Master Thesis:
Monetary and Fiscal Policy in a Two Country Model with Sticky Prices

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24.09.2007

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1 Abstract

In this paper we develop a dynamic stochastic general equilibrium (DSGE) model for an open economy where the uncovered interest rate parity is not required to hold. We extend the open economy DSGE model of De Walque, Smets and Wouter (2005) by incorporating stochastic fiscal policy into the model. The model includes several features of market rigidities. The focus is on explaining the theoretical model thoroughly and analyzing the impulse response function under calibrated parameters in Dynare.

Keywords: DSGE model; New open economy; Interest rate parity; Real and Nominal Rigidities

2 Introduction

Our motivation for the model is to construct a DSGE open economy model with sticky prices and wages to link the euro area and the US using specific variables. The model is a version of the "New Open Economy Model" (NOEM), and contains the salient features of its class with respect to the optimizing behaviour of the microeconomic units, firms and households, sluggishness of prices and wages, goods aggregation, exchange rate and current account, and the monetary authority. Hereafter, domestic intermediate and importing monopolistically competitive firms set prices and households set wages in a Calvo mechanism. This helps to explain inflation inertia and output persistence. A representative aggregator combines complete sets of differentiated types of labor, intermediate and imported goods and distributes the final consumption goods. Capital accumulation is subject to adjustment costs, so is capital intensity and domestic-foreign inputs ratio. Monetary policy intervenes in the form of interest rate setting rules; money is not explicitly modeled but assumed to be embodied in the utility function.

The domestic block emulates the economy from Smets and Wouters' previous work on the closed economy, but with a reduced number of stochastic shocks.

Preference shocks, inflation objective shocks, and labor supply shocks are excluded from the model. The main difference with respect to the intermediate production sector comes from the input of oil and non-oil inputs in the production function. In addition, distortional taxes on labor income, individual consumption, and capital earnings are taxed by the government to finance its own consumption; a part of the tax revenues return to the households as lump-sum transfers. A level of economic openness is achieved by integrating both models through international trade in goods and assets. The imperfect international capital market is stochastically represented, which helps to explain the departure from the uncovered rate parity condition and high short time volatility of exchange rate. The incomplete pass-through in the model originates only from nominal price rigidities. Current account is determined by an inter-temporal budget constraint, a typical assumption in the NOEM models. The set of variables and shocks is extended in order to express the net-trade flows, the import and consumption price inflation, the rate of depreciation and the oil price fluctuations.

In the present paper, we keep the initial specification of the open economy relatively simple. Richer models that explain the depreciation rate evolution address endogenously determined risk premiums on foreign currency associated with net foreign assets holdings i.e. Bergin (2005), Adolfson, Laséen, Lindé, and Villani (2005); or with monetary policy actions i.e. Obstfeld and Rogoff (2002). Bergin (2005) investigates the importance of producer currency pricing for exporters (pricing to market) and finds that this assumption is supported by the data.

The home bias helps to explain elasticity of substitution between domestic and foreign goods. In this setup the authors follow Corsetti et al. (2003) to determine the value of the elasticity of substitution via an estimated share of imports in the domestic service sector. Through the elasticity of substitution and relative domestic and foreign prices, the cost minimization objective function of the representative agent determines the proportions of various goods in the final product.

In this paper we do not propose to analyze the difference between high and low elasticity of substitution, as it is still a subject of controversy among researchers. Instead we simulate our model using estimated parameters for low elasticity of substitution, as it is shown by the authors performs better marginally. However, the difference is small and under certain assumptions both cases can be valid. Our purpose is to investigate the changes in the impulse-response function by the introduction of taxes for the case of low elasticity of substitution. We assume that in the steady state these taxes are not zero by following the Trabant and Uhlig (2006) calibrated values for these types of taxes in Europe and the U.S. These values might not be entirely accurate: first because of the time horizon, and secondly because the Euro Area does not include all the countries for which the average taxes have been computed. But for our exercise we consider them to be appropriate.

In this version of the model the standard assumption of constant elasticity of demand with respect to prices is altered for the intermediate producers; as a result, an additional parameter enters the price setting problem, following Eichenbaum and Fischer (2004).

The first concern of our paper is to explain the theoretical model in a detailed way that would allow us to make subsequent extensions to it. The second part, is the analysis of the impulse response functions of the model as implemented in Dynare and the Toolkit. In the appendix, we attempt to introduce an estimate of the model in Dynare.

The analysis of the domestic sector is complicated by the introduction of imports that combine with domestic goods in different stages. These feed back on the marginal cost and wages, and influencing real domestic variables. The external sector uses mainly proportions in which imports enter the final products, without very complex analytical derivations otherwise. The elasticity of demand for intermediated goods as a departure from the standard Dixit-Stiglitz assumtion is embeded in the model, and analysed. Taxes modify the households behavior with respect to consumption, investment, and labor supply decisions.

3 Literature

From the modeling perspective, NOEM can be seen as an extensions on a New Keynesian closed economy (e.g. Gali (2002)). It uses microeconomic RBC methodology to model the optimization function of the representative agent and expectations, as well as nominal and real rigidities to model frictions in the market. The theoretical foundations of the NOEM differ mainly with respect to the assumptions of the price setting mechanism for exported and imported goods, the nature of the goods being traded and their distribution in the domestic market, the nature of the international capital markets,and the consumer bias for domestically vs. imported goods. In addition, different stochastic shocks complement the DSGE models to explain the fluctuations in the main economic indicators.

The challenge to match New Keynesian models to the empirical evidence has prompted academics and researchers to look for adequate optimization tools that can fully account for the data. Building on Leeper and Sims's (1994) full-information maximum-likelihood methods and Schorfheide's (2000) Bayesian techniques, Smets and Wouters (2003) successfully estimate an optimization-based DSGE model of the Euro Area. Significant contribution is brought by Christiano, Eichenbaum, and Evans (2005) in explaining the monetary policy shocks. Similar achievements contributed to the DSGE models being used intensively for the analysis of the optimal monetary policy and of international policy coordination.

While closed economy studies have been quite abundant, there is relatively little empirical work on open economy. Recently, Bergin (2004) developed a two-country model that combines features of international real business cycle models with the NOEM; Adolfson, Laséen, Lindé, and Villani (2005) extend a model with imperfect international risk sharing that follows the framework of Christiano, Eichenbaum and Evans (2005); Lubik and Schorfheide (2005) built up a small-scale two-country model. They are the pioneers in estimating their open economy models using Bayesian techniques.

Following these advances in estimating the DSGE closed economy, Walque, Smets and Wouter (2005) launched a new initiative to estimate large scale models using over 20 shocks and time series in their model. Their theoretical setup explaining the international sector is successful in accounting for the role of the elasticity of substitution between domestic and foreign goods; current account is derived from the intertemporal decision, as the difference between savings and investment,and interest rate parity is modeled by introducing a stochastic component. This mirrors the imperfections in the international capital market and recoils on the capital account flows, and thereby on the current account through the balance of payments identity. The linkage between current account, international risk premiums, and exchange rate has been the subject of investigation for some of the authors' contemporaries. Mainly, the correlation between net foreign assets and the exchange rate through the intermediation of a risk premium in Bergin (2006) and Adolfson, Laséen, Lindé, and Villani (2005) is strongly supported by the data. An extensive body of research has provided evidence that fluctuations in fiscal policy seem to matter for the business cycle. In our contribution, we use a benchmark model where government issues no debt, which is consistent with Bergin (2005),and follows Baxter and King (1993) specifications. Another simplification used in our theoretical model is to assume increasing public debt (e.g. Trabant and Uhlig (2006)).

4 The Model

Our model consists of two coutries: EU and USA, that may differ in size, but are otherwise isomorphic, and the rest of the world. Hence, our exposition below focuses on the EU economy. The model incorporates features designed to account for the effects of oil and non-oil import shocks by allowing them to enter both the intermediate goods production and the final goods production.

4.1 Households

In each country, there is a continuum of households indicated by the index $\tau = [0;1]$, each one supplying a complete set of differentiated labour. The instantaneous utility function of each household depends positively on consumption C_t relative to an external habit variable H_t and negatively on labour supply l_t^τ:

$$U_t^\tau = \frac{1}{1-\sigma_c}(C_t^\tau - H_t)^{1-\sigma_c} \cdot exp(\frac{\sigma_c - 1}{1+\sigma_l}(l_t^\tau)^{1+\sigma_l}) \tag{1}$$

where σ_c determines the intertemporal elasticity of substitution and σ_l the elasticity of work effort with respect to real wage. Habit formation, which among economists is called "keeping up with the Joneses" is a constant fraction of the previous time consumption:

$$H_t = hC_{t-1} \tag{2}$$

Each household maximizes an intertemporal utility function with β as discount factor:

$$E_0 \sum_{t=0}^{\infty} \beta^t U_t^\tau \tag{3}$$

4.1.1 Income, consumption and savings

Households derive income by selling their labor at the real wage w_t^τ, renting capital to firms at the real rent r_t^k, receiving real dividends from the domestic intermediate firms Div_t^τ, and from government transfers TR_t^τ. Labor and capital income are subject to taxation. Capital tax allows for deduction of depreciation but it does not write off additional costs of capital utilization $\Psi(z_t^\tau)K_{t-1}^\tau$. This approach is consistent with individual income taxes often taxing the total income of the individual (allowing some deductions), while corporate income taxes often tax net income.

$$Y_t^\tau = (1-\tau_t^l)w_t^\tau l_t^\tau + (1-\tau_t^k)(r_t^k - \delta)z_t^\tau K_{t-1}^\tau + \delta z_t K_{t-1}^\tau - \Psi(z_t^\tau)K_{t-1}^\tau + Div_t^\tau + TR_t^\tau \quad (4)$$

We assume that the tax rates on labor and capital follow exogeneous AR(1) processes around a steady state tax rate:

$$\tau_t^l = \epsilon_t^l = \tau^l + \rho_l \epsilon_{t-1}^l + \eta_t^l, \text{ with } \eta_t^l \text{ an i.i.d. - Normal error term.}$$
$$\tau_t^k = \epsilon_t^k = \tau^k + \rho_k \epsilon_{t-1}^k + \eta_t^k, \text{ with } \eta_t^k \text{ an i.i.d. - Normal error term.}$$

Another part of households's income comes from net cash inflows from participating in the capital market. They can hold two types of noncontingent bonds: one denominated in home currency B_t^τ, and the other denominated in foreign currency $B_t^{\tau*}$. Bonds are one period securities with a nominal price $1/R_t$ paying B_t at maturity in period t+1.

$$\frac{1}{R_t^e}\frac{B_t^\tau}{P_t^C} + \frac{1}{R_t^{e*}}\frac{B_t^{\tau*}}{P_t^C S_t} = \frac{B_{t-1}^\tau}{P_t^C} + \frac{B_{t-1}^{\tau*}}{P_t^C S_t} + Y_t^\tau - (1+\tau_t^c)C_t^\tau - I_t^\tau \quad (5)$$

$$R_t^e = \frac{R_t}{\epsilon_t^b}, R_t^{e*} = \frac{R_t^*}{\epsilon_t^b \epsilon_t^S}$$

The effective returns on domestic and foreign bonds are affected by a risk premium on bold holdings represented by AR(1) shock $\epsilon_t^b = \rho_b \epsilon_{t-1}^b + \eta_t^b$, with η_t^b an i.i.d. - Normal error term. Foreign interest rate is in addition affected by a risk premium on foreign bond holdings shock, ϵ_t following a similar AR(1) process to ϵ_t^S.
Current income and financial wealth can be used for consumption and investment in physical capital. Real consumption C_t^τ corresponds to a real expenditure of $(1+\tau_t^c)C_t^\tau$, whereby τ_t^c, an exogeneous variable is designated as a tax based on consumption, with $\tau_t^c = \epsilon_t^c = \tau^c + \rho_c \epsilon_{t-1}^c + \eta_t^c$, with η_t^c an i.i.d. - Normal error term. Capital formation is described by equation (6), where we assume the adjustment cost function of changes in investment to have the following features: $S(1) = 0, S^{'}(1) = 0$, and $S^{''}(1) = 1/\varphi$ represents the adjustment costs.

