are some severe difficulties:

- Galí and Monacelli postulate world output equal to world consumption. If the production function in the rest of the world should also be expanded for capital, this assumption no longer holds. So beginning with (3.20) nearly every equation has not only to be respecified, but also gets a lot more nasty.

- Modeling foreign investment directly seems not to be liked very much: Kollmann (2001, p. 246; 2002, p. 4) supposes capital to be immobile internationally, Monacelli (2000, p. 8) assumes that "foreign investors do not hold assets denominated in domestic currency", Chari et al. (2001, p. 12) assume "that claims to the ownership of firms in each country are held by the residents of that country and cannot be traded." Perhaps it is a better way to find some indirect measure for foreign investment.

Though it would for sure be possible to get results even with the mentioned problems with the use of a computational solution method, it would be at the expense of the model's "elegance and tractability" one of its big advantages.[5] Therefore we lean on Woodford's findings[6] and resist a further investigation.

[5] McCallum and Nelson (2001), p. 11.
[6] Woodford (2002), chapter 3, note 17 on page 29, and chapter 4.

Appendix B

Further Tables and Figures

B.1 General Results and Results for CIT and PEG Policies

Table B.1: Standard Deviations of All the Six Models

		Basic Model			Trade Costs Model		
Variable		DIT	CIT	PEG	DIT	CIT	PEG
Domestic output	y_t	0.9405	0.9405	0.9405	0.9277	0.9277	0.9277
Domestic output gap	$\tilde{y}_t$	0.0000	0.1989	0.2966	0.0000	0.2067	0.3011
World output	y_t^*	0.9260	0.9260	0.9260	0.9260	0.9260	0.9260
Domestic consumption	c_t	0.8712	0.8712	0.8712	0.8728	0.8728	0.8728
Net exports	nx_t	0.1621	0.1621	0.1621	0.0198	0.0198	0.0198
Domestic CPI price level	p_t	0.2026	0	0.2317	0.2453	0.0000	0.2721
Domestic goods price level	$p_{H,t}$	0.0000	0.1732	0.3862	0	0.2056	0.4534
Domestic CPI inflation	π_t	0.1538	0.0000	0.1115	0.1862	0.0000	0.1269
Domestic goods inflation	$\pi_{H,t}$	0.0000	0.0966	0.1859	0.0000	0.1113	0.2114
Nominal exchange rate	e_t	0.5065	0.2598	0	0.6132	0.3083	0
Real exchange rate	q_t	0.3039	0.2598	0.2317	0.3679	0.3083	0.2721
Terms of trade	s_t	0.5065	0.4330	0.3862	0.6132	0.5139	0.4534
Domestic interest rate	r_t	0.0446	0.0721	0.0463	0.0461	0.0828	0.0463
Dom. real CPI interest rate	r_t^{CPI}	0.1636	0.0721	0.1295	0.1972	0.0828	0.1443
World interest rate	r_t^*	0.0463	0.0463	0.0463	0.0463	0.0463	0.0463
Domestic productivity	a_t	0.9260	0.9260	0.9260	0.9260	0.9260	0.9260
World productivity	a_t^*	0.9260	0.9260	0.9260	0.9260	0.9260	0.9260

Notes: DIT: Domestic inflation targeting. CIT: CPI inflation targeting. PEG: Exchange rate peg. The numbers are obtained by frequency-domain based calculations of the HP-filtered series for different policy rules, with the help of the `MOMENTS.M` file within the Toolkit program.

Table B.2: Covariance Matrix of the DIT-Model

Variable	y_t	y_t^*	c_t	nx_t	p_t	$p_{H,t}$	π_t	$\pi_{H,t}$	e_t	q_t	s_t	r_t	r_t^{CPI}	r_t^*	a_t	a_t^*
y_t	0.884	0.647	0.755	0.057	0.072	-0.000	0.021	0.000	0.180	0.108	0.180	-0.041	-0.062	-0.032	0.870	0.647
y_t^*	0.647	0.857	0.762	-0.051	-0.064	0.000	-0.018	0.000	-0.159	-0.095	-0.159	-0.035	-0.017	-0.043	0.660	0.857
c_t	0.755	0.762	0.759	-0.002	-0.002	0.000	-0.001	0.000	-0.005	-0.003	-0.005	-0.038	-0.037	-0.038	0.756	0.762
nx_t	0.057	-0.051	-0.002	0.026	0.033	-0.000	0.009	-0.000	0.082	0.049	0.082	-0.002	-0.011	0.003	0.051	-0.051
p_t	0.072	-0.064	-0.002	0.033	0.041	-0.000	0.012	-0.000	0.103	0.062	0.103	-0.002	-0.014	0.003	0.064	-0.064
$p_{H,t}$	-0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	-0.000	0.000	0.000	-0.000	-0.000	0.000
π_t	0.021	-0.018	-0.001	0.009	0.012	-0.000	0.024	-0.000	0.030	0.018	0.030	-0.001	-0.024	0.001	0.018	-0.018
$\pi_{H,t}$	0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	0.000	0.000
e_t	0.180	-0.159	-0.005	0.082	0.103	-0.000	0.030	-0.000	0.257	0.154	0.257	-0.005	-0.034	0.008	0.159	-0.159
q_t	0.108	-0.095	-0.003	0.049	0.062	-0.000	0.018	-0.000	0.154	0.092	0.154	-0.003	-0.021	0.005	0.095	-0.095
s_t	0.180	-0.159	-0.005	0.082	0.103	-0.000	0.030	-0.000	0.257	0.154	0.257	-0.005	-0.034	0.008	0.159	-0.159
r_t	-0.041	-0.035	-0.038	-0.002	-0.002	0.000	-0.001	-0.000	-0.005	-0.003	-0.005	0.002	0.003	0.002	-0.041	-0.035
r_t^{CPI}	-0.062	-0.017	-0.037	-0.011	-0.014	0.000	-0.024	0.000	-0.034	-0.021	-0.034	0.003	0.027	0.001	-0.059	-0.017
r_t^*	-0.032	-0.043	-0.038	0.003	0.003	-0.000	0.001	-0.000	0.008	0.005	0.008	0.002	0.001	0.002	-0.033	-0.043
a_t	0.870	0.660	0.756	0.051	0.064	-0.000	0.018	0.000	0.159	0.095	0.159	-0.041	-0.059	-0.033	0.857	0.660
a_t^*	0.647	0.857	0.762	-0.051	-0.064	0.000	-0.018	0.000	-0.159	-0.095	-0.159	-0.035	-0.017	-0.043	0.660	0.857

Notes: For the names of the variables see table B.1. 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. The world output gap, world inflation and the domestic output gap are assumed to be perfectly stabilized, therefore they do not show up here.

Table B.3: Business Cycle in the CPI Inflation Targeting Model

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	0.9405	-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	0.1989	-0.06	-0.08	-0.11	-0.15	-0.18	-0.23	0.04	0.12	0.13	0.12	0.11
World output	0.9260	-0.02	0.08	0.20	0.35	0.53	0.74	0.53	0.35	0.20	0.08	-0.02
Domestic consumption	0.8712	-0.02	0.10	0.25	0.43	0.66	0.92	0.66	0.43	0.25	0.10	-0.02
Net exports	0.1621	-0.01	0.04	0.10	0.18	0.27	0.38	0.27	0.18	0.10	0.04	-0.01
Domestic CPI price level	0.0000	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Domestic goods price level	0.1732	0.03	-0.02	-0.08	-0.16	-0.25	-0.36	-0.33	-0.25	-0.16	-0.09	-0.03
Domestic CPI inflation	0.0000	-0.06	-0.03	0.02	0.08	0.16	0.25	0.36	0.33	0.25	0.16	0.09
Domestic goods inflation	0.0966	-0.06	-0.08	-0.11	-0.14	-0.17	-0.20	0.06	0.14	0.15	0.13	0.11
Nominal exchange rate	0.2598	-0.03	0.02	0.08	0.16	0.25	0.36	0.33	0.25	0.16	0.09	0.03
Real exchange rate	0.2598	-0.03	0.02	0.08	0.16	0.25	0.36	0.33	0.25	0.16	0.09	0.03
Terms of trade	0.4330	-0.03	0.02	0.08	0.16	0.25	0.36	0.33	0.25	0.16	0.09	0.03
Domestic interest rate	0.0721	0.06	0.01	-0.06	-0.14	-0.25	-0.38	-0.42	-0.35	-0.25	-0.16	-0.07
Dom. real CPI interest rate	0.0721	0.06	0.01	-0.06	-0.14	-0.25	-0.38	-0.42	-0.35	-0.25	-0.16	-0.07
World interest rate	0.0463	0.02	-0.08	-0.20	-0.35	-0.53	-0.74	-0.53	-0.35	-0.20	-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	0.20	0.35	0.53	0.74	0.53	0.35	0.20	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.

Figure B.1: Impulse Responses of the CPI Inflation Targeting Model

Shock to Domestic Productivity Shock to World Productivity

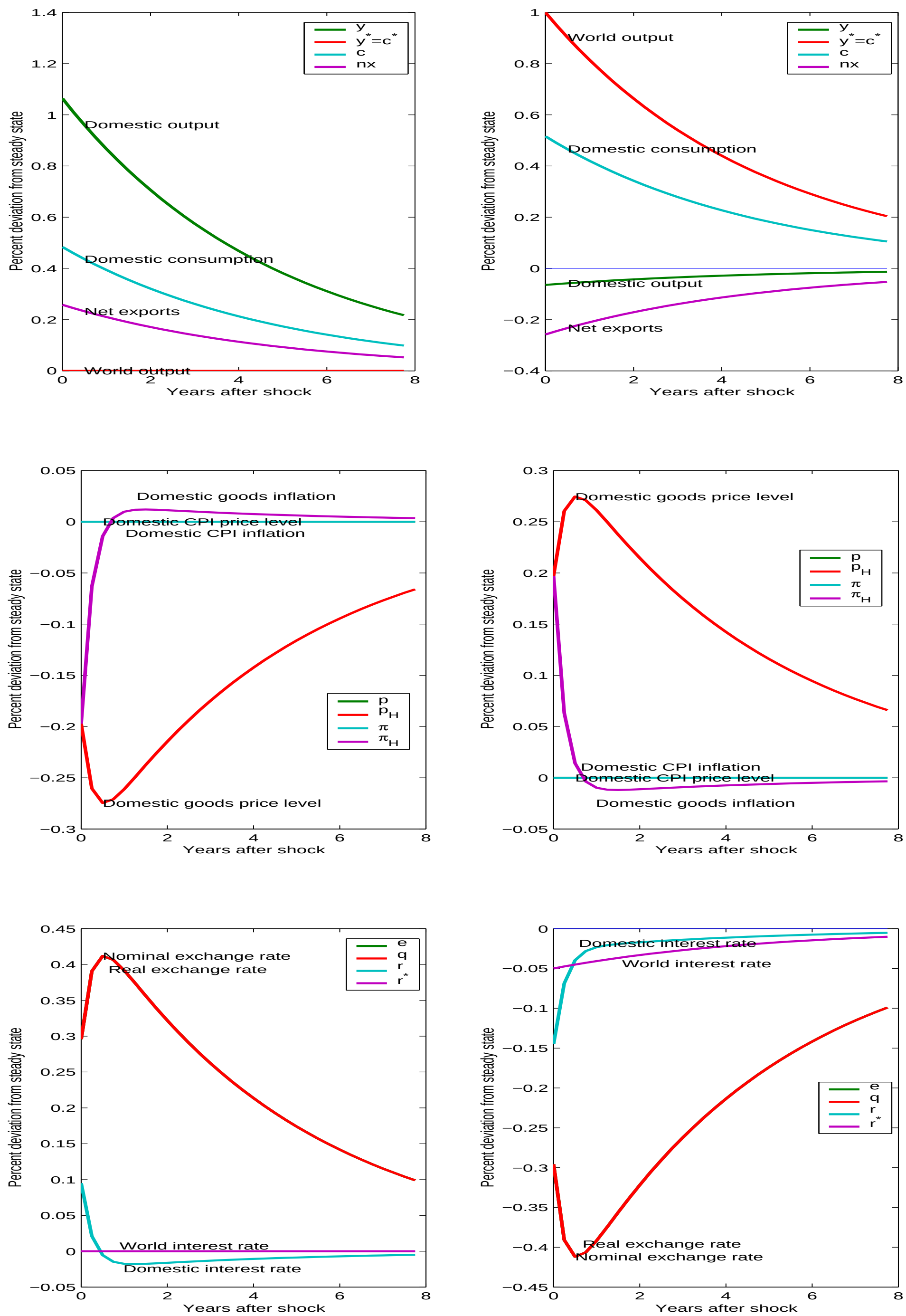


Table B.4: Business Cycle in the Exchange Rate Peg Model

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	0.9405	-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	0.2966	-0.06	-0.09	-0.13	-0.17	-0.21	-0.26	-0.02	0.09	0.13	0.14	0.13
World output	0.9260	-0.02	0.08	0.20	0.35	0.53	0.74	0.53	0.35	0.20	0.08	-0.02
Domestic consumption	0.8712	-0.02	0.10	0.25	0.43	0.66	0.92	0.66	0.43	0.25	0.10	-0.02
Net exports	0.1621	-0.01	0.04	0.10	0.18	0.27	0.38	0.27	0.18	0.10	0.04	-0.01
Domestic CPI price level	0.2317	0.05	0.00	-0.06	-0.13	-0.23	-0.34	-0.34	-0.28	-0.21	-0.13	-0.07
Domestic goods price level	0.3862	0.05	0.00	-0.06	-0.13	-0.23	-0.34	-0.34	-0.28	-0.21	-0.13	-0.07
Domestic CPI inflation	0.1115	-0.07	-0.09	-0.12	-0.16	-0.20	-0.24	0.01	0.12	0.15	0.16	0.14
Domestic goods inflation	0.1859	-0.07	-0.09	-0.12	-0.16	-0.20	-0.24	0.01	0.12	0.15	0.16	0.14
Nominal exchange rate	0.0000	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Real exchange rate	0.2317	-0.05	-0.00	0.06	0.13	0.23	0.34	0.34	0.28	0.21	0.13	0.07
Terms of trade	0.3862	-0.05	-0.00	0.06	0.13	0.23	0.34	0.34	0.28	0.21	0.13	0.07
Domestic interest rate	0.0463	0.02	-0.08	-0.20	-0.35	-0.53	-0.74	-0.53	-0.35	-0.20	-0.08	0.02
Dom. real CPI interest rate	0.1295	0.06	0.05	0.04	0.01	-0.02	-0.06	-0.20	-0.22	-0.20	-0.16	-0.12
World interest rate	0.0463	0.02	-0.08	-0.20	-0.35	-0.53	-0.74	-0.53	-0.35	-0.20	-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	0.20	0.35	0.53	0.74	0.53	0.35	0.20	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.