$$K_t = K_{t-1}(1-\delta) + (1 - S\left(\frac{\epsilon_t^I I_t}{I_{t-1}}\right))I_t \tag{6}$$

4.1.2 Labor market:

The labour supply and wage-setting processes are modelled as in Smets and Wouters (2003). The elasticity of demand for individual labor supply is assumed to be constant. Households are wage-setters in the labour market and, following Calvo (1983), they can set their wage optimaly with probability $1-\xi_w$. With the complementary probability, their wage is indexed to both past inflation in the consumption price and trend inflation with respective shares γ_w and $1-\gamma_w$. Thus, households choose nominal wage in order to maximise their intertemporal objective function subject to the intertemporal budget constraint and to the following labour demand:

$$l_t^\tau = \left(\frac{W_t^\tau}{W_t}\right)^{-(1+\lambda_w)/\lambda_w} L_t \tag{7}$$

4.2 Intermediate firms

Intermediate goods y_t^j are produced in a monopolistic competition by a continuum of differentiated producers (indexed by i= [0; 1]) characterized with sticky prices. The Calvo model makes some very specific assumptions about the elasticity of demand, holding it constant. The previous case of wage setting is such an example that follows Dixit-Stiglitz specification of a constant mark-up. For the intermediate firms we follow Eichenbaum and Fisher (2003), and allow for the possibility that the elasticity of demand is a function of firm's price. In order to define this elasticity first we need to define the technology of the domestic good firm D_t as :

$$\int_0^1 G(y_t^j/D_t) = 1 \tag{8}$$

Function G includes the relative price of individual producers P_t^j and the aggregate P_t^D, as well as elasticity. Following the specifications of Kimball (1995), G is increasing, and strictly concave, $G(1) = 1$.
The standard Dixit-Stiglitz specification corresponds to the specific case:

$$G(y_t^j/D_t) = (y_t^j/D_t)^{\frac{1}{1+\lambda_p}} \tag{9}$$

The intermediate goods are produced with a Cobb-Douglas technology function nested in a Leontieff production function:

$$v_t^j = \epsilon_t^a \cdot \tilde{K}_{j,t}^{\alpha} \cdot L_{j,t}^{1-\alpha} \tag{10}$$

$$\tilde{K}_{j,t} = z_t K_{j,t-1} \tag{11}$$

$$y_t^j = min\left\{(1-\omega-\zeta)\cdot v_t^j; \omega \cdot O_p^{j,t}; \zeta \cdot M_p^{j,t}\right\} - \Phi \tag{12}$$

with $\epsilon_t^a = \rho_a \epsilon_{t-1}^a + \eta_t^a$, with η_t^w an i.i.d. - Normal error term, where ϵ_t^a is a productivity shock, $\tilde{K}_{j,t}$ the capital stock effectively utilised, $L_{j,t}$ an index of various types of labour hired by the firm, and Φ a fixed cost introduced to ensure zero profits in steady state. Variables Op $O_p^{j,t}$ and $M_p^{j,t}$ are respectively the oil and non-oil imported goods necessary for the production process. Parameters ω and ζ represent their respective shares.

4.3 Final goods sector

The final good F_t is produced by a representative "consumption good distributor" from the intermediate good Θ_t and oil O_t^f following a Leontieff technology with a fixed proportion θ of oil :

$$F_t = min\left\{(1-\theta)\Theta_t; \theta O_t^f\right\} \tag{13}$$

For the use in the production of final goods, the imports are combined with domestic goods via a distribution channel:

$$M_t^d = min\left\{(1-\nu)D_t^d; \nu M_t^f\right\} \tag{14}$$

The intermediate good combines domestically produced and the imported-and-distributed through a CES technology:

$$\Theta_t = \left[\mu^{\frac{\rho}{1+\rho}}(D_t^d)^{\frac{1}{1+\rho}} + (1-\mu)^{\frac{\rho}{1+\rho}}(\Omega_t M_t^d)^{\frac{1}{1+\rho}}\right]^{1+\rho} \tag{15}$$

The form of the production function mirrors the preferences of households over consumption of domestically-produced goods and imports. Accordingly, the quasi-share parameter may be interpreted as determining household preferences for home relative to foreign goods, or equivalently, the degree of home bias in household consumption expenditure.
Following Laxton and Pesenti (2003), the allocation of final domestic demand between the baskets of domestic and foreign goods depends on the relative price of the two goods and is subject to a reallocation adjustment cost which is modelled as a quadratic function:

$$\Omega_t = \left[1 - \Omega \left(1 - \frac{M_t^d / D_t^d}{M_{t-1}^d / D_{t-1}^f}\right)^2\right] \tag{16}$$

This adjustment cost implies that the reallocation between domestic and imported goods will happen only gradually depending on the perceived persistence of the relative price changes. This specifcation implies that it is costly to change the proportion of domestic and foreign goods in the aggregate consumption bundle, even though the level of imports may jump costlessly in response to changes in overall consumption demand. It aims to capture the intuitively-appealing notion that households may have limited ability in the short-run to vary the mix of domestic goods relative to foreign goods in producing consumption services, even if longer-run substitution possibilities are more favorable. The authors posit that this specification is consistent from an empirical perspective, with evidence which suggests that imports adjust slowly in response to relative price changes, but respond rapidly to changes in real activity.

4.4 Imported goods sector

Total imports are made up by non-oil and oil imports:

$$M_t^T = M_t + O_t \tag{17}$$

Non-oil imported goods M_t enter the final good production process at two levels. First, indirectly, as inputs of the domestically produced intermediate goods y_t^j and secondly as the main input M_t^f used to produce the imported-and-distributed goods. Therefore, total non-oil imports are given by:

$$M_t = M_t^p + M_t^f \tag{18}$$

Non-oil imported goods are provided by a continuum of importing firms indexed by l, with l=[0, 1]. Importers for the euro area produce an homogeneous good by combining fixed shares of the exported final goods from the two other economies, i.e. the US and the Rest of the World. These importing firms then differentiate it, e.g. by brand naming. The differentiated good they produce m_t^l is sold on the euro area market at price $P_t^{M,l}$. It is assumed that importers can set optimally their price according to a random Calvo process with probability $1 - \xi_m$. The share m of the importers who cannot optimise their price index to the previous period inflation rate in the imported price.
Assuming that the differentiated import goods are combined through a CES technology, we have:

$$M_t = \left[\int_0^1 (m_t^l)^{\frac{1}{1+\lambda_m}} \right]^{1+\lambda_m} \tag{19}$$

and the demand faced by each importing firm is:

$$m_t^l = M_t \left(\frac{P_t^{M,l}}{P_t^M} \right)^{-\frac{1+\lambda_m}{\lambda_m}} \tag{20}$$

Like non-oil imports, oil intervenes both in the final good production and the intermediary domestic good production process. The demand for oil is assumed to be proportional to total demand and total production of domestically produced intermediate good: no substitution effects are allowed.

$$O_t = O_t^p + O_t^f \tag{21}$$

The oil price together with the non-oil import price feed immediately into the final good price without any rigidity, while both prices affect the domestic output price gradually through the marginal production cost and the Calvo price setting assumption.
The link of the external sector with the world economy is made by expressing the imports as weighted exports of the US and rest of the world economies, and in the opposite direction deriving exports as foreign imports among the same parties, with β_m the share of imports and β_x the share of exports of US economy from and to domestic economy:

$$M_t = \beta_m X_t^* + (1 - \beta_m) X_t^{ROW*} \tag{22}$$

X_t^{ROW*} will be used at a later stage to determine the marginal cost of importing firms and their impact on imported inflation modelled subsequently in the paper.

$$X_t = \beta_x M_t^* + (1 - \beta_x) M_t^{ROW*} \tag{23}$$

Since the imports of the Rest of the World M_t^{ROW*} are not observed and do not enter the model, we treat them as a demand shock affecting the exports of the economy: $M_t^{ROW*} = \epsilon_t^{NT*} = \rho_{NT*}\epsilon_{t-1}^{NT*} + \eta_t^{NT*}$, with η_t^{NT*} an i.i.d. - Normal error term.

4.5 Government

For simplicity, we abstain from government issue of debt, so that the government consumption is entirely financed by taxes less transfers. Given that the model has no features to break Ricardian equivalence, this simplification has no impact on the results:

$$G_t = T_t - TR_t \tag{24}$$

where TR_t has the interpretation of a budget deficit (we follow Baxter and King (1993),). Consequently, there is no government debt. Government expenditure is modelled as an exogenous variable equal to 0 in the steady state: $G_t = \epsilon_t^G = \rho_G \epsilon_{t-1}^G + \eta_t^G$, with η_t^G an i.i.d. - Normal error term.
Government tax revenues can be summarize as:

$$T_t = \tau_t^c C_t + \tau_t^l L_t w_t + \tau_t^k (r_t^k - \delta)\tilde{K}_t \tag{25}$$

4.6 Balance of Payments

We use the definition of trade balance to write the balance of payments condition:

$$\frac{1}{R_t^e}\frac{B_t^{\tau *}}{P_t^C S_t} - \frac{B_{t-1}^{\tau *}}{P_t^C S_t} = X_t - \frac{P_t^M}{P_t^D} M_t - \frac{P_t^o}{S_t P_t^D} O_t \tag{26}$$

The current account relationship determines the accumulation of foreign assets B_t^*:

$$CA_t = \frac{1}{R_t^e}\frac{B_t^{\tau *}}{P_t^C S_t} - \frac{1}{R_{t-1}^e}\frac{B_{t-1}^{\tau *}}{P_t^C S_t} \tag{27}$$

4.7 Market equilibrium

The final good market is in equilibrium if the production equals the demand by domestic consumers and investors plus exportation to the US and the Rest of the World economies:

$$F_t = C_t + I_t + X_t \tag{28}$$

Government spending is assumed to be realized exclusively in domestic goods so aggregate demand for the intermediate good is given by:

$$D_t = D_t^p + D_t^f + G_t \tag{29}$$

The equilibrium of the trade bock imposes the equalisation of imports and exports

$$M_t^T = X_t \tag{30}$$

The capital rental market is in equilibrium if the demand for capital expressed by the intermediate goods domestic producer equals the supply by the households. Equilibrium on the labour market is realized if the firm's labour demand equals the labor supply at the wage set by the households. The interest rate is determined by an empirical reaction function describing monetary policy decisions. These are governed by a Taylor type reaction rule. The specific form of the monetary policy reaction function will be introduced in log-linearized version in the next section.

5 Model analysis

We find it more convenient to treat the first order conditions, steady state and log-linearized equations together. For the purpose of the paper, we need to write the model in log-linearized form. This emerges from the first order condition equations and linearizing the equations around the steady state.

5.1 Households: Optimization problem

Write the Lagrange function:

$$
\begin{aligned}
H = {} & E_0 \sum_{t=0}^{\infty} \beta^t [(\frac{1}{1-\sigma_c}(C_t^\tau - H_t))^{1-\sigma_c} \cdot exp(\frac{\sigma_c - 1}{1+\sigma_l}(l_t^\tau)^{1+\sigma_l}) \\
& + \lambda_t(\frac{1}{R_t^e}\frac{B_t^\tau}{P_t^C} + \frac{1}{R_t^{e*}}\frac{B_t^{\tau *}}{P_t^C S_t} - \frac{B_{t-1}^\tau}{P_t^C} - \frac{B_{t-1}^{\tau *}}{P_t^C S_t} + (1+\tau_t^c)C_t^\tau + I_t^\tau \\
& - (1-\tau_t^l)w_t^\tau l_t^\tau - ((1-\tau_t^k)(r_t^k - \delta)z_t^\tau K_{t-1}^\tau) - \delta z_t K_{t-1}^\tau + \Psi(z_t^\tau)K_{t-1}^\tau - Div_t^\tau - TR_t^\tau) \\
& + \mu_t(K_t - K_{t-1}(1-\delta) - (1 - S\left(\frac{\epsilon_t^I I_t}{I_{t-1}}\right))I_t)]
\end{aligned}
$$

where λ_t is the marginal value in utils of one real domestic currency's worth of bonds and μ_t is the marginal value of a unit of capital in utils (as defined in Kimball (1995)). The marginal value of capital Q_t is:

$$
Q_t = \frac{\mu_t}{\lambda_t} \tag{31}
$$

Given the Ricardian equivalence implied by the model, it is not necessary to keep track of the household stock of bonds or the government's budget constraint. Deriving the Lagrangian function with respect to holdings of domestic and foreign bonds, capital, investment, capital utilization, labor yields the following FOCs:

$$E_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\frac{R_t^e P_t^C}{P_{t+1}^C}\right]=1 \tag{32}$$

$$E_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\frac{S_t}{S_{t+1}}\frac{R_t^{e*} P_t^C}{P_{t+1}^C}\right]=1 \tag{33}$$

$$\frac{R_t \epsilon_t^S}{R_t^*}=\frac{S_t}{S_{t+1}} \tag{34}$$

Making abstraction of the term ϵ_t^S we obtain the uncovered interest rate parity. However, it is well known from empirical studies that UIP condition is strongly rejected by the data. One of the reasons for this is the imperfect integration of the financial markets. We therefore add the term ϵ_t^S to the left hand side of the last equation.

The benchmark model de Walque et al.(2005) only includes the shock in the numerator of real effective exchange rate on foreign bonds, while the Dynare code suggests the placement of the shock in the denominator. The inconsistency between the theoretical model as regards to the sign of the stochastic component of the risk premium and the Dynare code provided by the authors prompted us to proceed for further investigations of the nature of this premium. Our first intuition was that, in order to increase the return on foreign bonds it should be placed similarly to the risk premium on bond holdings, namely at the denominator in the last equation. In order to support to our reasoning, we consulted the theoretical set up and impulse-response graphs in Bergin(2006) and Linde at al(2005). They model the risk premium as a function strictly decreasing in real aggregate net foreign asset position of the domestic econoy $b_t^*=\frac{1}{R_t^{e*}}\frac{B_t^{\tau*}}{P_t^C S_t}$:

$$RP(b_t^*,\epsilon_t^S)=exp(-RP\cdot b_t^*+\epsilon_t^S) \tag{35}$$

with RP positive. The risk premium is a function decreasing in net foreign assets, which means that that foreign interest rate faced by the households is increased by a premium when the domestic economy is a net borrower and reduced by a discount when it is a net lender. The risk premium has a second component, a mean-zero disturbance ϵ_t^S, which serves as an uncovered rate parity shock, as in our model, with the same sign in the linearized form as the rate of return on foreign bonds.

Firstly, the graphs produced in Dynare and that displayed in the models used for comparison are the same, proving the authors right when they change the sign of the shock when modelling the impulse-response analysis. Second, between the theoretical benchmark models and De Walque et al.(2005) there is consistency when placing the risk premium.

Because the evidence is ambiguous, we chose to represent the model to match the Dynare codes and our intuition, and assume that the positioning of the stochastic term is probably related to the expectation formation or modeling the current account:

$$\hat{R}_t - \hat{R}_t^* + \hat{\epsilon}_t^S = \hat{S}_t - \hat{S}_{t+1} \tag{36}$$

The equation shows that a higher interest rate home implies a lower expected forward rate which corresponds to an appreciation of domestic currency in terms of the foreign coin.

To derive consumption we write Euler equation as follows:

$$E_t \left[\beta \frac{U_{t+1}^c}{U_t^c} \frac{1 + \tau_t^c}{1 + \tau_{t+1}^c} \frac{R_t^e P_t^C}{P_{t+1}^C} \right] = 1 \tag{37}$$

In the log-linearized version taxes are expressed as deviations from the steady state value and rescaled by multiplying in every case respectivelly with $1 - \tau^c$, $1 - \tau^l$, $1 + \tau^c$.

$$\hat{U}^c_{t+1} - \hat{U}^c_t + \hat{\tau}^c_t - \hat{\tau}^c_{t+1} - \hat{\pi}^C_{t+1} + \hat{R}_t - \hat{\epsilon}^b_t = 0 \tag{38}$$

$$\hat{U}^c_t = -\sigma_c \frac{1}{1-h}(\hat{C}_t - h\hat{C}_{t-1}) + (\sigma_c - 1)(\bar{l}^\tau)^{1+\sigma_l}\hat{L}_t (39)$$

In this equation, steady state labor supply of individual households $\bar{l}^\tau$ is obtained using the equation () for wage optimization, derived later in the paper In additon, in steady state the entire income from labor is used for private consumption, namely $W^\tau l^\tau = P^C C$. To show this, insert TR from budget constraint into the households budget constraint, evaluated at the aggregate level, which implies that all the tax-terms cancel as they should (government consumption is zero in the steady state). In addition, the return on capital is used entirely for the investment to rebuild the steady state level of capital affected by depreciation. These result in: $(\bar{l}^\tau)^{1+\sigma_l} = \frac{-1}{(1+\lambda_w)(1-h)}\frac{1-\tau^l}{1+\tau^c}$. This gives us the law of motion for consumption:

$$\begin{aligned}\hat{C}_t = \frac{1}{1+h}(\hat{C}_{t+1} - h\hat{C}_{t-1}) + \frac{\sigma_c - 1}{\sigma_c(1+h)(1+\lambda_w)}\frac{1-\tau^l}{1+\tau^c}(\hat{L}_t - \hat{L}_{t+1}) \\ - \frac{1-h}{\sigma_c(1+h)}(\hat{R}_t - \hat{\pi}^C_{t+1} - \epsilon^b_t + \tilde{\tau}^c_t - \tilde{\tau}^c_{t+1})\end{aligned} \tag{40}$$

We use again the definition of Q_t to derive investment:

$$Q_t(1-S\left(\frac{\epsilon^I_t I_t}{I_{t-1}}\right))=Q_t S'\left(\frac{\epsilon^I_t I_t}{I_{t-1}}\right)\frac{\epsilon^I_t I_t}{I_{t-1}}+1-E_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}Q_{t+1}S'\left(\frac{\epsilon^I_{t+1}I_{t+1}}{I_t}\right)\left(\frac{\epsilon^I_{t+1}I_{t+1}}{I_t}\right)\frac{I_{t+1}}{I_t}\right] \tag{41}$$

Rather than log-linearization for real consumption, we use a fraction of intertemporal investment:

$$\hat{I}_t = \frac{1}{1+\beta}(\hat{I}_{t-1} + \beta \hat{I}_{t+1} + \varphi \hat{Q}_t) + \hat{\epsilon}_t^I \tag{42}$$

If we derive the Lagrangian function with respect to K_t and use the definition of Q_t we obtain:

$$Q_t = E_t\left[\beta \frac{\lambda_{t+1}}{\lambda_t}\left(Q_{t+1}(1-\delta)+(1-\tau_{t+1}^k)(r_{t+1}^k-\delta)z_{t+1}^\tau+\delta z_{t+1}-\Psi(z_{t+1}^\tau)\right)\right] \tag{43}$$

Now taking the derivative with respect to investment, gives us in steady state $\mu = \lambda$ which implies $Q = 1$; then from the equation above we get in steady state: $(1-\tau^k)(r^k-\delta) = \frac{1-\beta}{\beta}$. We use it to log linearize:

$$\hat{Q}_t = -\hat{R}_t + \hat{\pi}_t^C + \beta(1-\delta)\hat{Q}_{t+1} - (1-\beta)\hat{\tau}_{t+1}^k + (1-\beta)\frac{r^k}{r^k-\delta}\hat{r}_{t+1}^k + \hat{\epsilon}_t^b \tag{44}$$

Notice that capital utilization z_t does not show up in the equation. This is because, using for linearization the approximation $\hat{f}(x_t) = \frac{f^{'}(\bar{x})\bar{x}}{f(\bar{x})}$ and the condition for the capital utilization bellow in the steady state, the term vanishes:

$$(1-\tau_t^k)(r_t^k-\delta) + \delta = \Psi\prime(z_t^\tau) \tag{45}$$

$$\frac{1-\beta}{1-\beta+\beta\delta}[-\hat{\tau}_{t+1}^k + \frac{r^k}{r^k-delta}\hat{r}_t^k] = \frac{1}{\psi}\hat{z}_t \tag{46}$$

with ψ inverse of the elasticity of the capital utilization cost function.
We add in this section the capital accumulation and capital intensity equations:

$$\hat{K}_t = (1-\tau)\hat{K}_{t-1} + \tau \hat{I}_{t-1} + \tau(1+\beta)\frac{1}{\varphi}\hat{\epsilon}_t^I \tag{47}$$

$$\hat{\tilde{K}}_t = \hat{K}_t + \hat{z}_t \tag{48}$$

In the next section we derive labor supply decisions and the wage setting equations. We first solve for the case of flexible wages.

We write $\Lambda_t = \frac{\lambda_t}{P_t^C}$, the Lagrange multiplier in nominal terms and $W_t^\tau = w_t^\tau P_t^C$ the nominal wage. Deriving with respect to l_t^τ gives:

$$(U_t^\tau)_l = W_t^\tau \frac{1}{1+\lambda_{w,t}} \Lambda_t (1-\tau_t^l) \tag{49}$$

Combining this equation with the marginal utility of consumption $(U_t^\tau)_c = (1+\tau_t^c)P_t^C \Lambda_t$, yields:

$$\frac{(U_t^\tau)_l}{(U_t^\tau)_c} = \frac{W_t^\tau}{P_t^C} \frac{1}{1+\lambda_{w,t}} \frac{1-\tau_t^l}{1+\tau_t^c} \tag{50}$$

$$(U_t^\tau)_l = -(l_t^\tau)^{\sigma_l}(C_t^\tau - H_t)^{1-\sigma_c} \cdot exp(\frac{\sigma_c - 1}{1+\sigma_l}(l_t^\tau)^{1+\sigma_l}) \tag{51}$$

$$(U_t^\tau)_c = (C_t^\tau - H_t)^{-\sigma_c} \cdot exp(\frac{\sigma_c - 1}{1+\sigma_l}(l_t^\tau)^{1+\sigma_l}) \tag{52}$$

Simplifying, we reach the following condition for nominal wages in the flexible setup:

$$W_t^\tau = -P_t^C \frac{1+\tau_t^c}{1-\tau_t^l}(1+\lambda_{w,t})(l_t^\tau)^{\sigma_l}(C_t^\tau - H_t) \tag{53}$$

But the households know that it is possible to maximize their nominal wage in t but not before and including t+i; their wage in each period t+i between to optimizations will be be indexed to the previous year CPI inflation: $W_{t+i}^\tau = W_t^\tau (P_{t-1+i}^C / P_{t-1}^C)^{\gamma_p} \bar{\pi}^{1-\gamma_p}$. Therefore, the intertemporal optimization solution sums over all states of nature weighted by the probability of their occurence; we obtain for the optimal nominal wage in t (after having substituted l_t^τ as in Chen (2007)):

$$E_t\Big[\textstyle\sum_0^\infty (\beta\xi_w)^i \tilde{W}_t (P_{t-1+i}^C / P_{t-1}^C)^{\gamma_p} \bar{\pi}^{1-\gamma_p}\Big] =$$

$$E_t\left[\textstyle\sum_0^\infty (\beta\xi_w)^i - P_{t+i}^C \frac{1+\tau_{t+i}^c}{1-\tau_{t+i}^l}(1+\lambda_{w,t+i})\left(\left(\frac{\tilde{W}_t^\tau (P_{t-1+i}^C / P_{t-1}^C)^{\gamma_p} \bar{\pi}^{1-\gamma_p}}{W_{t+i}}\right)^{\frac{-(1+\lambda_{w,t+i})}{\lambda_{w,t+i}}} L_t \right)^{\sigma_l} (C_{t+i}^\tau - H_{t+i})\right] \tag{54}$$

Detrending and log-linearizing equation (52), after several computations we obtain:

$$\hat{w}_t^* + \hat{P}_t^C - \gamma_p \hat{P}_{t-1}^C =$$

$$-\frac{(1-\beta\xi_w)}{1+\frac{(1+\lambda_w)\sigma_l}{\lambda_w}}[\hat{w}_t - \sigma_l \hat{L}_t - \frac{1}{1-h}(\hat{C}_t - \hat{C}_{t-1}) - \hat{\tau}_t^c - \hat{\tau}_t^l] + (1-\beta\xi_w)(\hat{w}_t + \hat{P}_t^C) + \beta\xi_w(\hat{w}_{t+1}^* + \hat{P}_{t+1}^C - \gamma_p \hat{P}_t^C) + \hat{\lambda}_{w,t} \tag{55}$$

Notice that the shock $\hat{\lambda}_{w,t}$ has been rescaled, by multiplyning it with the inverse of $\frac{1}{\xi_w(1+\beta)} \frac{(1-\beta\xi_w)(1-\xi_w)}{1+\frac{(1+\lambda_w)\sigma_l}{\lambda_w}}$. It follows $\lambda_{p,t} = \lambda_p + \rho_p \lambda_{p,t-1} - \phi_p \eta_{t-1}^p + \eta_t^p$, with η_t^p an i.i.d. - Normal error term.