Figure B.2: Impulse Responses of the Exchange Rate Peg Model

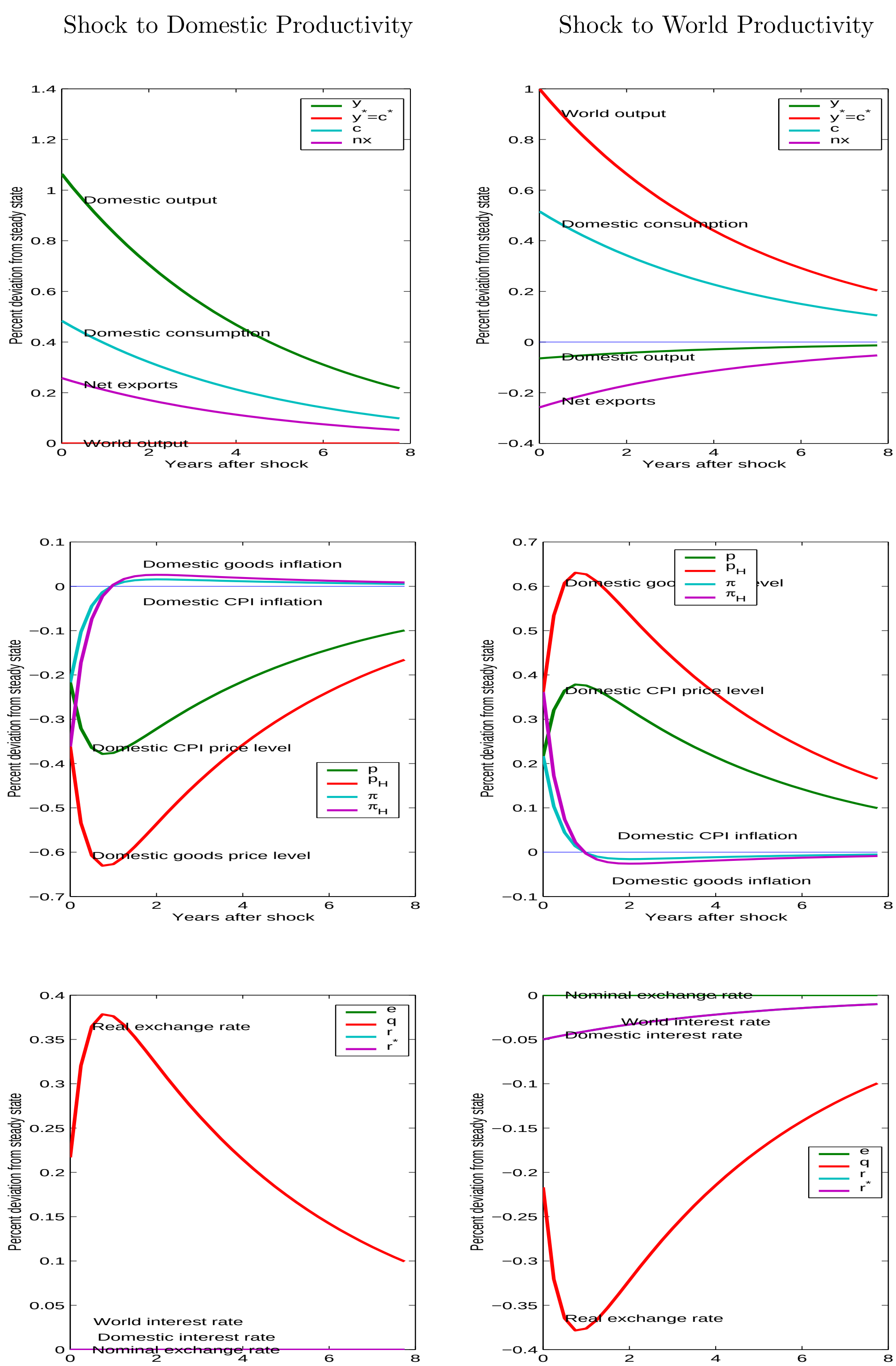


Table B.5: Business Cycle in the CIT-Model with Trade Costs $\Xi = 0.25$

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	0.2067	-0.05	-0.08	-0.11	-0.14	-0.17	-0.21	0.02	0.10	0.12	0.12	0.10
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	0.0000	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	0.2056	0.03	-0.01	-0.07	-0.14	-0.22	-0.33	-0.30	-0.23	-0.16	-0.09	-0.03
Domestic CPI inflation	0.0000	-0.06	-0.03	0.01	0.07	0.14	0.22	0.33	0.30	0.23	0.16	0.09
Domestic goods inflation	0.1113	-0.06	-0.08	-0.10	-0.13	-0.16	-0.19	0.05	0.13	0.14	0.13	0.11
Nominal exchange rate	0.3083	-0.03	0.01	0.07	0.14	0.22	0.33	0.30	0.23	0.16	0.09	0.03
Real exchange rate	0.3083	-0.03	0.01	0.07	0.14	0.22	0.33	0.30	0.23	0.16	0.09	0.03
Terms of trade	0.5139	-0.03	0.01	0.07	0.14	0.22	0.33	0.30	0.23	0.16	0.09	0.03
Domestic interest rate	0.0828	0.06	0.01	-0.04	-0.12	-0.21	-0.32	-0.38	-0.32	-0.24	-0.15	-0.08
Dom. real CPI interest rate	0.0828	0.06	0.01	-0.04	-0.12	-0.21	-0.32	-0.38	-0.32	-0.24	-0.15	-0.08
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.

Figure B.3: Impulse Responses of the CIT-Model with Trade Costs

Shock to Domestic Productivity Shock to World Productivity

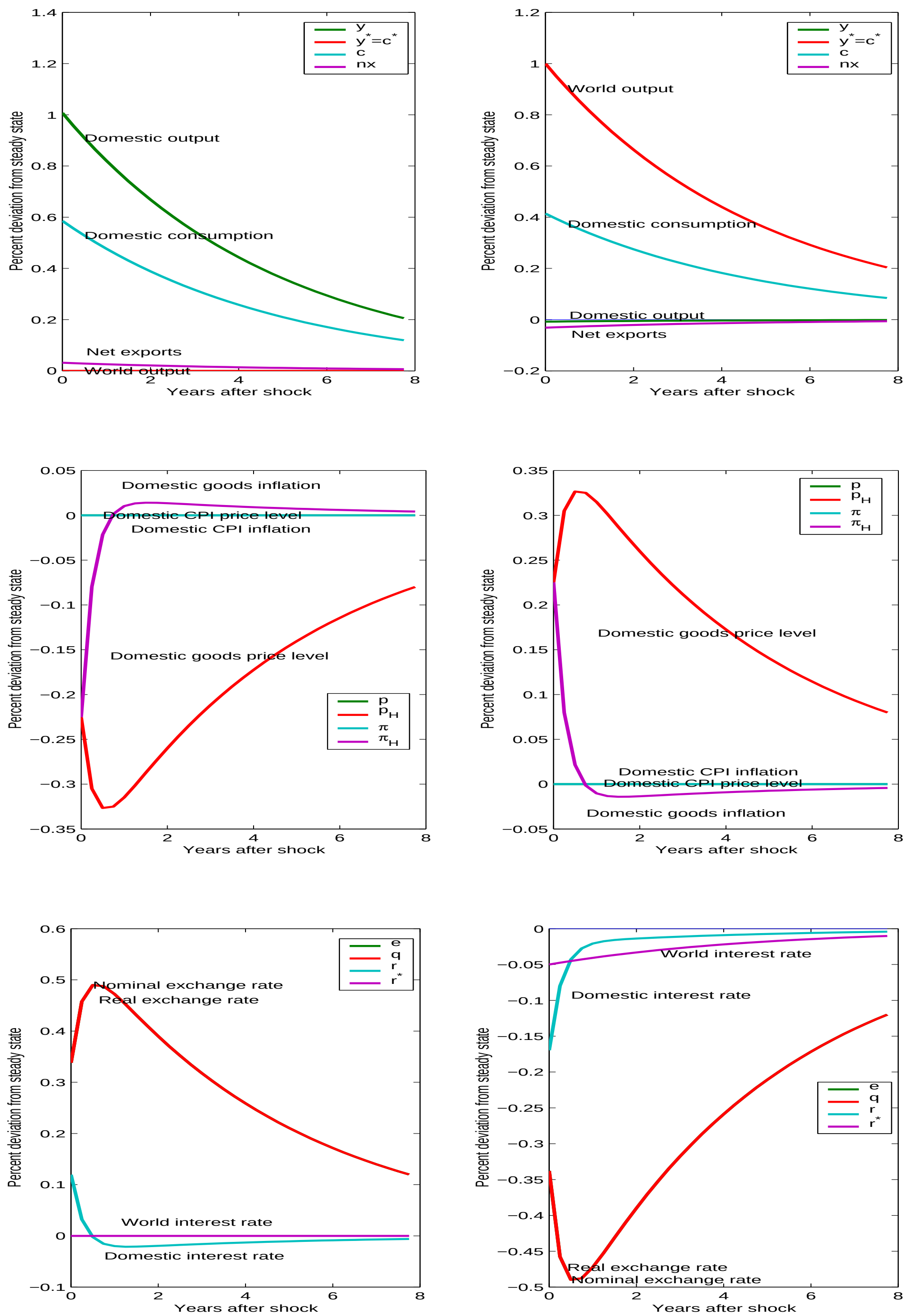


Table B.6: Business Cycle in the PEG-Model with Trade Costs $\Xi = 0.25$

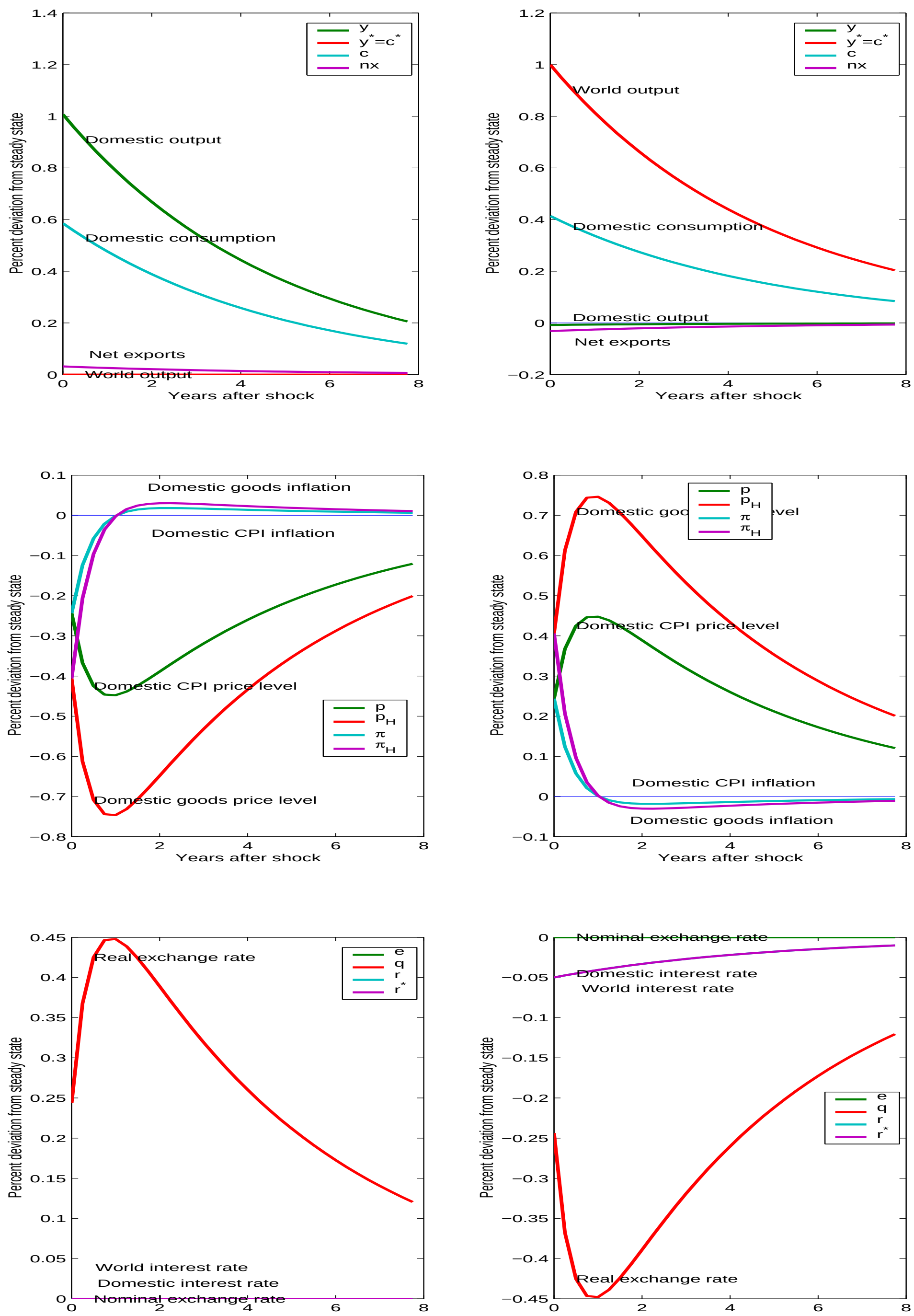
Variable	SD %	Cross-Correlation of Output with:										
		x_{t-5}	x_{t-4}	x_{t-3}	x_{t-2}	x_{t-1}	x_t	x_{t+1}	x_{t+2}	x_{t+3}	x_{t+4}	x_{t+5}
Domestic output	0.9277	-0.02	0.11	0.27	0.47	0.71	1.00	0.71	0.47	0.27	0.11	-0.02
Domestic output gap	0.3011	-0.06	-0.09	-0.12	-0.16	-0.20	-0.25	-0.03	0.07	0.12	0.13	0.12
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	0.2721	0.05	0.01	-0.05	-0.12	-0.20	-0.31	-0.31	-0.26	-0.20	-0.13	-0.07
Domestic goods price level	0.4534	0.05	0.01	-0.05	-0.12	-0.20	-0.31	-0.31	-0.26	-0.20	-0.13	-0.07
Domestic CPI inflation	0.1269	-0.06	-0.09	-0.12	-0.15	-0.18	-0.22	-0.00	0.10	0.14	0.14	0.13
Domestic goods inflation	0.2114	-0.06	-0.09	-0.12	-0.15	-0.18	-0.22	-0.00	0.10	0.14	0.14	0.13
Nominal exchange rate	0.0000	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Real exchange rate	0.2721	-0.05	-0.01	0.05	0.12	0.20	0.31	0.31	0.26	0.20	0.13	0.07
Terms of trade	0.4534	-0.05	-0.01	0.05	0.12	0.20	0.31	0.31	0.26	0.20	0.13	0.07
Domestic 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
Dom. real CPI interest rate	0.1443	0.06	0.05	0.04	0.02	-0.01	-0.05	-0.17	-0.20	-0.19	-0.15	-0.11
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.