Aggregation of the nominal wages in log-linearized form is given by:

$$\hat{W}_t = (1-\xi_w)\hat{W}_t^* + \xi_w(\hat{W}_{t-1} + \gamma_p \hat{\pi}_{t-1}^C) \tag{56}$$

Writing in real terms and substracting $\gamma_p \hat{P}^C_{t-1}$ from the both terms of the equation:

$$\hat{w}_t + \hat{P}^C_t - \gamma_p \hat{P}^C_{t-1} = (1-\xi_w)(\hat{w}^*_t + \hat{P}^C_t - \gamma_p \hat{P}^C_{t-1}) + \xi_w(\hat{w}_{t-1} + \hat{P}^C_{t-1} - \gamma_p \hat{P}^C_{t-2}) \quad (57)$$

Combining the two equations gives us the low of motion for the real wages:

$$\hat{w}_t = \frac{\beta}{1+\beta} E_t \hat{w}_{t+1} + \frac{1}{1+\beta} E_t \hat{w}_{t-1} + \frac{\beta}{1+\beta} E_t \hat{\pi}_{t+1} - \frac{1+\beta\gamma_w}{1+\beta} E_t \hat{\pi}_t + \frac{\gamma_w}{1+\beta} E_t \hat{\pi}_{t-1}$$
$$- \frac{1}{\xi_w(1+\beta)} \frac{(1-\beta\xi_w)(1-\xi_w)}{1+\frac{(1+\lambda_w)\sigma_l}{\lambda_w}} [\hat{w}_t - \sigma_l \hat{L}_t - \frac{1}{1-h}(\hat{C}_t - \hat{C}_{t-1}) - \hat{\tau}^c_t - \hat{\tau}^l_t] + \hat{\lambda}_{w,t} \quad (58)$$

5.2 Intermediate firms: Optimization problem

The domestic intermediate firm chooses D_t and y_t to maximize profits, $P^D_t D_t - \int_0^1 P^j_t y^j_t$. From the cost minimization, one obtains the demand for each intermediate producer:

$$y^j_t = D_t G^{'-1} \left(\frac{P^j_t}{P^D_t} \int_0^1 G^{'}(y^j_t/D_t)(y^i_t/D_t) dj \right) \quad (59)$$

Before proceeding further, we want to explain shortly the implications of variable elasticity of demand, as displayed by Kimball (1995). The assumption on G imply that the demand for input y^j_t is a decreasing function in its relative price. In other words, the firm must take into account when optimizing their objective function that setting a higher price might result into lower profits due to decreasing demand for their goods. The elasticity of demand for the output of intermediate goods is not explicitly modelled by the authors. We follow Eichenbaum and Fisher (2004) and define it as $\eta(x) = -G^{'}(x)/xG^{''}(x)$, where $x = y^j_t/D_t$ In our model the elasticity of demand for a given intermediate good is $\eta(x) = \frac{(\lambda^j_{p,t}+1)}{\lambda^j_{p,t}}$, with $\lambda_{p,t}$ the variable mark-up of the firm, defined as $\eta(1)/(\eta(1)-1)-1$. It follows an exogenoeus ARMA(1,1) process around λ_p, the steady state mark-up: $\lambda_{p,t} = \lambda_p + \rho_p \lambda_{p,t-1} - \phi_p \eta^p_{t-1} + \eta^p_t$, with η^p_t an i.i.d. - Normal error term

Next, we compute ϵ, the percent change in the elasticity of demand due to one percent change in the relative price of good, evaluated in the steady state: $\epsilon = (\delta\eta(1)/\eta(1))/(\delta P/P)$. Using equation (57), it can be proved that $\frac{1}{\epsilon\lambda_p+1} = \frac{1+G''(1)/G'}{2+G'''(1)/G''}$.

Returning to our optimization problem, each firm chooses K^j_t and L^j_t, taking as given both the rental price of capital R^k_t and the aggregate wage index W_t defined bellow.

$$W_t = (1-\alpha) p^j_t \epsilon^a_t \tilde{K}^{\alpha}_{j,t} L^{-\alpha}_{j,t} \tag{60}$$

$$R^k_t = \alpha p^j_t \epsilon^a_t \cdot \tilde{K}^{\alpha-1}_{j,t} L^{1-\alpha}_{j,t} \tag{61}$$

$$\frac{P_{tC} w_t L_{j,t}}{r^k_t \tilde{K}_{j,t} P^D_t} = \frac{1-\alpha}{\alpha} \tag{62}$$

The equation gives us the optimal input of capital and labor.

$$rk_t = (\hat{w}_t + \hat{\frac{\hat{P^C_t}}{P^D_t}}) + \hat{L}_t - \hat{\tilde{K}}_t (63)$$

The term $\frac{\hat{P^C_t}}{P^D_t}$ shows up because the nominal wages and capital returns are deflated by CPI respectively GDP deflator.

For the domestic economy, we assume that in any given period only a constant fraction, i.e., ξ_e of firms is able to adjust employment to its desired total labor input. This gives rise to the following auxiliary equation for employment:

$$\hat{E}_t = \hat{E}_{t-1} + \hat{E}_{t+1} - \hat{E}_t + \frac{(1-\beta\xi_e)(1-\xi_e)}{\xi_e}(\hat{L}_t - \hat{E}_t) \tag{64}$$

Further, the FOC for the other imput factors, oil and imports gives the following relative quantities:

$$\frac{v_t^j}{O_p^{j,t}} = \frac{1-\omega-\zeta}{\omega} \tag{65}$$

$$\frac{v_t^j}{M_p^{j,t}} = \frac{1-\omega-\zeta}{\zeta} \tag{66}$$

Total costs faced by the firms is:

$$TC_t^j = W_t L_{j,t} + R_t^k K_{j,t} + P_t^o O_p^{j,t} + P_t^M M_p^{j,t} \tag{67}$$

Firms can costlessly adjust all factor of production. Thus, the perfect mobiliy of factors between firms implies that all firms have identical marginal cost per unit of output, MC_t.

$$MC_t = (1-\omega-\zeta)\frac{W_t^{1-\alpha} \cdot (R_t^k)^\alpha}{\alpha^\alpha(1-\alpha)^{1-\alpha} \cdot \epsilon_t^a} + \omega\frac{P_t^o}{S_t} + \zeta P_t^M \tag{68}$$

All profits are distributed at the end of each period to households as dividents:

$$Div_{t+i}^j = (P_{t+1}^j - MC_{t+i})y_t^j - MC_{t+i}\Phi \tag{69}$$

Households use the following rule for discounting:

$$\tilde{V}_t^j(P_t^j) = \sum_{i=0}^{\infty} \epsilon_p^i E[\Lambda_{t,t+k} t Div_{t+i}^j(P_{t+i}^j)] \tag{70}$$

$$\Lambda_t = \frac{\lambda_t}{P_t^C} \tag{71}$$

$$\Lambda_{t,t+i} = \beta^i \frac{\lambda_{t+i}}{\lambda_t} \frac{P_t^C}{P_{t+i}^C} \tag{72}$$

As discussed in the introduction of the model, prices are also sticky and not all firms will optimize their price in each t. Therefore the firm chooses to maximize the following function subject to (57).

$$\tilde{V}_t^j(\tilde{P}_t^j) = \sum_{i=0}^{\infty} \xi_p^i \Lambda_{t,t+i} \Big[\Big(\tilde{P}_t^j (P_{t-1+i}^D / P_{t-1}^D)^{\gamma_p} \bar{\pi}^{i 1-\gamma_p} - MC_{t+i} \Big) y_{t+i}^j - MC_{t+i} \Phi \Big] \tag{73}$$

The firms that cannot optimize the prices, will index them acordingly:

$$P_{t+i}^j = \tilde{P}_t^j (P_{t-1+i}^D / P_{t-1}^D)^{\gamma_p} (\bar{\pi}^i / \epsilon_t^{\hat{\pi}})^{1-\gamma_p} \tag{74}$$

Following a procedure similar to the wage setting, obtain the domestic goods inflation, with $\frac{1}{\epsilon \lambda_p + 1}$ defined before and an additional term, not explicitely modeled to account for the feed back of a shock in consumption inflation on domestic prices:

$$\hat{\pi}_t^D = \frac{1}{1+\beta\gamma_p} \Big[\beta \hat{\pi}_{t+1}^D + \gamma_p \hat{\pi}_{t-1}^D + \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p} \cdot \frac{1}{\epsilon\lambda_p + 1} \cdot \hat{mc}_t^D \Big] + \lambda_{p,t} - cpy \cdot \eta_t^{PC} \tag{75}$$

$$\hat{mc}_t=(1-\omega-\zeta)(\alpha\hat{r}_t^k+(1-\alpha)(\hat{w}_t+\hat{\frac{P_t^C}{P_t^D}})-\hat{\epsilon_t^a})+\omega(\hat{P_t^o}-\hat{S}_t+\hat{\frac{P_t^M}{P_t^D}}-\hat{\frac{P_t^M}{P_t^{D*}}})+\xi\hat{\frac{P_t^M}{P_t^D}} \quad (76)$$

To obtain the marginal cost in real terms we must deflate all variables by domestic producer price. Real wages are originally deflated by CPI and the price of oil is deflated with GDP deflator for US.

Last equation for the intermediate domestic sector uses the specific production function.

$$\hat{Y}_t = \phi(\hat{\epsilon}_t^a + \alpha\hat{\bar{K}}_t + (1-\alpha)\hat{L}_t) \tag{77}$$

We use $\hat{I}_{t-1}$ instead of $\hat{I}_t$ because in Dynare the variables are introduced at the time decision is being made.

5.3 Importing firms: Optimization problem

The optimization problem is almost identical to the intermediate goods with the distinction that here $\epsilon = 0$. Non-oil import goods inflation:

$$\hat{\pi}_t^M = \frac{1}{1+\beta\gamma_m}\left[\beta\hat{\pi}_{t+1}^M + \gamma_p\hat{\pi}_{t-1}^M + \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p}\hat{mc}_t^M\right] + \hat{\epsilon}_t^m \tag{78}$$

The nominal marginal cost is simply the weighted value of imports from US and ROW.

$$MC_t^M = \beta_m\frac{P_t^*}{S_t} + (1-\beta)P_t\epsilon_t^{PM} \tag{79}$$

Import prices are deflated by the import price index. Also, the import price of the ROW, not explicitelly modelled, but expalined in terms of domestic price P_t^D and stochastic shock ϵ_t^{PM}

$$\hat{mc}_t^M = \beta_m(\frac{-\hat{P}_t^M}{P_t^{D*}} - \hat{S}_t) + (1-\beta_m)(-\hat{\frac{P_t^M}{P_t^D}}) \tag{80}$$

5.4 Final goods sector: Optimization problem

Final goods sector follows next on our list of log-linearized equations. Given the presence of adjustment costs, the representative consumption goods distributor chooses a contingency plan for D_t^f and M_t^d to minimize its discounted expected costs of producing the aggregate consumption good:

$$max \sum_{0}^{\infty} \beta^i \Lambda_{t,t+i} \left[P_{t+i}^C F_{t+i} - P_{t+i}^D D_{t+i}^f - P_{t+i}^{M^d} M_{t+i}^d - P_{t+i}^o O_{t+i}^f \right] \tag{81}$$

The first order conditions for equations (13) and (14) are being displayed below:

$$F_t(1-\theta) = \Theta_t \tag{82}$$

$$F_t\theta = M_t^f \tag{83}$$

The optimization problem for $D_t^f andM_t^d$ is very complicated, as showed in the first draft of the paper. Instead of solving analitically, the authors follow Corsetti et al. (2003) and introduce another parameter, namely the proportion of imports in final goods χ:

$$\Theta_t(1-\chi) = D_t^f \tag{84}$$

$$\Theta_t\chi = M_t^d \tag{85}$$

Finally, for the distribution sector:

$$M_t^d(1-\nu) = D_t^d \tag{86}$$

$$M_t^d \nu = M_t^f \tag{87}$$

In the steady state, we choose to express these conditions as a fraction of domestic output, rather than of final goods. In addition, at this stage we use the market equilibrium conditions to derive the necessary equations. For this:

$$\frac{\bar{F}}{\bar{Y}} = \frac{\bar{C}}{\bar{Y}} + \frac{\bar{I}}{\bar{Y}} + \frac{\bar{X}}{\bar{Y}} \tag{88}$$

$$\bar{X} = \bar{Y}(\zeta + \omega) + \bar{F}(\chi + \theta) \tag{89}$$

Which gives for $\frac{\bar{X}}{\bar{Y}}$ the following equation:

$$\frac{\bar{X}}{\bar{Y}} = \frac{\zeta + \omega + (\chi + \theta)(\frac{\bar{C}}{\bar{Y}} + \frac{\bar{I}}{\bar{Y}})}{1 - \chi - \theta} \tag{90}$$

We re-scale χ to express the proportion of imports in the final goods rather than distribution sector by dividing it by ν and obtain the following equations for the inputs of final sector in the steady state:

$$\frac{\bar{D}^f}{\bar{Y}} = (1 - \frac{\chi}{\nu})(1-\theta)(\frac{\bar{C}}{\bar{Y}} + \frac{\bar{I}}{\bar{Y}} + \frac{\bar{X}}{\bar{Y}}) \tag{91}$$

$$\frac{\bar{M}^d}{\bar{Y}} = \frac{\chi}{\nu}(1-\theta)(\frac{\bar{C}}{\bar{Y}} + \frac{\bar{I}}{\bar{Y}} + \frac{\bar{X}}{\bar{Y}}) \tag{92}$$

$$\frac{\bar{D}^d}{\bar{Y}} = (1-\nu)\frac{\chi}{\nu}(1-\theta)(\frac{\bar{C}}{\bar{Y}} + \frac{\bar{I}}{\bar{Y}} + \frac{\bar{X}}{\bar{Y}}) \tag{93}$$

$$\frac{\bar{M}^f}{\bar{Y}} = (1-\nu)\frac{\chi}{\nu}(1-\theta)(\frac{\bar{C}}{\bar{Y}} + \frac{\bar{I}}{\bar{Y}} + \frac{\bar{X}}{\bar{Y}}) \tag{94}$$

$$\frac{\bar{O}^f}{\bar{Y}} = \theta(\frac{\bar{C}}{\bar{Y}} + \frac{\bar{I}}{\bar{Y}} + \frac{\bar{X}}{\bar{Y}}) \tag{95}$$

$$\frac{\bar{\Theta}^f}{\bar{Y}} = (1-\theta)(\frac{\bar{C}}{\bar{Y}} + \frac{\bar{I}}{\bar{Y}} + \frac{\bar{X}}{\bar{Y}}) \tag{96}$$

In order to reduce the number of variables we simply express them as a function of D_t and M_t. The law of motion for the relative domestic vs. foreign imputs that are combined in the distribution sector depends on their elasticity of substitution and relative prices:

$$\hat{D}_t^f - \hat{M}_t^d = -\frac{\rho}{1+\rho}(-\frac{\hat{P_t^{M^d}}}{P_t^D} - \Omega(\hat{D}_t^f - \hat{M}_t^d - (\hat{D}_{t-1}^f - \hat{M}_{t-1}^d)) + \beta\Omega(\hat{D}_{t+1}^f - \hat{M}_{t+1}^d - (\hat{D}_t^f - \hat{M}_t^d)) \tag{97}$$

Market equilibrium equations (28) and (29) as well as (17), (18), (21) and (22) gives us:

$$\frac{\bar{C}}{\bar{Y}}\hat{C}_t + \frac{\bar{I}}{\bar{Y}}\hat{I}_t + \frac{\bar{X}}{\bar{Y}}\hat{X}_t = (\frac{\bar{C}}{\bar{Y}} + \frac{\bar{I}}{\bar{Y}} + \frac{\bar{X}}{\bar{Y}})[(1-\frac{\chi}{\nu})\hat{D}_t^f + \frac{\chi}{\nu}\hat{M}_t^d] \tag{98}$$

$$(1+\zeta+\theta)\hat{Y}_t = (\frac{\bar{C}}{\bar{Y}} + \frac{\bar{I}}{\bar{Y}} + \frac{\bar{X}}{\bar{Y}})(1-\theta)[(1-\frac{\chi}{\nu})\hat{D}_t^f + \frac{\chi}{\nu}(1-\nu)\hat{M}_t^d] + \frac{\bar{G}}{\bar{Y}}\hat{G}_t \tag{99}$$

$$\frac{\bar{X}}{\bar{Y}}\hat{M}_t^T = \nu(1-\theta)\frac{\chi}{\nu}(\frac{\bar{C}}{\bar{Y}} + \frac{\bar{I}}{\bar{Y}} + \frac{\bar{X}}{\bar{Y}})\hat{M}_t^d + \theta(\frac{\bar{C}}{\bar{Y}}\hat{C}_t + \frac{\bar{I}}{\bar{Y}}\hat{I}_t + \frac{\bar{X}}{\bar{Y}}\hat{X}_t) + (\zeta+\omega)\hat{Y}_t \tag{100}$$

$$\hat{X}_t = \beta_x \hat{M^d}^*_t + \hat{\epsilon}_t^{NT} \tag{101}$$

For the nominal variables, we obtain the following equations:
Consumer inflation:

$$\hat{\pi}_t^C = (1-\theta)\left[(1-cmc)\hat{\pi}_t^C + cmc\hat{\pi}_t^M\right] + \theta(\hat{\pi}_t^{Poil} - \hat{S}_t\hat{S}_{t-1} + \hat{\pi}_t^{D^*}) + \eta_t^{PC} \tag{102}$$

PI MD inflation:

$$\hat{\pi}_t^{M^d} = \nu\hat{\pi}_t^M + (1-\nu)\hat{\pi}_t^D \tag{103}$$

Total imports inflation:

$$\frac{\bar{X}}{\bar{Y}}\hat{\pi}_t^{M^T} = (\frac{\bar{X}}{\bar{Y}} - \omega - \theta(\frac{\bar{C}}{\bar{Y}} + \frac{\bar{I}}{\bar{Y}} + \frac{\bar{X}}{\bar{Y}}))\hat{\pi}_t^M + (\omega + \theta(\frac{\bar{C}}{\bar{Y}} + \frac{\bar{I}}{\bar{Y}} + \frac{\bar{X}}{\bar{Y}}))(\hat{\pi}_t^{Oil} - \hat{S}_t + \hat{S}_{t-1} + \hat{\pi}_t^{D^*}) \tag{104}$$

$$\frac{\hat{P_t^{M^d}}}{P_t^D} - \frac{\hat{P_{t-1}^{M^d}}}{P_{t-1}^D} = \hat{\pi}_t^{M^d} - \hat{\pi}_t^D \tag{105}$$

$$\frac{\hat{P_t^C}}{P_t^D} - \frac{\hat{P_{t-1}^C}}{P_{t-1}^D} = \hat{\pi}_t^C - \hat{\pi}_t^D \tag{106}$$

$$\frac{\hat{P_t^M}}{P_t^D} - \frac{\hat{P_{t-1}^M}}{P_{t-1}^D} = \hat{\pi}_t^M - \hat{\pi}_t^D \tag{107}$$

The last equations for the external sector express the trade balance and current account:

$$T\hat{B}_t = \frac{\bar{X}}{\bar{Y}}(\hat{X}_t - \hat{M}_t^T) \tag{108}$$

$$C\hat{A}_t = \frac{1}{\beta}C\hat{A}_t + \frac{\bar{X}}{\bar{Y}}(\hat{X}_t - \hat{M}_t^T - \frac{\hat{P_t^{M^T}}}{P_t^D}) \tag{109}$$

$$C\hat{A}_t = \hat{b}_t^* - \hat{b}_{t-1}^* \tag{110}$$

5.5 Monetary and fiscal policy

Finally,we write the equations for fiscal and monetary policy. In steady-state government consumption is assumed to be 0, so the transfers equal the tax revenues:

$$\frac{\bar{TR}}{\bar{Y}} = \tau^c \frac{\bar{C}}{\bar{Y}} + \tau^l \frac{\bar{w}\bar{L}}{\bar{Y}} + \tau^k (r^k - \delta) \frac{\bar{K}}{\bar{Y}} \tag{111}$$

In this equation we know $\frac{\bar{C}}{\bar{Y}}$; $\frac{\bar{w}\bar{L}}{\bar{Y}} = 1-\alpha$, $r^k - \delta = (\frac{1}{\beta}-1)\frac{1}{1-\tau^k}$ and $\frac{\bar{K}}{\bar{Y}} = \frac{\bar{I}}{\bar{Y}\delta}$ follow from FOC equalities of respective variables in the steady state.

Expressing government as percentage deviation from the steady state output $G_t = \bar{Y}\hat{G}_t$ we have the log-linearized budget constraint:

$$\hat{G}_t = \tau^c \frac{\bar{C}}{\bar{Y}}(\hat{\tau}_t^c + \hat{C}_t) + \tau^l (1-\alpha))(\hat{\tau}_l^c + \hat{L}_t + \hat{w}_t) + \tau^k (r^k - \delta) \frac{\bar{K}}{\bar{Y}}(\hat{\tau}_t^k + \frac{r^k}{r^k - \delta}\hat{r}_t^k + \hat{\hat{K}}_t) - \frac{\bar{TR}}{\bar{Y}}\hat{TR}_t \tag{112}$$

With some allowance for interest rate smoothing introduced by parameter ρ, monetary policy is described by the following interest rate reaction function:

$$\hat{R}_t = \rho \hat{R}_t + (1-\rho)\left\{ r_\pi \hat{\pi}_t^C + r_y(\hat{Y}_t^D - \hat{Y}_t^{D,flex})\right\} + r_{dy}\left\{ (\hat{Y}_t^D - \hat{Y}_t^{D,flex}) - (\hat{Y}_{t-1}^D - \hat{Y}_{t-1}^{D,flex})\right\} + \epsilon_t^{ms} \tag{113}$$

$\epsilon_t^{ms} = \rho\epsilon_{t-1}^{ms} + \eta_t^{ms}$, with η_t^{ms} an i.i.d. - Normal error term

The interest rate reacts on current inflation, lagged interest rate, current and lagged output gap, expressed as the difference between real and potential output.

6 Impulse response functions for the shocks

In this section we analyze the impulse-response functions obtained from the implementation in the Toolkit and Dynare.

In the paper most of the shocks are modelled as AR(1) processes, with the following exceptions: oil, price, and wage mark-ups, and investment specific technology shocks. To the existing 22 shocks in the paper of De Walque et al. (2005), we add 6 more shocks representing taxes described by AR(1) processes around a steady state value. The effects of these shocks on the economic variables are described bellow.

6.1 TFP shock

A productivity shock increases the real wages and therefore real income of households which produces an increase of real consumption. On the other hand, expected return of capital increases and, together with it, investment picks up. Stimulated by a decrease in real marginal cost, domestic output rises in order to meet the increased aggregate demand. Not all firms can optimize their price once their own marginal costs drop; this translates in higher CPI inflation due to the sluggishness of the price mechanism in the intermediate goods framework. Cheaper marginal costs at home means that domestic goods are more competitive and coupled with a depreciation of the euro on the short run, favors imports. The real rate of return drops shortly, whereafter its recovery produces a depreciation of the national currency on the short term with a negative effect on the net trade. Net foreign assets decrease with the drop of the net trade on medium term, but stabilizes after the terms of trade reverse.