Figure B.4: Impulse Responses of the PEG-Model with Trade Costs

Shock to Domestic Productivity

Shock to World Productivity



B.2 Results for the Galí and Monacelli (2002) Calibration

Table B.7: Parameter Values of Galí and Monacelli (2002)

Parameter	Value	Explanation
		Preferences
β	0.99	Discount factor
η	1.00	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;
		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	0.1823	Log of the gross steady state markup
		Processes
σ_ϵ	0.8738	Standard deviation of domestic and world productivity shock
ρ_a	0.90	Autocorrelation of domestic productivity AR(1) process
ρ_a^*	0.90	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 Galí and Monacelli (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.

Table B.8: Business Cycle in the Galí and Monacelli-Calibrated DIT-Model

		Cross-Correlation of Output with:										
Variable	SD %	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	1.1199	-0.05	0.07	0.23	0.44	0.69	1.00	0.69	0.44	0.23	0.07	-0.05
Domestic output gap	0.0000	0.01	-0.02	-0.06	-0.11	-0.18	-0.25	-0.18	-0.11	-0.06	-0.02	0.01
World output	1.1199	-0.04	0.05	0.18	0.34	0.53	0.77	0.53	0.34	0.18	0.05	-0.04
Domestic consumption	1.0563	-0.05	0.07	0.22	0.42	0.67	0.96	0.67	0.42	0.22	0.07	-0.05
Net exports	0.0000	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Domestic CPI price level	0.3038	-0.02	0.02	0.08	0.15	0.23	0.34	0.23	0.15	0.08	0.02	-0.02
Domestic goods price level	0.0000	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Domestic CPI inflation	0.2388	0.04	0.05	0.07	0.09	0.11	0.13	-0.13	-0.11	-0.09	-0.07	-0.05
Domestic goods inflation	0.0000	-0.02	0.02	0.08	0.15	0.23	0.34	0.23	0.15	0.08	0.02	-0.02
Nominal exchange rate	0.7596	-0.02	0.02	0.08	0.15	0.23	0.34	0.23	0.15	0.08	0.02	-0.02
Real exchange rate	0.4557	-0.02	0.02	0.08	0.15	0.23	0.34	0.23	0.15	0.08	0.02	-0.02
Terms of trade	0.7596	-0.02	0.02	0.08	0.15	0.23	0.34	0.23	0.15	0.08	0.02	-0.02
Domestic interest rate	0.1120	0.05	-0.07	-0.23	-0.44	-0.69	-1.00	-0.69	-0.44	-0.23	-0.07	0.05
Dom. real CPI interest rate	0.2770	-0.01	-0.07	-0.15	-0.25	-0.37	-0.52	-0.16	-0.08	-0.02	0.03	0.07
World interest rate	0.1120	0.04	-0.05	-0.18	-0.34	-0.53	-0.77	-0.53	-0.34	-0.18	-0.05	0.04
Domestic productivity	1.1199	-0.05	0.07	0.23	0.44	0.69	1.00	0.69	0.44	0.23	0.07	-0.05
World productivity	1.1199	-0.04	0.05	0.18	0.34	0.53	0.77	0.53	0.34	0.18	0.05	-0.04

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.

Figure B.5: Impulse Responses of the Galí and Monacelli-Calibrated DIT-Model

Shock to Domestic Productivity   Shock to World Productivity

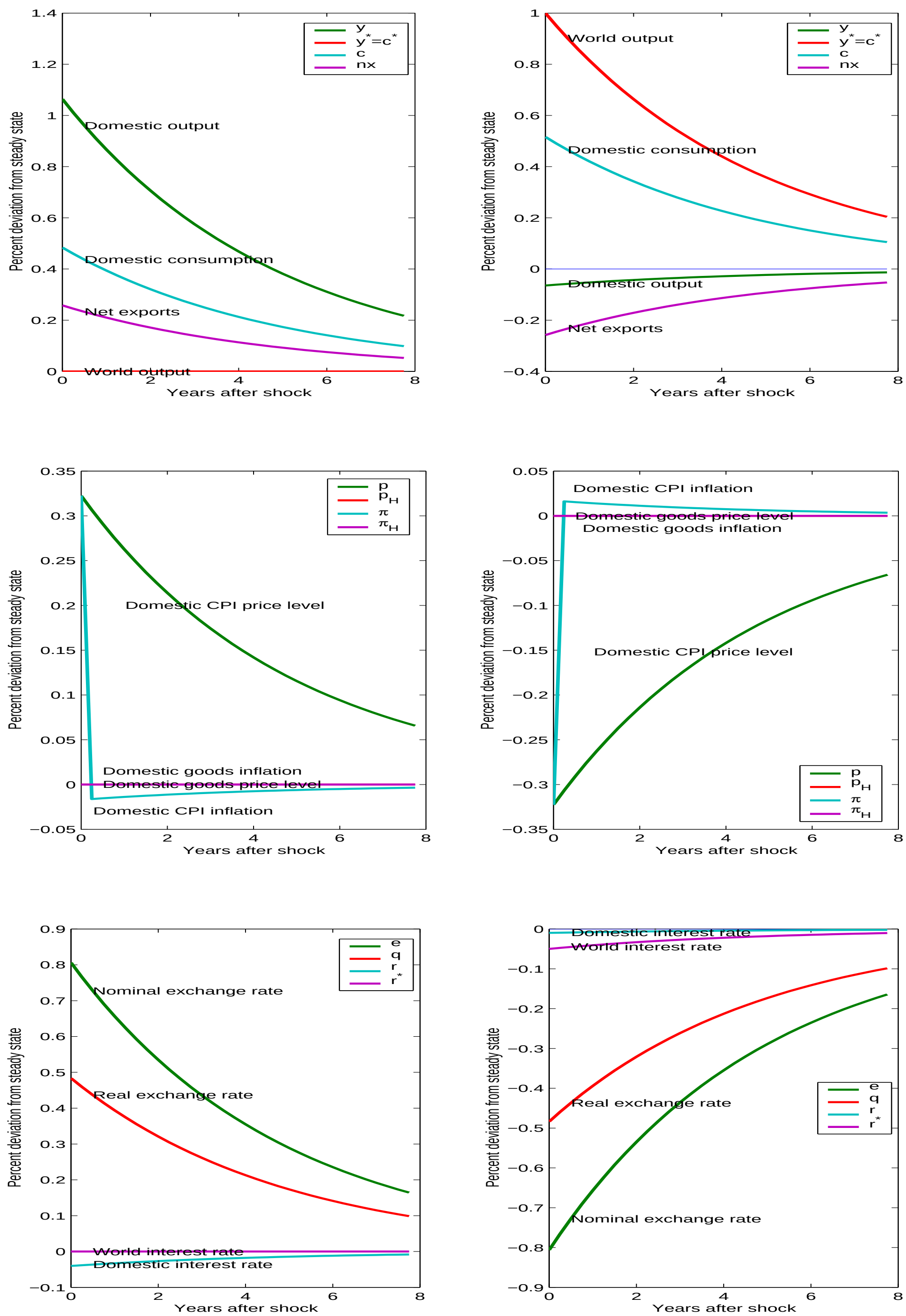


Table B.9: Business Cycle in the Galí and Monacelli-Calibrated CIT-Model

		Cross-Correlation of Output with:										
Variable	SD %	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	1.1199	-0.05	0.07	0.23	0.44	0.69	1.00	0.69	0.44	0.23	0.07	-0.05
Domestic output gap	0.2667	-0.04	-0.07	-0.10	-0.14	-0.18	-0.23	0.00	0.09	0.11	0.11	0.09
World output	1.1199	-0.04	0.05	0.18	0.34	0.53	0.77	0.53	0.34	0.18	0.05	-0.04
Domestic consumption	1.0563	-0.05	0.07	0.22	0.42	0.67	0.96	0.67	0.42	0.22	0.07	-0.05
Net exports	0.0000	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Domestic CPI price level	0.0000	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Domestic goods price level	0.2432	0.04	0.00	-0.05	-0.12	-0.21	-0.32	-0.29	-0.22	-0.15	-0.08	-0.02
Domestic CPI inflation	0.0000	-0.07	-0.04	-0.00	0.05	0.12	0.21	0.32	0.29	0.22	0.15	0.08
Domestic goods inflation	0.1363	-0.05	-0.07	-0.10	-0.13	-0.16	-0.19	0.05	0.13	0.14	0.12	0.10
Nominal exchange rate	0.3647	-0.04	-0.00	0.05	0.12	0.21	0.32	0.29	0.22	0.15	0.08	0.02
Real exchange rate	0.3647	-0.04	-0.00	0.05	0.12	0.21	0.32	0.29	0.22	0.15	0.08	0.02
Terms of trade	0.6079	-0.04	-0.00	0.05	0.12	0.21	0.32	0.29	0.22	0.15	0.08	0.02
Domestic interest rate	0.1396	0.07	-0.00	-0.10	-0.22	-0.37	-0.56	-0.50	-0.37	-0.24	-0.12	-0.03
Dom. real CPI interest rate	0.1396	0.07	-0.00	-0.10	-0.22	-0.37	-0.56	-0.50	-0.37	-0.24	-0.12	-0.03
World interest rate	0.1120	0.04	-0.05	-0.18	-0.34	-0.53	-0.77	-0.53	-0.34	-0.18	-0.05	0.04
Domestic productivity	1.1199	-0.05	0.07	0.23	0.44	0.69	1.00	0.69	0.44	0.23	0.07	-0.05
World productivity	1.1199	-0.04	0.05	0.18	0.34	0.53	0.77	0.53	0.34	0.18	0.05	-0.04

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.