6.2 UIRP shock

As expected an UIRP shock has an opposite effect on the domestic and foreign interest rate. The decrease of the first makes investment in home more profitable with positive effects on real output and consumption. It has a different effect in the foreign country because the savings increase at the expense of real economy output. As in the previous case of TFP shock a high depreciation leads to a strong decrease of import prices; this goes hand in hand with a decrease in net trade. But current account increases since households prefer to hold foreign instead of domestic bonds.

6.3 Government consumption shock

Government spending diminishes the domestic output used in the production of final goods, with a crowding out effect on consumption, investment, and net trade. Labor supply declines on the short run due to an increase in real wage. On the capital market, real return on capital follows a J-shaped decline and real interest rate a hump-curve increase. Real wage increases more than the return on capital, which feeds back on the marginal cost and therefore inflation.

6.4 Monetary policy shock

A monetary policy shock induces a one time increase in the interest rate and the exchange rate appreciates, with negative positive effects on the real exports on the short run. Net foreign assets react more slowly to the appreciation of the term of trade, and in a fashion consistent with the interest rate evolution. Higher interest rates have the effects that slow down real activity. In line with the close economy model, real wages fall.

6.5 Investment-specific technology shock

An investment-specific technology shock (ARMA (1,1)) leads to a hump-shaped increase of investments that returns to a lower level than before the shock. Consumption is less responsive (moving in the opposite direction) on the long run, so the effect on output is always negative. Capital value increases steadily together with real wages and return on capital. Net trade responds to the fluctuations in consumption and investment, the response curve emulates the negativity of input.

6.6 Consumption tax shock

A higher tax levied on consumption decreases consumption, as households having to spend more of their income for the same level of consumption. As a result, the other two components of the final good, investment and net exports increase. The real output is very responsive to this shock. It's level decreases, with negative effects on real wages and capital return.

6.7 Capital tax shock

Responses of real variables to a capital tax shock are less persistent for most variables. After a short decline, labor, return on capital, output, investment and capital value return to the steady state. Consumption and real wage reach a higher level after stabilization that suggests an increase of consumption via a labor income channel. Given Calvo mechanism, inflation is also more persistent and sustained by higher sustained costs of labor that increases the marginal cost.

6.8 Labor tax shock

This shock produces a sharp decrease in the level of labor supply and employment as it rises the costs afferent to the labor utilization. A fall in the level of employment increases real wage and medium term return on capital level, but decreases the real output, consumption, and investment.

6.9 ROW demand shock

In our setup, a shock in ROW demand implies a depreciation of the exchange rate and consequently an increase in the current account. Exports diminish relative to imports and the demand for domestic goods follow a slight decline. The effect of the shock on nominal variables depends on the share of ROW in the total imports and the degree of stickiness in the import prices.

6.10 Oil price shock

A shock in the oil price is highly persistent as we could notice from its ARMA(1,1) representation. This increase falls directly in the production cost, without any rigidity and produces a sharp decrease of output, together with investment and consumption. On one hand, the monetary authority responds with a one-time increase of the interest rate. On the other hand, the depreciation of the terms of trade produces losses in wealth. The impact of net current account is positive because of higher costs of imports. The negative effect on trade balance can be explained as a loss in the competitiveness of the domestic firms.

6.11 ROW importing price shock

The effect of this shock on domestic economy depends on the respective shares of imports from ROW in the intermediate and final goods, as well as the Calvo parameters. The effect on the net trade is positive as the domestic goods will be preferred to the foreign ones, depending on their relative prices and substitution of elasticity. The effect on domestic output is similar to a shock in oil price, with the difference that the pass through of the shock meets price adjustment rigidities.

6.12 Prices and wages mark-up shock

A mark-up shock in domestic prices and wages translates, both modeled as ARMA (1,1) in a positive current account and net trade, as a result of the amelioration in the terms of trade; change induced by lower consumption and investment at home. The inflationary effects of these shocks reduce aggregate demand for goods. This slow down of the economy reduces labor demand, and increases real wages and capital return.

7 Conclusions

In this model we have built on De Walque, Smets and Wouters (2005)' open economy model, by introducing fiscal policy. The reaction of economic variables to shocks existent before in the model does not change significantly by introducing taxes and the sense of their movement is not distorted. Eventually, there is a modification in the intensity of the reaction to shock, but not significant enough to reverse the sense of other variables in the system. Since for most of reactions of the variables the authors suggest matching with empirical evidence, we conclude that it has been a successful exercise in introducing the fiscal sector in our model.

The analysis of the theoretical model leads us to the conclusion that relaxing the UIRP condition by introducing a stochastic component can be helpful in explaining the changes in the terms of trade and movements of current account and net trade. In a certain measure the same thing is achieved through a monetary policy channel and shocks in demand and prices of imports.

At the same time, the pass-through of different shocks depends on a series of rigidities, on the proportions in which different goods are combined, as well as on preferences, which are indirectly modeled.

In the theoretical model, we believe that the assumption of a variable elasticity of demand for intermediary goods improves the model through a more realistic assumption. Further investigation is needed in order incorporate other linkages between exchange rate movements and variables that have an impact on it, as proven by the empirical studies.

8 Refferences

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9 Appendixes

9.1 Appendix 1

Data description for the estimation

The final purpose of our paper was to re-estimate the model using as a benchmark the estimated parameters obtained by the authors in their 2005 version. For this, two sets of quarterly data have been prepared: (1) one set sent by the authors including time series over 1970/1-2004/4; (2) another set of data that has been collected from the international sources following the indications of the authors with regard to the data, in their paper.

The variables in the model are not stationary; therefore we use in the estimation their growth rates, namely log-differences for consumption, investment, output, real wages, labor (employment), and deflators, and try to estimate the trend in each of them. Interest rate is in nominal terms; so are oil price and exchange rate. Net trade is expresses simply as difference between exports and imports.

Some other doing research in the area might find it useful to consult our transformations and sources for the data.

1. for the United states
$CONS = LN(C/GD)/Pop) * 100$
$INV = LN(I/GD)/Pop) * 100$
$GDP = LN(Y/GD)/PoP * 100$
$HOURS = LN(H * Emp)/Pop) * 100$
$WAGE = LN(W/GD) * 100$
$GDPinf = LN(GD/GD(-1)) * 100$
$CPIinf = LN(CPI/CPI(-1)) * 100$
$IMPinf = LN(ID/ID(-1)) * 100$
$R = FFR/4$
$NT = (EX - IM)/PoP$

$PoPindex = PoP(1992 : 3) = 1$
$EMPindex = EMP(1992 : 3) = 1$

Sources for the original data :

GD: United States, Implicit Price Deflator, Gross Domestic Product, Total, Index, 2000=100 Source: U.S. Department of Commerce, Bureau of Economic Analysis Ecowin: ew:usa01025

C: United States, Personal Outlays, Personal Consumption Expenditures, Overall, Total Source: U.S. Department of Commerce, Bureau of Economic Analysis Ecowin: ew:usa01205

I: United States, Investment Account, Private Fixed Investment, Overall, Total Source: U.S. Department of Commerce, Bureau of Economic Analysis Ecowin: ew:usa01231

Y: United States, Real gross domestic product, Billions of chained 2000 Dollars Source: U.S. Department of Commerce, Bureau of Economic Analysis Ecowin: bea:naa191rx$1_1 1_6 q$

W: United States, Nonfarm business, Hourly Compensation, Index Source: Bureau of Labor Statistics Ecowin: blspr:prs85006103

H: United States, Nonfarm business, Average Weekly Hours, Index Source: Bureau of Labor Statistics Ecowin: blspr:prs85006023

Emp: United States, Employment including self-employed, Civilian employment, All persons, Civilian employment: all persons Source: OECD Ecowin: oecd:usa$_e mescvtt_s tsaq$

PoP: US Civilian Noninstitutional Population - (16 yrsover) Source: Bureau of Labor Statistics Datastream: USCIVILPF CPI: Consumer Price Index, 2000=100 Source: OECD, MEI Ecowin: oecd:usa$_c paltt01_i xobsaq$

ID: United States, Imports of goodsservices, deflator,national accounts basis Source: OECD Ecowin: oe:usa$_p mgsq$

FFR : United States, Immediate rates (less than 24 hrs), Federal funds rate, Total Source: OECD, MEI Ecowin: oecd:usa$_i rstfr01_s tq$

EX : Real Exports of Goods Services, Billions of Chained 2000 Dollars Source: U.S. Department of Commerce, Bureau of Economic Analysis FRED2: EXPGSC96

IM: Real Imports of Goods Services, Billions of Chained 2000 Dollars Source: U.S. Department of Commerce, Bureau of Economic Analysis FRED2: IMPGSC96

2. Data for the euro area:

For the euro area we use the same transformations as before, with the following differences: consumption and investment are already expressed in real terms (or they are deflated with their own deflator) and instead of hours worked use employment. All the data is taken from Area Wide model. The description is below:

GD: GDP deflator (YED)
C: Private consumption (PCR)
I: Real gross investments (ITR)

Y: Real GDP (YER)
W: Nominal wages (WRN)
Emp: Total employment (LNN)
PoP: Labor Force (LFN)
CPI: HICP
ID: Imports deflator (MTD)
FFR : Short term interest rate (STN)
EX : Real exports (XTR)
IM: Real imports (MTR)

3. Oil price and exchange rate

OP: Oil price UK Brent (Market Price) Source: IMF International Financial Statistics Datastream: UKY76AAZA

ER: (1999 onwards) Euro Zone, Exchange rate, fund position or international liquidity, MARKET RATE National Currency per US Dollar, Period Average Source: IMF International Financial Statistics Ecowin: ifs:s16300rf0zfq

(1970-1999) Synthetic bilateral exchange rates that correspond the real GDP weights underlying the construction of the AWM databasered[1] (These weights are: BE=0.036; DE=0.283; ES=0.111; FR=0.201; IE=0.015; IT=0.195; LU=0.003; NL=0.060; AT=0.030; PT=0.024; FI=0.017; GR=0.025) Source: IMF International Financial Statistics Ecowin: ifs:s13200rf0zfq; ifs:s13400rf0zfq; ifs:s17400rf0zfq; ifs:s18200rf0zfq, ifs:s18400rf0zfq; ifs:s12400rf0zfq; ifs:s13800rf0zfq; ifs:s12800rf0zfq; ifs:s13600rf0zfq; ifs:s12200rf0zfq; ifs:s17200rf0zfq; ifs:s17800rf0zfq.