Figure B.6: Impulse Responses of the Galí and Monacelli-Calibrated CIT-Model

Shock to Domestic Productivity

Shock to World Productivity

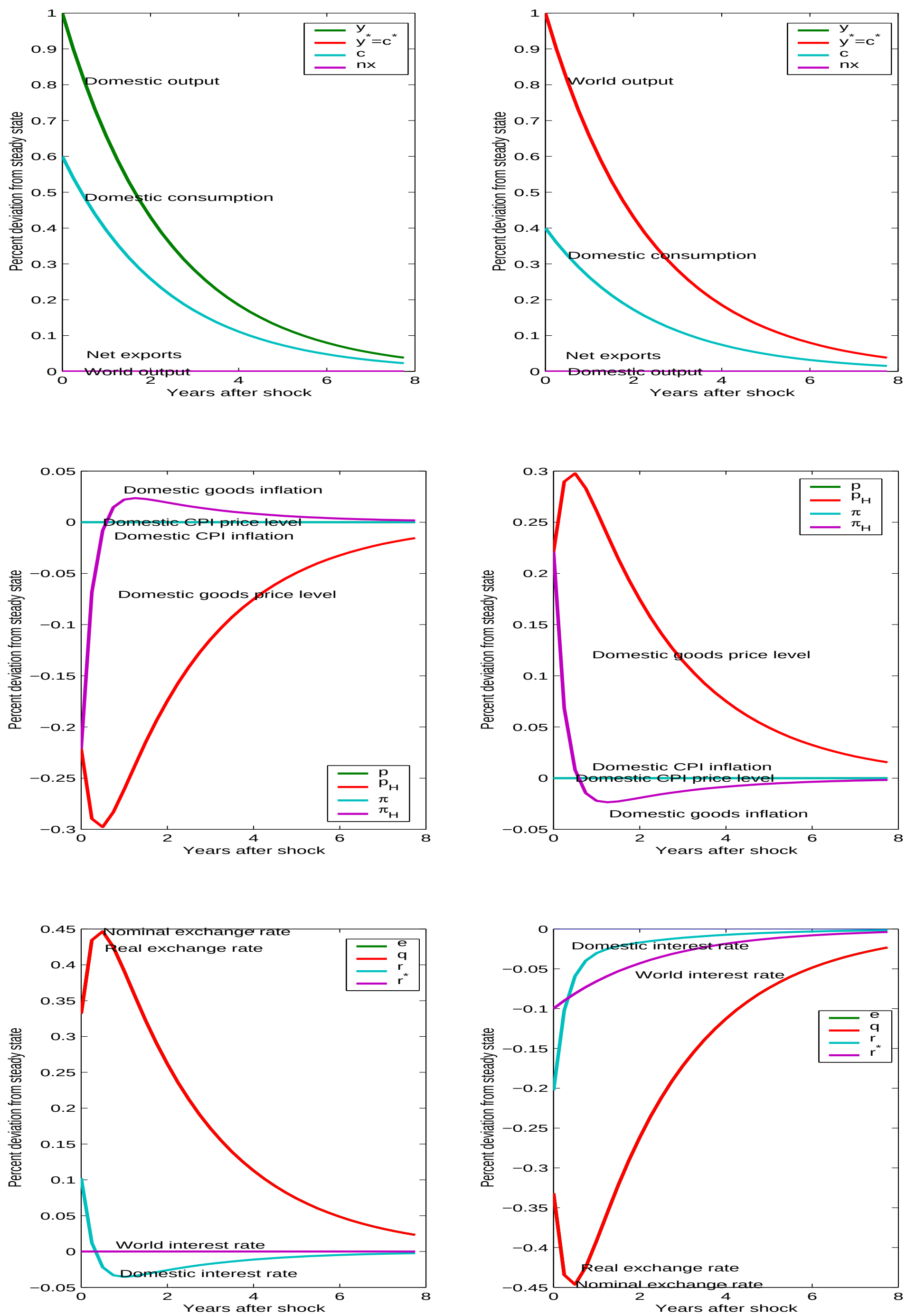


Table B.10: Business Cycle in the Galí and Monacelli-Calibrated PEG-Model

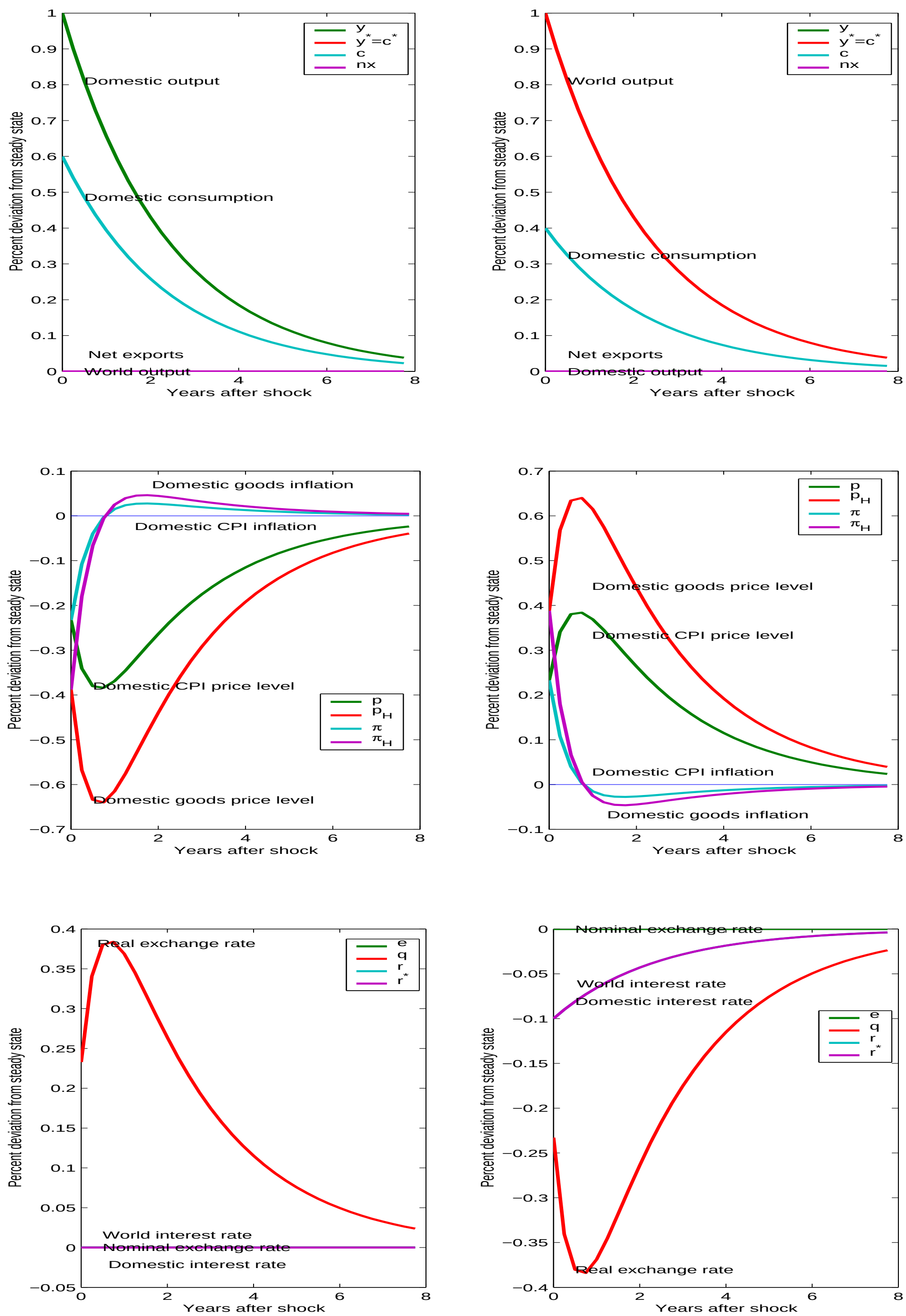
		Cross-Correlation of Output with:										
Variable	SD %	x_{t-5}	x_{t-4}	x_{t-3}	x_{t-2}	x_{t-1}	x_t	x_{t+1}	x_{t+2}	x_{t+3}	x_{t+4}	x_{t+5}
Domestic output	1.1199	-0.05	0.07	0.23	0.44	0.69	1.00	0.69	0.44	0.23	0.07	-0.05
Domestic output gap	0.3851	-0.04	-0.07	-0.11	-0.15	-0.20	-0.26	-0.06	0.05	0.10	0.11	0.11
World output	1.1199	-0.04	0.05	0.18	0.34	0.53	0.77	0.53	0.34	0.18	0.05	-0.04
Domestic consumption	1.0563	-0.05	0.07	0.22	0.42	0.67	0.96	0.67	0.42	0.22	0.07	-0.05
Net exports	0.0000	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Domestic CPI price level	0.3114	0.06	0.02	-0.03	-0.10	-0.19	-0.30	-0.30	-0.25	-0.19	-0.12	-0.06
Domestic goods price level	0.5190	0.06	0.02	-0.03	-0.10	-0.19	-0.30	-0.30	-0.25	-0.19	-0.12	-0.06
Domestic CPI inflation	0.1505	-0.05	-0.08	-0.11	-0.14	-0.18	-0.23	-0.00	0.10	0.14	0.14	0.13
Domestic goods inflation	0.2509	-0.05	-0.08	-0.11	-0.14	-0.18	-0.23	-0.00	0.10	0.14	0.14	0.13
Nominal exchange rate	0.0000	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Real exchange rate	0.3114	-0.06	-0.02	0.03	0.10	0.19	0.30	0.30	0.25	0.19	0.12	0.06
Terms of trade	0.5190	-0.06	-0.02	0.03	0.10	0.19	0.30	0.30	0.25	0.19	0.12	0.06
Domestic interest rate	0.1120	0.04	-0.05	-0.18	-0.34	-0.53	-0.77	-0.53	-0.34	-0.18	-0.05	0.04
Real CPI interest rate	0.2069	0.06	0.03	-0.02	-0.08	-0.16	-0.25	-0.29	-0.25	-0.20	-0.13	-0.07
World interest rate	0.1120	0.04	-0.05	-0.18	-0.34	-0.53	-0.77	-0.53	-0.34	-0.18	-0.05	0.04
Domestic productivity	1.1199	-0.05	0.07	0.23	0.44	0.69	1.00	0.69	0.44	0.23	0.07	-0.05
World productivity	1.1199	-0.04	0.05	0.18	0.34	0.53	0.77	0.53	0.34	0.18	0.05	-0.04

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.

Figure B.7: Impulse Responses of the Galí and Monacelli-Calibrated PEG-Model

Shock to Domestic Productivity

Shock to World Productivity



Appendix C

The Matlab® Codes

C.1 The Basic Galí and Monacelli Model GM_basic.m

```
% First, parameters are set and the steady state is calculated. Next, the matrices are
% declared.  In the last line, the model is solved and analyzed by calling DO_IT.M
% Copyright: H. Uhlig.  Feel free to copy, modify and use at your own risk.
% However, you are not allowed to sell this software or otherwise impinge
% on its free distribution.
% Adapted by Stefan Ried.

disp('-------------------------------------------------------------');
disp('          Monetary Policy and Exchange Rate Volatility     ');
disp('                  in a Small Open Economy                  ');
disp('                                                           ');
disp('            by Jordi Gali and Tommaso Monacelli            ');
disp('                        April 2002                         ');
disp('                  NBER Working Paper 8905                  ');
disp('                                                           ');
disp('Implementation in H. Uhlig´s Toolkit program by Stefan Ried');
disp('                                                           ');
disp(' You can choose a Policy Rule for the Small Open Economy   ');
disp(' by setting the variable POLICY equal to                   ');
disp(' 1 for Domestic Inflation Targeting (DIT; default)         ');
disp(' 2 for CPI Inflation Targeting (CIT)                       ');
disp(' 3 for an Exchange Rate Peg with the World Economy (PEG)   ');
disp('                                                           ');

disp('Hit any key when ready...');
pause;

if exist('POLICY')~=1,
   POLICY = 1;
end;

% Setting parameters (in order of appearance in the paper):

betta       = .987; % Discount factor
eta         = 1.5;  % Elasticity of substitution between domestic and foreign goods
epsilon     = 6;    % Elasticity of substitution among goods within each category  !>1
sigma       = 1;    % "Elasticity of Consumption"
phi         = 3;    % Labor supply elasticity
alpha       = .4;   % "Degree of openness" of the SOE, share of imports in domestic consumption
alpha_star  = 0.001;       % Gali and Monacelli (2002, p. 5): "assumed to be negligible"
rho_a       = .95;   % Autocorrelation of AR(1) process for domestic productivity
```

```
rho_astar   = .95;   % Autocorrelation of AR(1) process for world productivity
rho_a_astar = .77;  % Correlation of productivity shocks
sigma_eps   = .712; % Percentage standard deviation of domestic ...
                            %... as well as world productivity shock SET
theta_big   = .75;  % Percentage of firms which cannot set prices in period t
theta_bigstar  = .75;      % World opposite of theta_big

rho         =-log(betta);
theta       = alpha_star/alpha;  % constant dependent on initial distribution of wealth
tau         = 1-((1-1/epsilon)/(1-alpha));   % employment subsidy in the small open economy
tau_star    = 1/epsilon;   % employment subsidy in the world economy
nu          = -log(1-tau);
nu_star     = -log(1-tau_star);
mu          = log(epsilon/(epsilon-1)); % log of gross markup in the steady state: ...
                                  % ... optimal markup in the flexible price equilibrium
omega_alpha = 1+alpha*(sigma*eta-1)*(2-alpha);  %
phi_alpha   = (1-alpha)/omega_alpha;
lambda_big  = (2-alpha)*(sigma*eta-1)+(1-sigma);
lambda      = (1-theta_big)*(1-betta*theta_big)/theta_big;  %
omega_bigzero = (nu_star-mu)/(sigma+phi);
gamma_bigzero= (1+phi)/(sigma+phi);
kappa_zero    = lambda*(sigma+phi);
omega_bigalpha= omega_alpha*(nu-mu)/(sigma+omega_alpha*phi);
gamma_bigalpha= omega_alpha*(1+phi)/(sigma+omega_alpha*phi);
theta_bigalpha= sigma*(1-omega_alpha)/(sigma+omega_alpha*phi);
kappa_alpha   = lambda*(sigma/omega_alpha+phi);

%   Policy Rules
phi_pih = 1.5; % DIT coefficients to rule out indeterminacy: the exact values do not matter,
phi_y   = .5;  % since in the DIT case pi_h and y_~ are equal to zero. See Gali (2001), p. 23.
gamma_c     = 1+betta+lambda/alpha*(1+phi*omega_alpha/sigma);    % CIT rule coefficient
xi_c        = 1/(2*betta)*(gamma_c-sqrt(gamma_c^2-4*betta));
zeta_c      = lambda*xi_c*(1+phi)/(1-xi_c*betta*rho_a);
gamma_e      = 1+betta+lambda*(1+phi*omega_alpha/sigma);         % PEG rule coefficient
xi_e        = 1/(2*betta)*(gamma_e-sqrt(gamma_e^2-4*betta));
zeta_e      = lambda*xi_e*(1+phi)/(1-xi_e*betta*rho_a);

% Calculating the steady state:
mc_bar              = 1-(1/epsilon);
mcstar_bar          = 1-(1/epsilon);
pi_h_bar            = 0;                % Domestic goods inflation
pi_bar              = 0;                % CPI-inflation
pi_star_bar         = 0;                % World inflation  = pi_fstar
a_bar               = 1;                % Productivity
s_bar               = 1;
e_bar               = 1;
q_bar               = 1;

% Declaring the matrices.
VARNAMES = ['Domestic goods inflation   ',      %pi_h       1 domestic goods price index infl.
            'World real CPI inflation   ',      %pi_star    2
            'Domestic output gap        ',      %y_~        3
            'Domestic interest rate     ',      %r          4
            'World output gap           ',      %y_~star    5
            'Domestic CPI price level   ',      %p          6
            'Domestic goods price level ',      %p_h        7
            'Net exports                ',      %nx         8
            'World interest rate        ',      %r_star     9
            'Domestic CPI inflation     ',      %pi         10
            'Nominal exchange rate      ',      %e          11
            'Real exchange rate         ',      %q          12
            'Domestic consumption       ',      %c          13
```

```
           'World consumption          ',      %c_star     14
           'Domestic output            ',      %y          15
           'World output               ',      %y_star     16
           'Terms of trade             ',      %s          17
           'Dom. real CPI interest rate',      %r_CPI      18
           'Domestic productivity      ',      %a          19
           'World productivity         '];     %a_star     20

TEXNAMES=['\pi_{H}    '; '\pi^{*}    '; 'y^{*}      '; 'r          '; '{y}^{~*}   '; 'p          '
          'p_{H}      '; 'nx         '; 'r^{*}      '; '\pi        '; 'e          '; 'q          '
          'c          '; 'c^{*}=y^{*}'; 'y          '; 'y^{*}=c^{*}'; 's          '; 'r^{CPI}    '
          'a          '; 'a^{*}      '];

% Translating into coefficient matrices.
% The equations are, conveniently ordered:
%                          For DIT
% 0 = - r_star(t) - sigma(1- rho_stara) Gamma_zero a_star(t)      1
% 0 = - pi(t) + p(t) - p(t-1)
% 0 = - e(t) + (sigma * (1 + phi)/(sigma + phi * omega_alpha) * (a(t)-a_star(t)
% 0 = - q(t) + (1 - alpha) * e(t)
% 0 = - c(t) + phi_alpha * y(t) + (1 - phi_alpha) * y_star(t)
% 0 = - c_star(t) + y_star(t)
% 0 = - y(t) + y_~ + omega_bigalpha + gamma_bigalpha * a(t) + theta_bigalpha y_star(t)
% 0 = - y_star(t) + y_~star + omega_bigzero + gamma_bigzero * a_star(t)
% 0 = - s(t) + 1/alpha * (p(t) - p_h(t))
% 0 = - r_CPI(t) + r(t) - pi(t)
% 0 = E(t) [ kappa_zero * y_~star(t) - pi_star(t) + betta * pi_star(t+1) ]
% 0 = E(t) [ - y_~star(t) + y_~star(t+1) + 1/sigma * pi_star(t+1) - 1/sigma * r_star(t) - ...
%           ... (1 - rho_astar) gamma_bigzero a_star(t) ]
% 0 = E(t) [  kappa_alpha * y_~(t) - pi_h(t) + betta * pi_h(t+1) ]
% 0 = E(t) [ - y_~(t) + y_~(t+1) + omega_alpha/sigma * pi_h(t+1) - (omega_alpha/sigma)* phi  ...
%           ... * theta_bigalpha * (y_~star(t+1)-y_~star(t)) - (1 - rho_a)*omega_alpha  ...
%           ... *(1+phi)/(sigma + phi*omega_alpha) * a_(t) -  (omega_alpha/sigma) r(t)]
% 0 = E(t) [ -r(t) + phi * theta_bigalpha / sigma *(pi_star(t+1) -  r_star(t)) ...
%           ... - sigma*(1+phi)*(1-rho_a)/(sigma+phi*omega_alpha)*a(t)+phi_pih pi_h(t)+phi_y y_~(t)]
% 0 = E(t) [-p(t) + alpha * sigma * (1+phi)/(sigma+phi*omega_alpha) *(a(t)-a_star(t)) ]
% 0 = E(t) [-p_h(t)]
% 0 = E(t) [-nx(t) + (alpha * lambda_big)/omega_alpha * ( y(t) - y_star(t))]

%                           For CIT
% 0 = - r_star(t) - sigma(1- rho_stara) Gamma_zero a_star(t)
% 0 = pi(t)
% 0 = -e(t)-(1-alpha)/alpha * p_h(t)
% 0 = -q(t) + e(t)
% 0 = - c(t) + phi_alpha * y(t) + (1 - phi_alpha) * y_star(t)
% 0 = - c_star(t) + y_star(t)
% 0 = - y(t) + y_~ + omega_bigalpha + gamma_bigalpha * a(t) + theta_bigalpha y_star(t)
% 0 = - y_star(t) + y_~star + omega_bigzero + gamma_bigzero * a_star(t)
% 0 = - s(t) + 1/alpha * (p(t) - p_h(t)
% 0 = - r_CPI(t) + r(t) - pi(t)
% 0 = E(t) [ kappa_zero * y_~star(t) - pi_star(t) + betta * pi_star(t+1) ]
% 0 = E(t) [ - y_~star(t) + y_~star(t+1) + 1/sigma * pi_star(t+1) - 1/sigma * r_star(t) - ...
%                                    ... (1 - rho_astar) gamma_bigzero a_star(t) ]
% 0 = E(t) [  kappa_alpha * y_~(t) - pi_h(t) + betta * pi_h(t+1) ]
% 0 = E(t) [ - y_~(t) + y_~(t+1) + omega_alpha/sigma * pi_h(t+1) - (omega_alpha/sigma)* phi  ...
%           ... * theta_bigalpha * (y_~star(t+1)-y_~star(t)) - (1 - rho_a)*omega_alpha  ...
%           ... *(1+phi)/(sigma + phi*omega_alpha) * a_(t) -  (omega_alpha/sigma) r(t)]
% 0 = E(t) [ - pi_h(t) + p_h(t) - p_h(t-1) ]
% 0 = E(t) [ - p(t) ]
% 0 = E(t) [ - p_h(t) + xi_c * p_h(t-1) - zeta_c * (a(t)-a_star(t)) ]
% 0 = E(t) [-nx(t) + (alpha * lambda_big)/omega_alpha * ( y(t) - y_star(t))]
```

```
%                           For PEG
% 0 = - r_star(t) - sigma(1- rho_stara) Gamma_zero a_star(t)
% 0 = - pi(t) + (1-alpha) pi_h(t)
% 0 = e(t)
% 0 = q(t) + p(t)
% 0 = - c(t) + phi_alpha * y(t) + (1 - phi_alpha) * y_star(t)
% 0 = - c_star(t) + y_star(t)
% 0 = - y(t) + y_~ + omega_bigalpha + gamma_bigalpha * a(t) + theta_bigalpha y_star(t)
% 0 = - y_star(t) + y_~star + omega_bigzero + gamma_bigzero * a_star(t)
% 0 = - s(t) + 1/alpha * (p(t) - p_h(t)
% 0 = - r_CPI(t) + r(t) - pi(t)
% 0 = E(t) [ kappa_zero * y_~star(t) - pi_star(t) + betta * pi_star(t+1) ]
% 0 = E(t) [ - y_~star(t) + y_~star(t+1) + 1/sigma * pi_star(t+1) - 1/sigma * r_star(t) - ...
%                                  ... (1 - rho_astar) gamma_bigzero a_star(t) ]
% 0 = E(t) [  kappa_alpha * y_~(t) - pi_h(t) + betta * pi_h(t+1) ]
% 0 = E(t) [ - y_~(t) + y_~(t+1) + omega_alpha/sigma * pi_h(t+1) - (omega_alpha/sigma)* phi  ...
%           ... * theta_bigalpha * (y_~star(t+1)-y_~star(t)) - (1 - rho_a)*omega_alpha  ...
%           ... *(1+phi)/(sigma + phi*omega_alpha) * a_(t) -  (omega_alpha/sigma) r(t)]
% 0 = E(t) [  - pi_h(t) + p_h(t) - p_h(t-1) ]
% 0 = E(t) [ (1-alpha) * p_h(t) - p(t) ]
% 0 = E(t) [ - p_h(t) + xi_e * p_h(t-1) - zeta_e * (a(t)-a_star(t)) ]
% 0 = E(t) [-nx(t) + (alpha * lambda_big)/omega_alpha * ( y(t) - y_star(t))]

%                        .... and for all three:
% a(t)      = rho_a * a(t-1) + epsilon(t)
% a_star(t) = rho_astar * a_star(t-1) + epsilon_star(t)

% CHECK: 20 equations, 20 variables.

% Endogenous state variables "x(t)": pi_h, pi_star, y_~, r, y_~star, p, p_h, nx
% Endogenous other variables "y(t)": r_star, pi, e, q, c,  c_star,  y,   y_star, s, r_CPI
% Exogenous state variables  "z(t)": a(t), a_star(t)
% Switch to that notation.  Find matrices for format

% 0 = AA x(t) + BB x(t-1) + CC y(t) + DD z(t)
% 0 = E_t [ FF x(t+1) + GG x(t) + HH x(t-1) + JJ y(t+1) + KK y(t) + LL z(t+1) + MM z(t)]
% z(t+1) = NN z(t) + epsilon(t+1) with E_t [ epsilon(t+1) ] = 0,

if POLICY == 1,                              % DIT

%Order: pi_h(t), pi_star(t), y_~(t), r(t), y_~star(t), p, p_h, nx
AA = [ zeros(1,8)
       zeros(1,5),                                    1, zeros(1,2)
       zeros(6,8)
       zeros(1,5),                              1/alpha, -1/alpha, 0
       zeros(1,3),                     1, zeros(1,4)  ];

%Order: pi_h(t), pi_star(t), y_~(t), r(t), y_~star(t), p, p_h, nx
BB = [zeros(1,8)
      zeros(1,5),                                  -1, 0,0
      zeros(8,8)                                             ];

% y(t): r_star(t), pi,          e,  q, c,  c_star,  y,   y_star, s, r_CPI
CC = [        -1,  0,          0,  0, zeros(1,6)
               0, -1,          0,  0, zeros(1,6)
               0,  0,         -1,  0, zeros(1,6)
               0,  0,    1-alpha, -1, zeros(1,6)
               zeros(1,4),           -1,  0,  phi_alpha,  1-phi_alpha, zeros(1,2)
               zeros(1,4),            0, -1,          0,     1, zeros(1,2)
               zeros(1,4),            0,  0,         -1,  theta_bigalpha, zeros(1,2)
               zeros(1,4),            0,  0,          0,    -1, zeros(1,2)
                                   zeros(1,8), -1,  0
```

```
                0,  -1,              zeros(1,6),  0, -1];

DD = [                                    0,     -(1-rho_astar)*gamma_bigzero
                                      zeros(1,2)
        sigma*(1+phi)/(sigma+phi*omega_alpha),    -sigma*(1+phi)/(sigma+phi*omega_alpha)
                                      zeros(3,2)
                             gamma_bigalpha,     0
                                          0,     gamma_bigzero
                                      zeros(2,2)          ];

%Order: pi_h(t),         pi_star(t),                 y_~(t),  r(t), y_~star(t), p, p_h,nx
FF = [        0,              betta,                      0,     0,          0, zeros(1,3)
              0,           1/sigma,                       0,     0,          1, zeros(1,3)
          betta,                 0,                       0,     0,          0, zeros(1,3)
 omega_alpha/sigma, omega_alpha*phi*theta_bigalpha/sigma^2,1,     0,          0, zeros(1,3)
              0,    phi*theta_bigalpha/sigma,             0,     0,          0, zeros(1,3)% DIT
                                  zeros(3,8)                                             ];

%Order: pi_h(t), pi_star(t),        y_~(t),               r(t),   y_~star(t), p, p_h, nx
GG = [        0,         -1,            0,                   0,   kappa_zero, zeros(1,3)
              0,          0,            0,                   0,           -1, zeros(1,3)
             -1,          0,   kappa_alpha,                  0,            0, zeros(1,3)
              0,          0,           -1, -omega_alpha/sigma,            0, zeros(1,3)
        phi_pih,          0,         phi_y,                 -1,            0, zeros(1,3)   % DIT
                                      zeros(1,5),                            -1, 0, zeros(1,1)
                                      zeros(1,5),                             0, -1, zeros(1,1)
                                      zeros(1,7), -1];

%Order: pi_h(t), pi_star(t), y_~(t), r(t), y_~star(t), p, p_h, nx
HH = [zeros(8,8)];

%Order: r_star(t), pi, e, q, c,  c_star,  y,   y_star, s, r_CPI
JJ = [zeros(8,10)];        % All Policies

%Order:                            r_star(t), pi, e, q, c,  c_star,  y,   y_star, s, r_CPI
KK = [                                    0,  0, 0, 0, zeros(1,6)
                                  -1/sigma,  0, 0, 0, zeros(1,6)
                                          0,  0, 0, 0, zeros(1,6)
      -omega_alpha*phi*theta_bigalpha/sigma^2,  0, 0, 0, zeros(1,6)
                   -phi*theta_bigalpha/sigma,  0, 0, 0, zeros(1,6)          % Policy Rule: DIT
                                  zeros(2,4)         , zeros(2,6)
       zeros(1,6), alpha*lambda_big/omega_alpha, -alpha*lambda_big/omega_alpha, 0, 0];

% Order:     a(t),   a_star(t)
LL = [zeros(8,2)];           % DIT

%Order:a(t),                                          a_star(t)
MM = [ 0,                                              0
       0,                                              -(1-rho_astar)*gamma_bigzero
       0,                                              0
  -omega_alpha*(1+phi)*(1-rho_a)/(sigma+phi*omega_alpha), 0
  -sigma*(1+phi)*(1-rho_a)/(sigma+phi*omega_alpha),      0 % DIT
  alpha*sigma*(1+phi)/(sigma+phi*omega_alpha),  - alpha*sigma*(1+phi)/(sigma+phi*omega_alpha)
                                    zeros(2,2)];

%==============================================================================================
elseif POLICY == 2,                      % CIT

%Order: pi_h(t), pi_star(t), y_~(t),      r(t), y_~star(t), p, p_h, nx
AA= [           zeros(2,8)
                zeros(1,6),                                   -(1-alpha)/alpha, 0
                zeros(5,8)
```

```
               zeros(1,5),                              1/alpha, -1/alpha, 0
               zeros(1,3),                      1, zeros(1,4)  ];

%Order: pi_h(t), pi_star(t), y_~(t),      r(t), y_~star(t), p, p_h, nx
BB= [zeros(10,8)];

% y(t): r_star(t), pi,          e,  q, c,  c_star,  y,   y_star, s, r_CPI
CC=[          -1,  0,          0,  0, zeros(1,6)
               0,  1,          0,  0, zeros(1,6)
               0,  0,         -1,  0, zeros(1,6)
               0,  0,          1, -1, zeros(1,6)
               zeros(1,4),           -1,  0,  phi_alpha,  1-phi_alpha, 0, 0
               zeros(1,4),            0, -1,         0,     1, 0, 0
               zeros(1,4),            0,  0,        -1,  theta_bigalpha, 0, 0
               zeros(1,4),            0,  0,         0,    -1, 0, 0
                     zeros(1,8), -1,  0
               0,  -1,              zeros(1,6),  0, -1];

DD=[             0,     -(1-rho_astar)*gamma_bigzero
                 zeros(3,2)
                 zeros(2,2)
      gamma_bigalpha,     0
                  0,    gamma_bigzero
                 zeros(2,2)       ];

%Order: pi_h(t),       pi_star(t),                  y_~(t),    r(t), y_~star(t), p, p_h, nx
FF=[        0,             betta,                       0,       0,          0, 0, 0, 0
            0,           1/sigma,                       0,       0,          1, 0, 0, 0
        betta,                 0,                       0,       0,          0, 0, 0, 0
   omega_alpha/sigma, omega_alpha*phi*theta_bigalpha/sigma^2,   1, 0,          0, 0, 0, 0
                                            zeros(4,8)                                  ];

%Order: pi_h(t), pi_star(t),        y_~(t),              r(t),   y_~star(t), p, p_h, nx
GG= [        0,        -1,            0,                 0,   kappa_zero, 0, 0, 0
             0,         0,            0,                 0,           -1, 0, 0, 0
            -1,         0,   kappa_alpha,                0,            0, 0, 0, 0
             0,         0,           -1, -omega_alpha/sigma,           0, 0, 0, 0
            -1,         0,            0,                 0,            0, 0, 1, 0
             0,         0,            0,                 0,            0,-1, 0, 0
             0,         0,            0,                 0,            0, 0,-1, 0
                                                    zeros(1,7), -1            ];

%Order: pi_h(t),  pi_star(t), y_~(t),      r(t), y_~star(t), p, p_h, nx
HH= [                    zeros(4,8)
                         zeros(1,6),                         -1, 0
                         zeros(1,8)
                         zeros(1,6),                         xi_c, 0
                         zeros(1,8)   ];

% y(t): r_star(t), pi,          e,  q, c,  c_star,  y,   y_star, s, r_CPI
JJ=  [zeros(8, 10)];

% y(t): r_star(t), pi,          e,  q, c,  c_star,  y,   y_star, s, r_CPI
KK= [                                      0,  0, 0, 0, zeros(1,6)
                                   -1/sigma,  0, 0, 0, zeros(1,6)
                                           0,  0, 0, 0, zeros(1,6)
      -omega_alpha*phi*theta_bigalpha/sigma^2,  0, 0, 0, zeros(1,6)
                                   zeros(3,10)
 zeros(1,6), alpha*lambda_big/omega_alpha, -alpha*lambda_big/omega_alpha, 0, 0];

LL= [zeros(8,2)];
```

```
MM = [  0,                                                 0
        0,                                                 -(1-rho_astar)*gamma_bigzero
        0,                                                 0
    -omega_alpha*(1+phi)*(1-rho_a)/(sigma+phi*omega_alpha), 0
                    zeros(2,2)
  -zeta_c,                                                 zeta_c                   % CIT
        0,                                                 0];

%==========================================================================================
else                                  % PEG

%Order: pi_h(t),        pi_star(t),                 y_~(t),   r(t), y_~star(t), p, p_h, nx
AA = [                               zeros(1,8)
        1-alpha,                 0,                        0,      0,          0, 0,  0, 0
                                     zeros(1,8)
                                     zeros(1,5),                                 1,  0, 0
                                     zeros(4,8)
                            zeros(1,5),                             1/alpha, -1/alpha, 0
                            zeros(1,3),                        1, zeros(1,4)  ];

%Order: pi_h(t),        pi_star(t),                 y_~(t),   r(t), y_~star(t), p, p_h, nx
BB = [zeros(10,8)];

% y(t): r_star(t), pi,          e,  q, c,  c_star,  y,   y_star, s, r_CPI
CC = [        -1,  0,          0,  0, zeros(1,6)
               0, -1,          0,  0, zeros(1,6)
               0,  0,          1,  0, zeros(1,6)
               0,  0,          0,  1, zeros(1,6)
               zeros(1,4),            -1,  0,  phi_alpha,  1-phi_alpha, 0, 0
               zeros(1,4),             0, -1,          0,     1, 0, 0
               zeros(1,4),             0,  0,         -1,  theta_bigalpha, 0, 0
               zeros(1,4),             0,  0,          0,    -1, 0, 0
                     zeros(1,8), -1,  0
               0,  -1,               zeros(1,6),  0, -1];

DD=[       0,     -(1-rho_astar)*gamma_bigzero
           zeros(3,2)
           zeros(2,2)
gamma_bigalpha,     0
          0,     gamma_bigzero
           zeros(2,2)        ];

%Order: pi_h(t),        pi_star(t),                  y_~(t),    r(t), y_~star(t), p, p_h, nx
FF=[          0,             betta,                        0,       0,          0, 0, 0, 0
              0,           1/sigma,                        0,       0,          1, 0, 0, 0
          betta,                 0,                        0,       0,          0, 0, 0, 0
     omega_alpha/sigma, omega_alpha*phi*theta_bigalpha/sigma^2,   1, 0,          0, 0, 0, 0
                                       zeros(4,8)                                          ];

%Order: pi_h(t), pi_star(t),        y_~(t),               r(t),   y_~star(t), p, p_h, nx
GG = [        0,         -1,            0,                   0,   kappa_zero, 0, 0, 0
              0,          0,            0,                   0,           -1, 0, 0, 0
             -1,          0,   kappa_alpha,                  0,            0, 0, 0, 0
              0,          0,           -1, -omega_alpha/sigma,             0, 0, 0, 0
             -1,          0,            0,                   0,            0, 0, 1, 0
                                     zeros(1,5),                            -1, 1-alpha, 0
                                     zeros(1,5),                             0, -1, 0
                                     zeros(1,7), -1];

%Order: pi_h(t), pi_star(t), y_~(t),  r(t), y_~star(t), p, p_h, nx
HH = [                        zeros(4,8)
                              zeros(1,6),                 -1, 0
```

```
                              zeros(1,8)
                              zeros(1,6),                  xi_e, 0
                              zeros(1,8)                              ];

% y(t): r_star(t), pi,          e,  q, c,  c_star,  y,   y_star, s, r_CPI
JJ= [zeros(8,10)];

% y(t): r_star(t), pi,          e,  q, c,  c_star,  y,   y_star, s, r_CPI
KK= [                                       0,  0, 0, 0, zeros(1,6)
                                    -1/sigma,  0, 0, 0, zeros(1,6)
                                            0,  0, 0, 0, zeros(1,6)
      -omega_alpha*phi*theta_bigalpha/sigma^2,  0, 0, 0, zeros(1,6)
                                   zeros(3,4)         , zeros(3,6)
     zeros(1,6), alpha*lambda_big/omega_alpha, -alpha*lambda_big/omega_alpha, 0, 0];

LL= [zeros(8,2)];

MM = [ 0,                                                      0
       0,                                                      -(1-rho_astar)*gamma_bigzero
       0,                                                      0
       -omega_alpha*(1+phi)*(1-rho_a)/(sigma+phi*omega_alpha), 0
                            zeros(2,2)
       -zeta_e,                                                      zeta_e   % PEG
       0,                                                      0 ];

end;
%==============================================================================================

NN = [      rho_a,   0
                0,   rho_astar    ];

Sigma = sigma_eps^2 * [             1,   rho_a_astar
                        rho_a_astar,   1           ];

% Setting the options:
[l_equ,m_states] = size(AA);
[l_equ,n_endog ] = size(CC);
[l_equ,k_exog  ] = size(DD);


PERIOD     = 4;  % number of periods per year, i.e., 12 for monthly, 4 for quarterly
GNP_INDEX  = 15;%1; % Index of output among the variables selected for HP filter; ...
               % ... refers to the index in HP_SELECT !
HP_SELECT  = 1:(m_states+n_endog+k_exog);%[15,3,16,13,8,6,7,10,1,11,12,17,4,18,9,19,20];%
          % Selecting the variables for the HP Filter calculations.
IMP_SELECT = [15,16,13,8];%[11,12,4,9];%[6,7,10,1];%[1, 3:4, 6:7, 9:15];
          %  a vector containing the indices of the variables to be plotted in the imp-resps
SIM_SELECT = 1:20;%[8,15,18];
          % a vector containing the indices of the variables to be plotted in the simulation
% SIM_JOINT  = 0;                  % for one single graph per variable simulation
DO_HP_FILTER = 1;    % 1:HP-Filtered series, 0: Original series
DO_SIMUL   = 1; % Calculates simulations
SIM_LENGTH = 500;%150;
DO_MOMENTS = 1; % Calculates moments based on frequency-domain methods

%SIM_GIVEN_EPS = 1; % = 1 to calculate simulation based moments for just one shock
%Sig_fac = chol(Sigma);  % upper triangular Cholesky-factor
%Sig_fac = Sig_fac';     % to get the lower triangular Cholesky factor
%given_eps   = Sig_fac*[randn(1,SIM_LENGTH); zeros(1,SIM_LENGTH)]; %for domestic shock only
%given_eps   = Sig_fac*[zeros(1,SIM_LENGTH); randn(1,SIM_LENGTH)]; %for world shock only

DISPLAY_AT_THE_END = 0;     % turns off messages
```

```
SIM_MODE   = 1; %2 gives repeated simulations
%SIM_N_SERIES = 500; % number of repetitions of simulation: default = 50
%SIM_N_LEAD_LAGS = 6; % see SIMUL.M

% Starting the calculations:
do_it;

if POLICY == 1,
  disp('                                                                              ');
  disp('GM_basic: The Model with Domestic Inflation Targeting (DIT) has been calculated.');
  disp('-------------------------------------------------------------------------------');
elseif POLICY == 2,
    disp('                                                                           ');
    disp('GM_basic: The Model with CPI Inflation Targeting (CIT) has been calculated.');
    disp('---------------------------------------------------------------------------');
else
    disp('                                                                          ');
    disp('GM_basic: The Model with an Exchange Rate Peg (PEG) has been calculated.');
    disp('------------------------------------------------------------------------');
end;
```