[1] Lubik and Schorfheide(2005)

9.2 Appendix 2

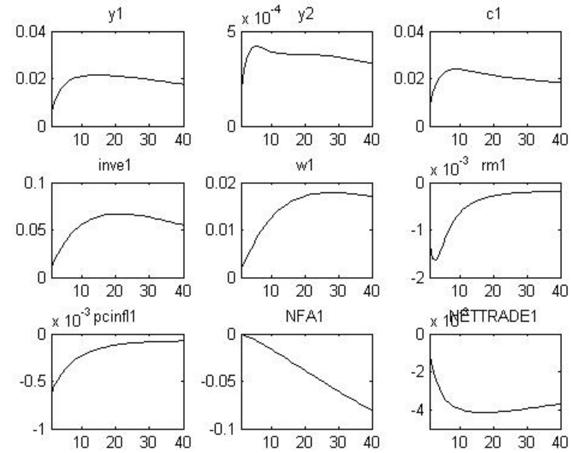

Figure 1: Impulse-response analysis: TFP shock

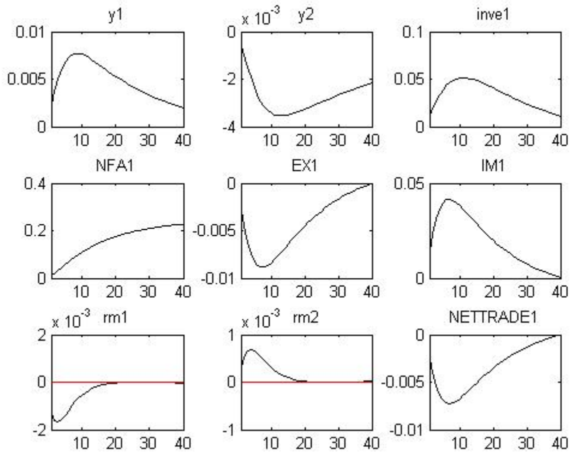

Figure 2: Impulse-response analysis: UIRP shock

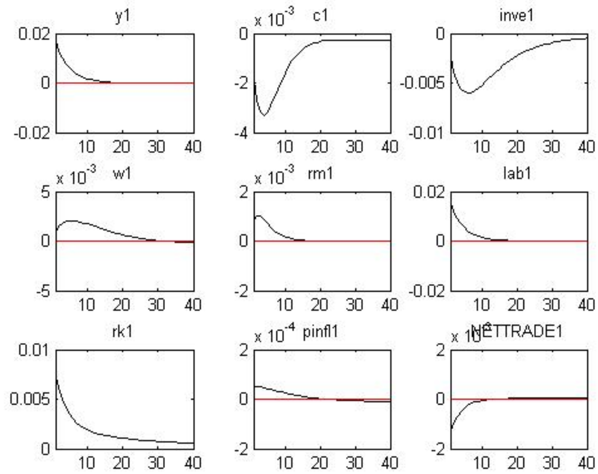

Figure 3: Impulse-response analysis: Government spending shock

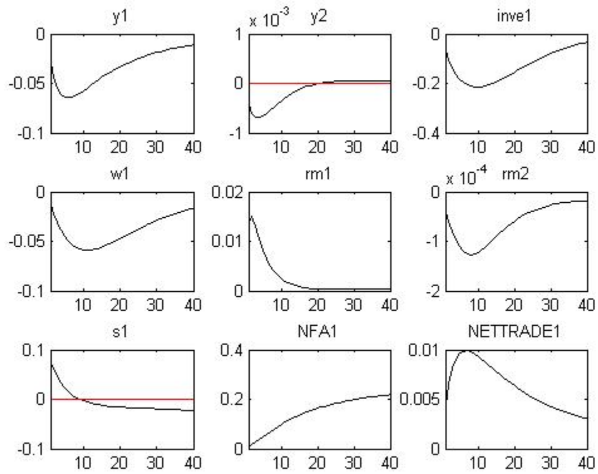

Figure 4: Impulse-response analysis: Monetary policy shock

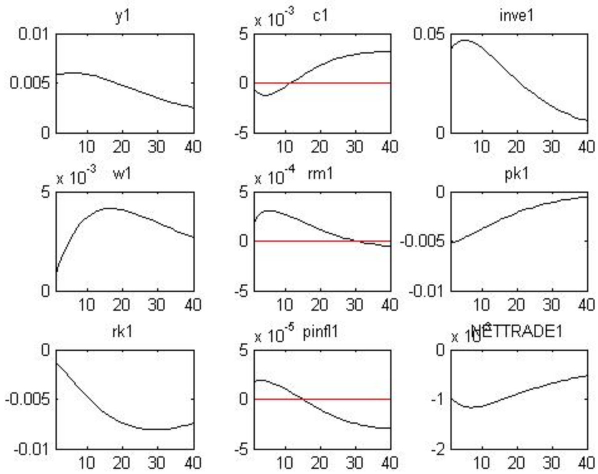

Figure 5: Impulse-response analysis: Investment-specific technology shock

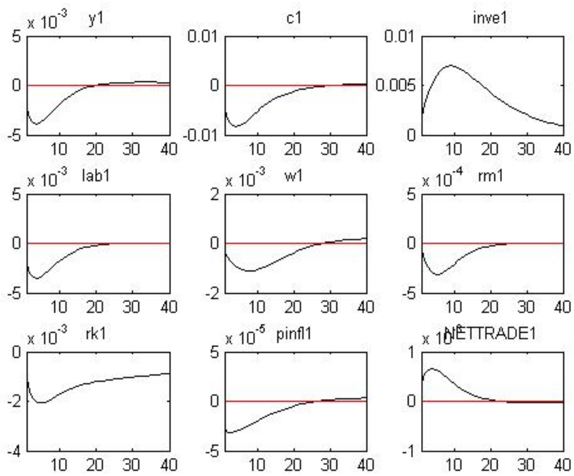

Figure 6: Impulse-response analysis: Consumption tax shock

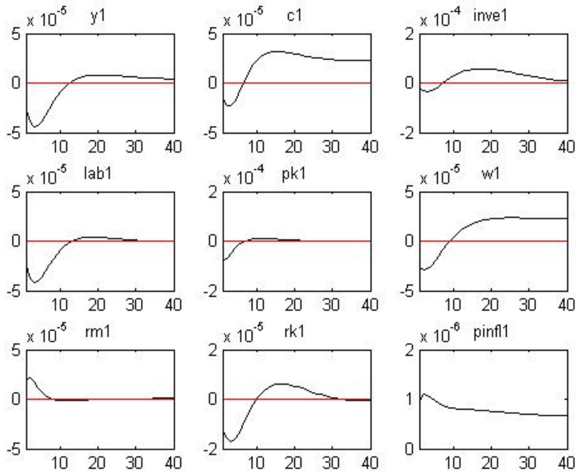

Figure 7: Impulse-response analysis: Capital tax shock

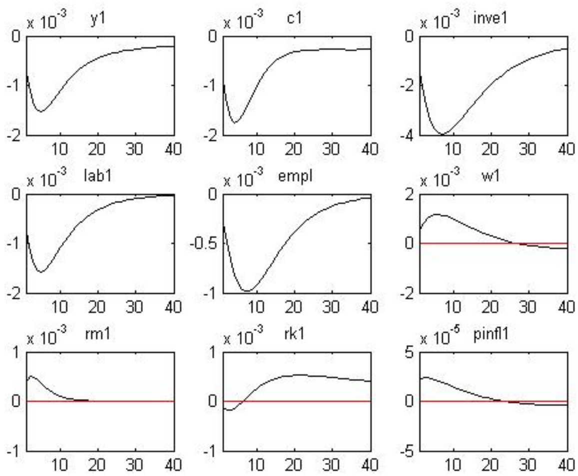

Figure 8: Impulse-response analysis: Labor tax shock

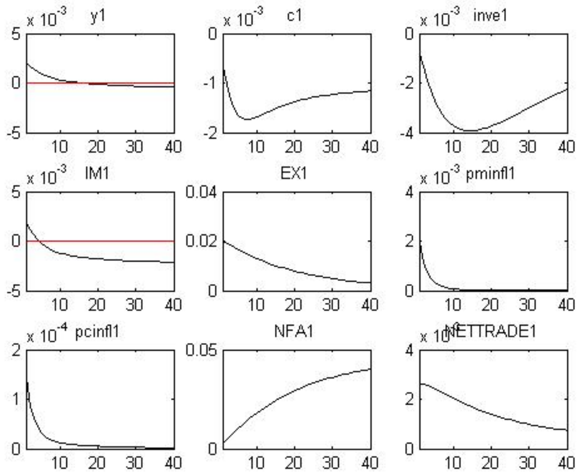

Figure 9: Impulse-response analysis: ROW demand shock

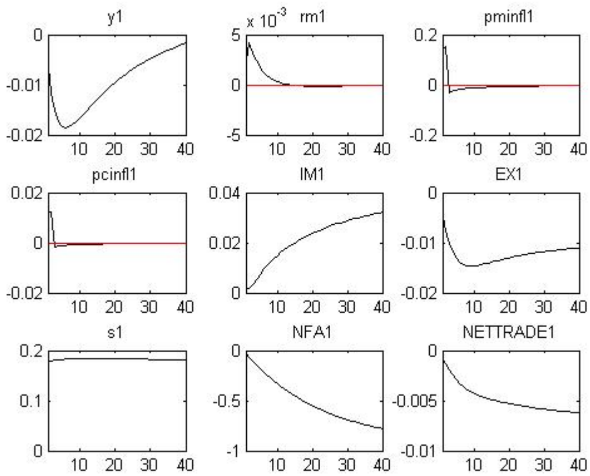

Figure 10: Impulse-response analysis: Oil price shock

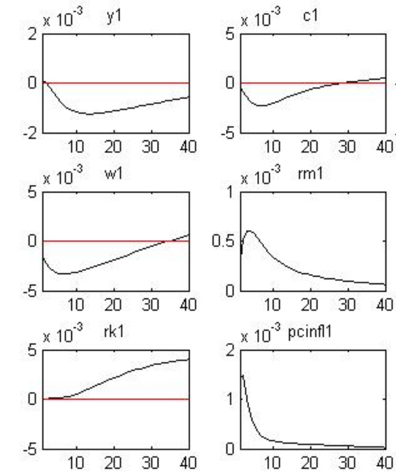

Figure 11: Impulse-response analysis: ROW importing price shock

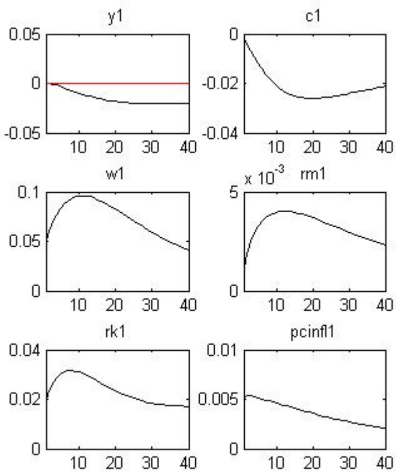

Figure 12: Impulse-response analysis: Wage mark-up shock

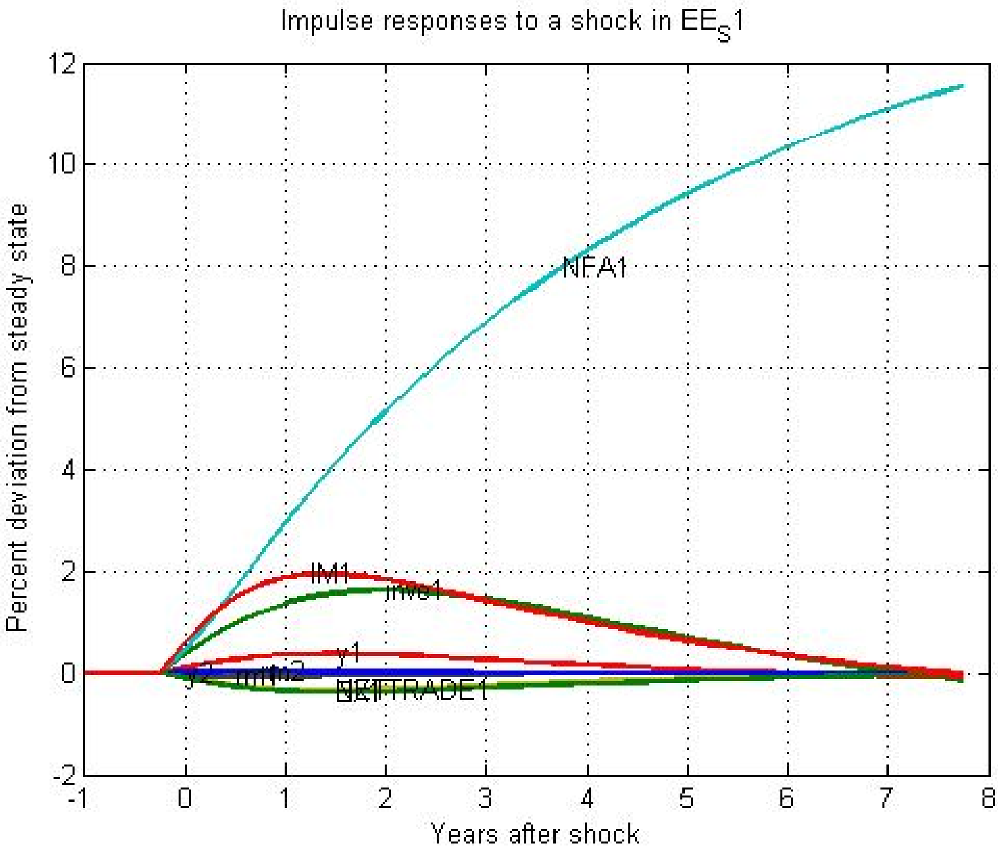

Figure 13: Impulse-response analysis: UIRP shock

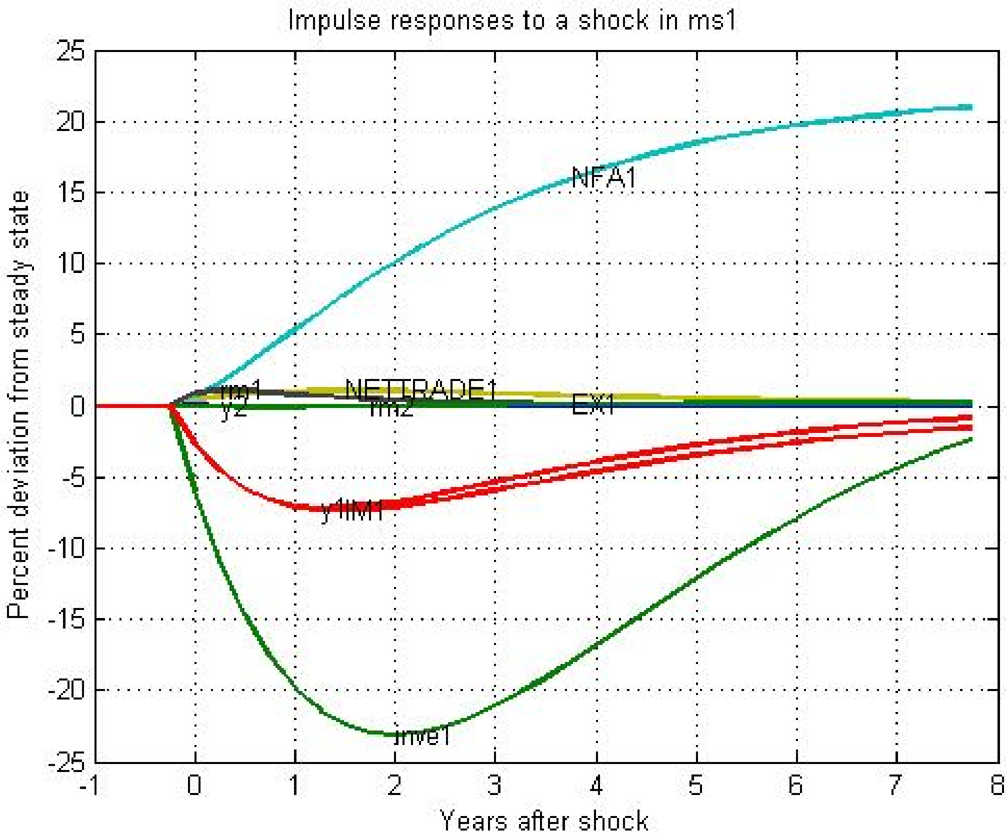

Figure 14: Impulse-response analysis: Monetary shock

10 Dynare code

```
var a1  a2  b1  b2  c1  c2  cf1 cf2 dC1 dC2 DD1 DD2 DDF1    DDF2    dE1
dI1 dI2 dL2 dS1 dS2 dW1 dW2 dY1 dY2 EE_NT1  EE_NT2  EE_PM1  EE_PM2
EE_S1   emp1    epinfma1    epinfma2    eqsma1  eqsma2  ETA_POILma
ewma1   ewma2   EX1 EX2 EXF1    EXF2    g1  g2  IM1 IM2 IMF1    IMF2
inve1   inve2   invef1  invef2  k1  k2  kf1 kf2 kp1 kp2 kpf1    kpf2
lab1    lab2    labf1   labf2   mc1 mc2 MD1 MD2 MDF1    MDF2    ms1 ms2
NETTRADE1   NETTRADE2   NETTRADEF1  NETTRADEF2  NFA1    NFAF1   PCINF1
PCINF2  pcinf11 pcinf12 pcpy1   pcpy2   pcpyf1  pcpyf2  pinf11  pinf12
pk1 pk2 pkf1    pkf2    PMDinf11    PMDinf12    PMINF1  PMINF2  pminf11
pminf12 PMNOILINF1  PMNOILINF2  pmpy1   pmpy2   pmpyf1  pmpyf2  poil
POILINF2    PYINF1  PYINF2  qs1 qs2 R1  R2  rk1 rk2 rkf1    rkf2    rm1
rm2 RPMD1P1 RPMD1PF1    RPMD2P2 RPMD2PF2    RPMNOIL1P1  RPMNOIL1P2
RPMNOIL1PF1 RPMNOIL2P1  RPMNOIL2P2  RPMNOIL2PF2 rrf1    rrf2    s1  s2
SF1 SF2 spinf1  spinf2  sw1 sw2 taxc1   taxc2   taxk1   taxk2   tax11
tax12   w1  w2  wf1 wf2 y1  y2  yf1 yf2 zcap1   zcap2   zcapf1  zcapf2
TR1     TR2   TRF1   TRF2;


varexo ea1  ea2 eb1 eb2 eg1 eg2 em1 em2 epinf1  epinf2  eqs1    eqs2
ETA_C1  ETA_C2  ETA_K1  ETA_K2  ETA_L1  ETA_L2  ETA_NT1 ETA_NT2 ETA_PC1
ETA_PC2 ETA_PM1 ETA_PM2 ETA_POIL    ETA_S1  ew1 ew2 ;

parameters ctouk1 ctoul1 ctouc1 ctouk2 ctoul2 ctouc2 crk1 ckap1 ctr1
crk2 ckap2 ctr2 crhoxk1 crhox11 crhoxc1 crhoxk2 crhox12 crhoxc2 cEFA
cpy1 cpy2 ctrend1 ctrend2 constepoil constepminf1 constepminf2 cprobpc1
cprobpc2 cindpc1 cindpc2 csrp calfa1 czcap1 cbeta1 csadjcost1 ctou1
csigma1 chabb1 ccs1 cinvs1 cfc1 cindw1 cprobw1 cindp1 cprobp1 csig11
clandaw1 crdpi1 crpi1 crdy1 cry1 crr1 ctrend duma cprobe cmy1 coilm1
cydc1 coilc1 coily1 crhoa1 crhob1 crhog1 crhoqs1 crhoms1 crhopinf1
crhow1 crhopm1 crhopoil crhos crhont1 cmaw1 cmap1 cmaq1 constelab1
constepinf1 conster1 calfa2 czcap2 cbeta2 csadjcost2 ctou2 csigma2
chabb2 ccs2 cinvs2 cfc2 cindw2 cprobw2 cindp2 cprobp2 csig12 clandaw2
crdpi2 crpi2 crdy2 cry2 crr2 cmy2 coilm2 cydc2 coilc2 coily2 crhoa2
crhob2 crhog2 crhoqs2 crhoms2 crhopinf2 crhow2 crhopm2 crhont2 cmaw2
cmap2 cmaq2 constelab2 constepinf2 conster2 cindpm1 cindpm2 cprobpm1
cprobpm2 cmy1 cmc1 cim1 csubst1 cadjc1 cmy2 cmc2 cim2 csubst2 cadjc2
cexpbeta1 cexpbeta2 cimpbeta1 cimpbeta2 csa1 csw1 csw2 cspm1 cspm2
csnt1 cspoil;

//exercise 1: simulation;
//calibrate parameters using de Walque, Smets and Wouters estimation
results (2005) and Trabant and Uhlig (2006) steady state for taxes