C.2 The Model with Trade Costs GM_trac.m

```
% First, parameters are set and the steady state is calculated. Next, the matrices are
% declared.  In the last line, the model is solved and analyzed by calling DO_IT.M
% Copyright: H. Uhlig.  Feel free to copy, modify and use at your own risk.
% However, you are not allowed to sell this software or otherwise impinge
% on its free distribution.
% Adapted by Stefan Ried.

disp('-----------------------------------------------------------');
disp('   The Gali and Monacelli (2002) Model with Trade Costs    ');
disp('                                                           ');
disp('    based on: Gali, Jordi, and Tommaso Monacelli (2002):   ');
disp('       "Monetary Policy and Exchange Rate Volatility       ');
disp('      in a Small Open Economy", NBER Working Paper 8905    ');
disp('                                                           ');
disp('Implementation in H. Uhlig´s Toolkit program by Stefan Ried');
disp('                                                           ');
disp(' You can choose a Policy Rule for the Small Open Economy   ');
disp(' by setting the variable POLICY equal to                   ');
disp(' 1 for Domestic Inflation Targeting (DIT; default)         ');
disp(' 2 for CPI Inflation Targeting (CIT)                       ');
disp(' 3 for an Exchange Rate Peg with the World Economy (PEG)   ');
disp('                                                           ');

disp('Hit any key when ready...');
pause;

if exist('POLICY')~=1,
   POLICY = 1;
end;

% Setting parameters (in order of appearance in the paper):
betta       = .987;  % Discount factor
eta         = 1.5;    % Elasticity of substitution between domestic and foreign goods
epsilon     = 6;    % Elasticity of substitution among goods within each category  !>1
sigma       = 1;    % "Elasticity of Consumption"
phi         = 3;    % Labor supply elasticity
```

```
alpha       = .4;   % "Degree of openness" of the SOE, share of imports in domestic consumption
alpha_star  = 0.001;       % Gali and Monacelli (2002, p. 5): "assumed to be negligible"
xi_big      = 0.25;   % Trade costs: only 1-xi_big percent arrive in the destination country NEW!
rho_a       = .95;   % Autocorrelation of AR(1) process for domestic productivity
rho_astar   = .95;   % Autocorrelation of AR(1) process for world productivity
rho_a_astar = .77;  % Correlation of productivity shocks
sigma_eps   = .712; % Percentage standard deviation of domestic ...
                       % ... as well as world productivity shock SET
theta_big   = .75;  % Percentage of firms which cannot set prices in period t
theta_bigstar  = .75;      % World opposite of theta_big

rho         =-log(betta);
theta       = alpha_star/alpha;  % constant dependent on initial distribution of wealth
tau         = 1-((1-1/epsilon)/(1-alpha));   % employment subsidy in the small open economy
tau_star    = 1/epsilon;   % employment subsidy in the world economy
nu          = -log(1-tau);
nu_star     = -log(1-tau_star);
mu          = log(epsilon/(epsilon-1)); % log of gross markup in the steady state: ...
                                 % ... optimal markup in the flexible price equilibrium
xi          = -log(1-xi_big);    %                                                      NEW!

omega_alpha = 1+alpha*(sigma*eta-1)*(2-alpha);
omega_xi    = omega_alpha - sigma * xi;                                              % NEW!
phi_alpha   = (1-alpha)/omega_alpha;
phi_alphap  = (1-alpha)/omega_xi;                                                    % NEW!
lambda_big  = (2-alpha)*(sigma*eta-1)+(1-sigma);
lambda      = (1-theta_big)*(1-betta*theta_big)/theta_big;  %
omega_bigzero = (nu_star-mu)/(sigma+phi);
gamma_bigzero= (1+phi)/(sigma+phi);
kappa_zero    = lambda*(sigma+phi);
omega_bigalpha= omega_alpha*(nu-mu)/(sigma+omega_alpha*phi);
gamma_bigalpha= omega_alpha*(1+phi)/(sigma+omega_alpha*phi);
theta_bigalpha= sigma*(1-omega_alpha)/(sigma+omega_alpha*phi);
kappa_alpha   = lambda*(sigma/omega_alpha+phi);
omega_bigxi   = (omega_xi*(nu-mu) - (sigma*eta+omega_xi/sigma)*xi)/(sigma+omega_xi*phi); % NEW!
gamma_bigxi   = omega_xi*(1+phi)/(sigma+omega_xi*phi);                                % NEW!
theta_bigxi   = sigma*(1-omega_xi)/(sigma+omega_xi*phi);                              % NEW!
kappa_xi      = lambda*(sigma/omega_xi+phi);                                          % NEW!

%   Policy Rules
phi_pih = 1.5; % DIT coefficients to rule out indeterminacy: the exact values do not matter,
phi_y   = .5;  % since in the DIT case pi_h and y_~ are equal to zero. See Gali (2001), p. 23.
gamma_c     = 1+betta+lambda/alpha*(1+phi*omega_alpha/sigma);    % CIT rule coefficient
gamma_cp    = 1+betta+lambda/alpha*(1+phi*omega_xi/sigma);    % CIT rule coefficient      NEW!
xi_c        = 1/(2*betta)*(gamma_c-sqrt(gamma_c^2-4*betta));
xi_cp       = 1/(2*betta)*(gamma_cp-sqrt(gamma_cp^2-4*betta));                       % NEW!
zeta_c      = lambda*xi_c*(1+phi)/(1-xi_c*betta*rho_a);
zeta_cp     = lambda*xi_cp*(1+phi)/(1-xi_cp*betta*rho_a);                            % NEW!
gamma_e     = 1+betta+lambda*(1+phi*omega_alpha/sigma);         % PEG rule coefficient
gamma_ep    = 1+betta+lambda*(1+phi*omega_xi/sigma);        % PEG rule coefficient       NEW!
xi_e        = 1/(2*betta)*(gamma_e-sqrt(gamma_e^2-4*betta));
xi_ep       = 1/(2*betta)*(gamma_ep-sqrt(gamma_ep^2-4*betta));                       % NEW!
zeta_e      = lambda*xi_e*(1+phi)/(1-xi_e*betta*rho_a);
zeta_ep     = lambda*xi_ep*(1+phi)/(1-xi_ep*betta*rho_a);                            % NEW!

% Calculating the steady state:
mc_bar             = 1-(1/epsilon);
mcstar_bar         = 1-(1/epsilon);
pi_h_bar           = 0;               % Domestic goods inflation
pi_bar             = 0;               % CPI-inflation
pi_star_bar        = 0;               % World inflation  = pi_fstar
a_bar              = 1;               % Productivity
```

```
s_bar              = 1;
e_bar              = 1-xi_big;
q_bar              = 1-xi_big;

% Declaring the matrices.

VARNAMES = ['Domestic goods inflation   ',      %pi_h       1  domestic goods price index inf.
            'World real CPI inflation   ',      %pi_star    2
            'Domestic output gap        ',      %y_~        3
            'Domestic interest rate     ',      %r          4
            'World output gap           ',      %y_~star    5
            'Domestic CPI price level   ',      %p          6
            'Domestic goods price level ',      %p_h        7
            'Net exports                ',      %nx         8
            'World interest rate        ',      %r_star     9
            'Domestic CPI inflation     ',      %pi         10
            'Nominal exchange rate      ',      %e          11
            'Real exchange rate         ',      %q          12
            'Domestic consumption       ',      %c          13
            'World consumption          ',      %c_star     14
            'Domestic output            ',      %y          15
            'World output               ',      %y_star     16
            'Terms of trade             ',      %s          17
            'Dom. real CPI interest rate',      %r_CPI      18
            'Domestic productivity      ',      %a          19
            'World productivity         '];     %a_star     20

TEXNAMES=['\pi_{H}    '; '\pi^{*}    '; 'y^{*}      '; 'r          '; '{y}^{~*}   '; 'p          '
          'p_{H}      '; 'nx         '; 'r^{*}      '; '\pi        '; 'e          '; 'q          '
          'c          '; 'c^{*}=y^{*}'; 'y          '; 'y^{*}=c^{*}'; 's          '; 'r^{CPI}    '
          'a          '; 'a^{*}      '];

% Translating into coefficient matrices.
% The equations are, conveniently ordered:
%                          For DIT
% 0 = - r_star(t) - sigma(1- rho_stara) Gamma_zero * a_star(t)
% 0 = - pi(t) + p(t) - p(t-1)
% 0 = - e(t) + (sigma * (1 + phi)/(sigma + phi * omega_xi) * (a(t)-a_star(t)
% 0 = - q(t) + (1 - alpha) * e(t)
% 0 = - c(t) + phi_alphap * y(t) + (1 - phi_alphap) * y_star(t)
% 0 = - c_star(t) + y_star(t)
% 0 = - y(t) + y_~ + gamma_bigxi * a(t) + theta_bigxi y_star(t)
% 0 = - y_star(t) + y_~star + omega_bigzero + gamma_bigzero * a_star(t)
% 0 = - s(t) + 1/alpha * (p(t) - p_h(t))
% 0 = - r_CPI(t) + r(t) - pi(t)
% 0 = E(t) [ kappa_zero * y_~star(t) - pi_star(t) + betta * pi_star(t+1) ]
% 0 = E(t) [ - y_~star(t) + y_~star(t+1) + 1/sigma * pi_star(t+1) - 1/sigma * r_star(t) - ...
%           ... (1 - rho_astar) gamma_bigzero a_star(t) ]
% 0 = E(t) [  kappa_xi * y_~(t) - pi_h(t) + betta * pi_h(t+1) ]
% 0 = E(t) [ - y_~(t) + y_~(t+1) + omega_xi/sigma * pi_h(t+1) - (omega_xi/sigma)* phi  ...
%           ... * theta_bigxi * 1/sigma*(r_star(t)-pi_star(t+1)) - (1 - rho_a)*omega_xi  ...
%           ... *(1+phi)/(sigma + phi*omega_xi) * a_(t) -  (omega_xi/sigma) r(t)]
% 0 = E(t) [ -r(t) + phi * theta_bigxi / sigma *(pi_star(t+1) -  r_star(t)) ...
%         ... - sigma*(1+phi)*(1-rho_a)/(sigma+phi*omega_xi)*a(t)+phi_pih pi_h(t)+phi_y y_~(t)]
% 0 = E(t) [-p(t) + alpha * sigma * (1+phi)/(sigma+phi*omega_xi) *(a(t)-a_star(t)) ]
% 0 = E(t) [-p_h(t)]
% 0 = E(t) [-nx(t) + (alpha * lambda_big - sigma*xi)/omega_xi * ( y(t) - y_star(t))]

%                           For CIT
% 0 = - r_star(t) - sigma(1- rho_stara) Gamma_zero a_star(t)
% 0 = pi(t)
% 0 = -e(t)-(1-alpha)/alpha * p_h(t)
```

```
% 0 = -q(t) + e(t)
% 0 = - c(t) + phi_alphap * y(t) + (1 - phi_alphap) * y_star(t)
% 0 = - c_star(t) + y_star(t)
% 0 = - y(t) + y_~ + gamma_bigxi * a(t) + theta_bigxi y_star(t)
% 0 = - y_star(t) + y_~star + omega_bigzero + gamma_bigzero * a_star(t)
% 0 = - s(t) + 1/alpha * (p(t) - p_h(t))
% 0 = - r_CPI(t) + r(t) - pi(t)
% 0 = E(t) [ kappa_zero * y_~star(t) - pi_star(t) + betta * pi_star(t+1) ]
% 0 = E(t) [ - y_~star(t) + y_~star(t+1) + 1/sigma * pi_star(t+1) - 1/sigma * r_star(t) - ...
%                                  ... (1 - rho_astar) gamma_bigzero a_star(t) ]
% 0 = E(t) [  kappa_xi * y_~(t) - pi_h(t) + betta * pi_h(t+1) ]
% 0 = E(t) [ - y_~(t) + y_~(t+1) + omega_xi/sigma * pi_h(t+1) - (omega_xi/sigma)* phi  ...
%           ... * theta_bigxi * (y_~star(t+1)-y_~star(t)) - (1 - rho_a)*omega_xi  ...
%           ... *(1+phi)/(sigma + phi*omega_xi) * a_(t) -  (omega_xi/sigma) r(t)]
% 0 = E(t) [ - pi_h(t) + p_h(t) - p_h(t-1) ]
% 0 = E(t) [ - p(t) ]
% 0 = E(t) [ - p_h(t) + xi_cp * p_h(t-1) - zeta_cp * (a(t)-a_star(t)) ]
% 0 = E(t) [-nx(t) + (alpha * lambda_big-sigma*xi)/omega_xi * ( y(t) - y_star(t))]

%                            For PEG
% 0 = - r_star(t) - sigma(1- rho_stara) Gamma_zero a_star(t)
% 0 = - pi(t) + (1-alpha) pi_h(t)
% 0 = e(t)
% 0 = q(t) + p(t)
% 0 = - c(t) + phi_alphap * y(t) + (1 - phi_alphap) * y_star(t)
% 0 = - c_star(t) + y_star(t)
% 0 = - y(t) + y_~ + gamma_bigxi * a(t) + theta_bigxi y_star(t)
% 0 = - y_star(t) + y_~star + omega_bigzero + gamma_bigzero * a_star(t)
% 0 = - s(t) + 1/alpha * (p(t) - p_h(t))
% 0 = - r_CPI(t) + r(t) - pi(t)
% 0 = E(t) [ kappa_zero * y_~star(t) - pi_star(t) + betta * pi_star(t+1) ]
% 0 = E(t) [ - y_~star(t) + y_~star(t+1) + 1/sigma * pi_star(t+1) - 1/sigma * r_star(t) - ...
%                                  ... (1 - rho_astar) gamma_bigzero a_star(t) ]
% 0 = E(t) [  kappa_xi * y_~(t) - pi_h(t) + betta * pi_h(t+1) ]
% 0 = E(t) [ - y_~(t) + y_~(t+1) + omega_xi/sigma * pi_h(t+1) - (omega_xi/sigma)* phi  ...
%           ... * theta_bigxi * (y_~star(t+1)-y_~star(t)) - (1 - rho_a)*omega_xi  ...
%           ... *(1+phi)/(sigma + phi*omega_xi) * a_(t) -  (omega_xi/sigma) r(t)]
% 0 = E(t) [  - pi_h(t) + p_h(t) - p_h(t-1) ]
% 0 = E(t) [ (1-alpha) * p_h(t) - p(t) ]
% 0 = E(t) [ - p_h(t) + xi_ep * p_h(t-1) - zeta_ep * (a(t)-a_star(t)) ]
% 0 = E(t) [-nx(t) + (alpha * lambda_big-sigma*xi)/omega_xi * ( y(t) - y_star(t))]

%                        .... and for all three:
% a(t)      = rho_a * a(t-1) + epsilon(t)
% a_star(t) = rho_astar * a_star(t-1) + epsilon_star(t)

% CHECK: 20 equations, 20 variables.

% Endogenous state variables "x(t)": pi_h, pi_star, y_~, r, y_~star, p, p_h, nx
% Endogenous other variables "y(t)": r_star, pi, e, q, c,  c_star,  y,   y_star, s, r_CPI
% Exogenous state variables  "z(t)": a(t), a_star(t)
% Switch to that notation.  Find matrices for format

% 0 = AA x(t) + BB x(t-1) + CC y(t) + DD z(t)
% 0 = E_t [ FF x(t+1) + GG x(t) + HH x(t-1) + JJ y(t+1) + KK y(t) + LL z(t+1) + MM z(t)]
% z(t+1) = NN z(t) + epsilon(t+1) with E_t [ epsilon(t+1) ] = 0,

if POLICY == 1,                              % DIT

%Order: pi_h(t), pi_star(t), y_~(t), r(t), y_~star(t), p, p_h, nx
AA = [ zeros(1,8)
       zeros(1,5),                                     1, zeros(1,2)
```

```
      zeros(6,8)
      zeros(1,5),                               1/alpha, -1/alpha, 0
      zeros(1,3),                       1, zeros(1,4)  ];

%Order: pi_h(t), pi_star(t), y_~(t), r(t), y_~star(t), p, p_h, nx
BB = [zeros(1,8)
      zeros(1,5),                                    -1, 0,0
      zeros(8,8)                                               ];

% y(t): r_star(t), pi,          e,  q, c,  c_star,  y,   y_star, s, r_CPI
CC = [        -1,  0,          0,  0, zeros(1,6)
               0, -1,          0,  0, zeros(1,6)
               0,  0,         -1,  0, zeros(1,6)
               0,  0,    1-alpha, -1, zeros(1,6)
               zeros(1,4),            -1,  0, phi_alphap, 1-phi_alphap, zeros(1,2)
               zeros(1,4),             0, -1,          0,     1, zeros(1,2)
               zeros(1,4),             0,  0,         -1,  theta_bigxi, zeros(1,2)
               zeros(1,4),             0,  0,          0,    -1, zeros(1,2)
                             zeros(1,8), -1,  0
               0,  -1,               zeros(1,6),  0, -1];

DD = [                                   0,     -(1-rho_astar)*gamma_bigzero
                                    zeros(1,2)
       sigma*(1+phi)/(sigma+phi*omega_xi)   ,    -sigma*(1+phi)/(sigma+phi*omega_xi)
                                    zeros(3,2)
                              gamma_bigxi,     0
                                         0,     gamma_bigzero
                                    zeros(2,2)           ];

%Order: pi_h(t),         pi_star(t),                 y_~(t), r(t), y_~star(t), p, p_h,nx
FF = [        0,             betta,                       0,   0,          0, zeros(1,3)
              0,           1/sigma,                       0,   0,          1, zeros(1,3)
          betta,                0,                        0,   0,          0, zeros(1,3)
    omega_xi/sigma, omega_xi*phi*theta_bigxi/sigma^2,      1,   0,          0, zeros(1,3)
              0,    phi*theta_bigxi/sigma,                0,   0,          0, zeros(1,3)% DIT
                              zeros(3,8)                                               ];

%Order: pi_h(t), pi_star(t),        y_~(t),            r(t),   y_~star(t), p, p_h, nx
GG = [        0,        -1,            0,               0,   kappa_zero, zeros(1,3)
              0,         0,            0,               0,          -1, zeros(1,3)
             -1,         0,      kappa_xi,              0,           0, zeros(1,3)
              0,         0,           -1, -omega_xi/sigma,           0, zeros(1,3)
        phi_pih,         0,         phi_y,             -1,           0, zeros(1,3)   % DIT
                                    zeros(1,5),                  -1, 0, zeros(1,1)
                                    zeros(1,5),                  0, -1, zeros(1,1)
                                    zeros(1,7), -1];

%Order: pi_h(t), pi_star(t), y_~(t), r(t), y_~star(t), p, p_h, nx
HH = [zeros(8,8)];

%Order: r_star(t), pi, e, q, c,  c_star,  y,   y_star, s, r_CPI
JJ = [zeros(8,10)];        % All Policies

%Order:                             r_star(t), pi, e, q, c,  c_star,  y,   y_star, s, r_CPI
KK = [                                       0,  0, 0, 0, zeros(1,6)
                                     -1/sigma,  0, 0, 0, zeros(1,6)
                                             0,  0, 0, 0, zeros(1,6)
           -omega_xi*phi*theta_bigxi/sigma^2,  0, 0, 0, zeros(1,6)
                      -phi*theta_bigxi/sigma,  0, 0, 0, zeros(1,6)       % Policy Rule: DIT
                                  zeros(2,4)         , zeros(2,6)
zeros(1,6), (alpha*lambda_big-sigma*xi)/omega_xi, -(alpha*lambda_big-sigma*xi)/omega_xi, 0, 0];
```

```
% Order:     a(t),   a_star(t)
LL = [zeros(8,2)];            % DIT

%Order:a(t),                                               a_star(t)
MM = [ 0,                                                  0
       0,                                                  -(1-rho_astar)*gamma_bigzero
       0,                                                  0
  -omega_xi*(1+phi)*(1-rho_a)/(sigma+phi*omega_xi),        0
  -sigma*(1+phi)*(1-rho_a)/(sigma+phi*omega_xi),           0 % DIT
  alpha*sigma*(1+phi)/(sigma+phi*omega_xi),              - alpha*sigma*(1+phi)/(sigma+phi*omega_xi)
                                      zeros(2,2)];

%===============================================================================================
elseif POLICY == 2,                       % CIT


%Order: pi_h(t), pi_star(t), y_~(t),      r(t), y_~star(t), p, p_h, nx
AA= [           zeros(2,8)
                zeros(1,6),                                 -(1-alpha)/alpha, 0
                zeros(5,8)
                zeros(1,5),                           1/alpha, -1/alpha, 0
                zeros(1,3),                      1, zeros(1,4)  ];

%Order: pi_h(t), pi_star(t), y_~(t),      r(t), y_~star(t), p, p_h, nx
BB= [zeros(10,8)];

% y(t): r_star(t), pi,          e,  q, c,  c_star,  y,   y_star, s, r_CPI
CC=[           -1,  0,          0,  0, zeros(1,6)
                0,  1,          0,  0, zeros(1,6)
                0,  0,         -1,  0, zeros(1,6)
                0,  0,          1, -1, zeros(1,6)
                zeros(1,4),           -1,  0, phi_alphap, 1-phi_alphap, 0, 0
                zeros(1,4),            0, -1,          0,     1, 0, 0
                zeros(1,4),            0,  0,         -1,  theta_bigxi, 0, 0
                zeros(1,4),            0,  0,          0,    -1, 0, 0
                      zeros(1,8), -1,  0
                0,  -1,              zeros(1,6),  0, -1];

DD=[              0,    -(1-rho_astar)*gamma_bigzero
                  zeros(3,2)
                  zeros(2,2)
        gamma_bigxi,     0
                   0,    gamma_bigzero
                  zeros(2,2)       ];

%Order: pi_h(t),       pi_star(t),               y_~(t),   r(t), y_~star(t), p, p_h, nx
FF=[        0,             betta,                    0,      0,         0, 0, 0, 0
            0,           1/sigma,                    0,      0,         1, 0, 0, 0
       betta,                0,                      0,      0,         0, 0, 0, 0
   omega_xi/sigma, omega_xi*phi*theta_bigxi/sigma^2,   1,      0,         0, 0, 0, 0
                                         zeros(4,8)                              ];

%Order: pi_h(t), pi_star(t),     y_~(t),            r(t),   y_~star(t), p, p_h, nx
GG= [         0,        -1,         0,               0,   kappa_zero, 0, 0, 0
              0,         0,         0,               0,           -1, 0, 0, 0
             -1,         0,   kappa_xi,              0,            0, 0, 0, 0
              0,         0,        -1, -omega_xi/sigma,            0, 0, 0, 0
             -1,         0,         0,               0,            0, 0, 1, 0
              0,         0,         0,               0,            0,-1, 0, 0
              0,         0,         0,               0,            0, 0,-1, 0
                                               zeros(1,7), -1            ];
```

```
%Order: pi_h(t),  pi_star(t), y_~(t), r(t), y_~star(t), p, p_h, nx
HH= [                     zeros(4,8)
                          zeros(1,6),                      -1, 0
                          zeros(1,8)
                          zeros(1,6),                   xi_cp, 0
                          zeros(1,8)                                  ];

% y(t): r_star(t), pi,          e,  q, c,  c_star,  y,   y_star, s, r_CPI
JJ=  [zeros(8, 10)];

% y(t): r_star(t), pi,          e,  q, c,  c_star,  y,   y_star, s, r_CPI
KK= [                                     0,  0, 0, 0, zeros(1,6)
                                   -1/sigma,  0, 0, 0, zeros(1,6)
                                          0,  0, 0, 0, zeros(1,6)
            -omega_xi*phi*theta_bigxi/sigma^2,  0, 0, 0, zeros(1,6)
                                  zeros(3,10)
 zeros(1,6), (alpha*lambda_big-sigma*xi)/omega_xi, -(alpha*lambda_big-sigma*xi)/omega_xi,0,0];

LL= [zeros(8,2)];

MM = [  0,                                              0
        0,                                              -(1-rho_astar)*gamma_bigzero
        0,                                              0
    -omega_xi*(1+phi)*(1-rho_a)/(sigma+phi*omega_xi), 0
                   zeros(2,2)
  -zeta_cp,                                                    zeta_cp               % CIT
        0,                                                   0];

%==========================================================================================
else                                 % PEG

%Order: pi_h(t),         pi_star(t),             y_~(t),      r(t), y_~star(t), p, p_h, nx
AA = [                                  zeros(1,8)
        1-alpha,                 0,                     0,         0,          0, 0,  0, 0
                                        zeros(1,8)
                                        zeros(1,5),                              1,  0, 0
                                        zeros(4,8)
                               zeros(1,5),                          1/alpha, -1/alpha, 0
                               zeros(1,3),                      1, zeros(1,4)  ];

%Order: pi_h(t),         pi_star(t),       y_~(t),      r(t), y_~star(t), p, p_h, nx
BB = [zeros(10,8)];

% y(t): r_star(t), pi,          e,  q, c,  c_star,  y,   y_star, s, r_CPI
CC = [         -1,  0,          0,  0, zeros(1,6)
                0, -1,          0,  0, zeros(1,6)
                0,  0,          1,  0, zeros(1,6)
                0,  0,          0,  1, zeros(1,6)
                zeros(1,4),           -1,  0, phi_alphap, 1-phi_alphap, 0, 0
                zeros(1,4),            0, -1,         0,            1, 0, 0
                zeros(1,4),            0,  0,        -1,  theta_bigxi, 0, 0
                zeros(1,4),            0,  0,         0,    -1, 0, 0
                      zeros(1,8), -1,  0
                0,  -1,              zeros(1,6),  0, -1];

DD=[       0,     -(1-rho_astar)*gamma_bigzero
           zeros(3,2)
           zeros(2,2)
 gamma_bigxi,     0
          0,     gamma_bigzero
           zeros(2,2)       ];
```

```
%Order: pi_h(t),         pi_star(t),                y_~(t),  r(t), y_~star(t), p, p_h, nx
FF=[          0,             betta,                     0,     0,          0, 0, 0, 0
              0,           1/sigma,                     0,     0,          1, 0, 0, 0
          betta,                0,                      0,     0,          0, 0, 0, 0
     omega_xi/sigma, omega_xi*phi*theta_bigxi/sigma^2,  1,     0,          0, 0, 0, 0
                                        zeros(4,8)                                ];

%Order: pi_h(t), pi_star(t),        y_~(t),              r(t),   y_~star(t), p, p_h, nx
GG = [        0,        -1,             0,                  0,   kappa_zero, 0, 0, 0
              0,         0,             0,                  0,           -1, 0, 0, 0
             -1,         0,      kappa_xi,                  0,            0, 0, 0, 0
              0,         0,            -1,    -omega_xi/sigma,            0, 0, 0, 0
             -1,         0,             0,                  0,            0, 0, 1, 0
                                       zeros(1,5),                       -1, 1-alpha, 0
                                       zeros(1,5),                          0, -1, 0
                                       zeros(1,7), -1];

%Order: pi_h(t), pi_star(t), y_~(t),  r(t), y_~star(t), p, p_h, nx
HH = [                        zeros(4,8)
                              zeros(1,6),                 -1, 0
                              zeros(1,8)
                              zeros(1,6),              xi_ep, 0
                              zeros(1,8)                              ];

% y(t): r_star(t), pi,          e,  q, c,  c_star,  y,   y_star, s, r_CPI
JJ= [zeros(8,10)];

% y(t): r_star(t), pi,          e,  q, c,  c_star,  y,   y_star, s, r_CPI
KK= [                                        0,  0, 0, 0, zeros(1,6)
                                     -1/sigma,  0, 0, 0, zeros(1,6)
                                             0,  0, 0, 0, zeros(1,6)
            -omega_xi*phi*theta_bigxi/sigma^2,  0, 0, 0, zeros(1,6)
                                   zeros(3,4)         , zeros(3,6)
zeros(1,6), (alpha*lambda_big-sigma*xi)/omega_xi, -(alpha*lambda_big-sigma*xi)/omega_xi,0,0];

LL= [zeros(8,2)];

MM = [ 0,                                              0
       0,                                              -(1-rho_astar)*gamma_bigzero
       0,                                              0
       -omega_xi*(1+phi)*(1-rho_a)/(sigma+phi*omega_xi), 0
                         zeros(2,2)
       -zeta_ep,                                       zeta_ep   % PEG
       0,                                              0 ];

end;
%==========================================================================================

NN = [      rho_a,   0
                0,   rho_astar    ];

Sigma = sigma_eps^2 * [             1,   rho_a_astar
                        rho_a_astar,   1           ];

% Setting the options:
[l_equ,m_states] = size(AA);
[l_equ,n_endog ] = size(CC);
[l_equ,k_exog  ] = size(DD);


PERIOD     = 4;  % number of periods per year, i.e., 12 for monthly, 4 for quarterly
GNP_INDEX  = 15; %1;% Index of output among the variables selected for HP filter; ...
```

```
                % ... refers to the index in HP_SELECT !
HP_SELECT  = 1:(m_states+n_endog+k_exog);%[15,3,16,13,8,6,7,10,1,11,12,17,4,18,9,19,20];%
     % Selecting the variables for the HP Filter calcs.
IMP_SELECT = [15,16,13,8];%[11,12,4,9];%[6,7,10,1];%[1, 3:4, 6:7, 9:15];
     % a vector containing the indices of the variables to be plotted in the imp.-responses
SIM_SELECT = 1:20;%[8,15,18];
          % a vector containing the indices of the variables to be plotted in the simulation
% SIM_JOINT  = 0;                   % for one single graph per variable simulation
DO_HP_FILTER = 1;    % 1:HP-Filtered series, 0: Original series
DO_SIMUL   = 1; %1 Calculates simulations
SIM_LENGTH = 150;
DO_MOMENTS = 1; % Calculates moments based on frequency-domain methods

%SIM_GIVEN_EPS = 1; % = 1 to calculate simulation based moments for just one shock
%Sig_fac = chol(Sigma);  % upper triangular Cholesky-factor
%Sig_fac = Sig_fac';     % to get the lower triangular Cholesky factor
%given_eps   = Sig_fac*[randn(1,SIM_LENGTH); zeros(1,SIM_LENGTH)]; %for domestic shock only
%given_eps   = Sig_fac*[zeros(1,SIM_LENGTH); randn(1,SIM_LENGTH)]; %for world shock only

DISPLAY_AT_THE_END = 0;     % turns off messages
SIM_MODE   = 1; %2 gives repeated simulations
SIM_N_SERIES = 500; % number of repetitions of simulation: default = 50
%SIM_N_LEAD_LAGS = 6; % see SIMUL.M
%N_LEADS_LAGS = 1;

% Starting the calculations:
do_it;

if POLICY == 1,
  disp('                                                             ');
  disp('GM_trac: The DIT-Model with Trade Costs has been calculated.  ');
  disp('-------------------------------------------------------------');
elseif POLICY == 2,
    disp('                                                           ');
    disp('GM_trac: The CIT-Model with Trade Costs has been calculated.');
    disp('-----------------------------------------------------------');
else
    disp('                                                           ');
    disp('GM_trac: The PEG-Model with Trade Costs has been calculated.');
    disp('-----------------------------------------------------------');
end;
```

Appendix D

Electronic Source

The CD-ROM on the next page includes everything you can see here printed, and a bit more. The disc is structured in five directories, which include the following files:

Thesis: The diploma thesis in PDF and Postscript, together with the main two Matlab® programs.

LaTeX: This document in tex-, dvi-, ps- and pdf-format, as well as the included graphics files and the usual files generated by LaTeX.

Programs: The Matlab® codes and the Toolkit by Harald Uhlig with little modifications for the figures. The file `GM_basic.m` includes the basic model in our calibration, `GM_trac.m` is the modified model with trade costs, and `GM_final.m` is again the basic model, but now with the parameter values chosen by Galí and Monacelli (2002).

Graphics: Additional graphics files which could be easily obtained with the programs, but maybe even easier by just opening them. Each file contains two graphs: on the left hand side there are impulse responses to a domestic productivity shock, on the right hand side to a world productivity shock. The names of the files have the following system: the first letter refers to the underlying domestic monetary policy, i.e., "C" for CIT, "D" for DIT, and "P" for PEG. The second letter stands for the included variables: "r" means "real" and refers to output, consumption, and net exports, "n" means "nominal" and refers to price levels and inflations, "c" means "comparatives" and refers to exchange and interest rates. "xi" stands for the model with trade costs, "GM" for the calibration of Galí and Monacelli (2002).

Literature: A collection of cited articles insofar as they were available for free on the web.

Electronic Source CD-ROM of the Diploma thesis by Stefan Ried

Erklärung zur Urheberschaft

Hiermit erkläre ich, dass ich die vorliegende Arbeit allein und nur unter Verwendung der aufgeführten Quellen und Hilfsmittel angefertigt habe.

Stefan Ried

Berlin, 4. September 2002