crhoa1 = 0.97956 // AR(1) coefficient productivity shock
crhob1 = 0.75044 // AR(1) coefficient risk premium on bond holdings
shock
crhog1 = 0.82951 // AR(1) coefficient government consumption shock
crhoms1 = 0.37664 // AR(1) coefficient monetary policy shock
crhoqs1 = 0.89768 // coefficient AR component in ARMA(1,1) investment
shock
crhopinf1 = 0.92099 //  coefficient AR component in ARMA(1,1) domestic
intermediate firms price markup shock
crhow1 = 0.97347 //  coefficient AR component in ARMA(1,1) wage markup
shock
crhoxk1=0.85 // AR(1) coefficient capital tax
crhox11=0.85 // AR(1) coefficient labor tax
```

Figure 15: Dynare code

```
crhoxcl=0.85 // AR(1) coefficient consumption tax
cmawl = 0.89319 // coefficient MA component in ARMA(1,1) wage markup
shock
cmapl=0.86631 // coefficient MA component in ARMA(1,1) domestic
intermediate firms price markup shock
cmaql = 0.86078 // coefficient MA component in ARMA(1,1) investment
shock
crhopml = 0.97699 // AR(1) coefficient ROW price shock
crhopoil = 0.95609 // AR(1) coefficient oil price shock
crhontl = 0.94922 // AR(1) coefficient imports from the ROW shock
cmyl = 0.07419 // imports share in intermediate good production
cmcl = 0.058625 // imports share in final good
ciml = 0.66129 // imports share distribution sector
coilcl = 0.0071469 // oil share in consumption
coilyl = 0.0066143 // oil share in intermediate good production
cimpbetal = 0.57801 // imports share from US
cexpbetal = 0.19179 // exports share to US
csubstl = 1.2645 // elasticity of substitution between domestic and
foreign goodss
cadjcl = 3.8746 // adjustment cost final good production
cprobpml=0.64338 // Calvo parameter for importing firms
cindpml=0.18145 // degree of indexation parameter for importing firms
csadjcostl=7.8538 // investment adjustment cost
csigmal=0.98263 // intertemporal elasticity of substitution
chabbl=0.74746 // external habit coefficient
clandawl = 0.51951 // steady state wage markup
cprobwl = 0.75864 // Calvo parameter for wages
csigll=2.2281 // elasticity of work effort with respect to real wage.
cprobpl=0.89583 // Calvo parameter for intermediate good firms
cindwl=0.25841 // degree of indexation parameter for wage indexed to
past inflation rate
cindpl=0.16245 // degree of indexation parameter for intermediate firm
setting its price indexed to past
cprobe=0.78661 // Calvo parameter for employment
czcapl=0.24434 // capital utilization
cfcl= 1.1978 // share of fix costs
crpil=1.665 // inflation coefficient in Taylor rule
crrl=0.88636 // lagged interest rate coefficient in Taylor rule
cryl=0.097623 // output gap coefficient in Taylor rule
crdyl=0.20981 // delta(output gap) coefficient in Taylor Rule
cpyl = 0.63 //coefficient relating shock in CPI with PPI
duma=1 // proportion fixed costs in intermediate producers' goods
calfal=.24 // capital share in production
cbetal=.99 // discount factor beta
ctoul=.025 // depreciation rate
ccsl=.65 // proportion of consumption in output
cinvsl=.17 // proportion of investment in output
ctoukl=0.34 // steady state tax rate on capital
ctoull=0.38 //steady state tax rate on labor
ctoucl=0.17 //steady state tax rate on consumption
ctrendl=0.4 //trend in output, consumption, investment
constepinfl=0.64393 //trend in inflation
consterl=0.61611 //trend in interest rate
constelabl=-0.072348 //trend in labor
constelabl=-0.072348 //trend in labor
constepminfl=0.63645 //trend in imported inflation
constepoil=-0.011895 //trend in oil
```

Figure 16: Dynare code

```
crhoa2 = 0.94953
crhob2 = 0.82467
crhog2 = 0.96686
crhoms2 = 0.04435
crhopinf2 = 0.82448
crhow2 = 0.91995
crhoxk2=0.85
crhoxl2=0.85
crhoxc2=0.85
cmap2 = 0.78536
cmaw2 = 0.86135
cmaq2 = 0.81357
crhopm2 = 0.96008
crhont2 = 0.99626
crhos = 0.94476
crhoqs2= 0.89768
cmy2 = 0.05914
cmc2 = 0.057209
cim2 = 0.64901
coilc2 = 0.0073062
coily2 = 0.0063135
cimpbeta2 = 0.33422
cexpbeta2 = 0.404
csubst2 = 1.1943
cadjc2 = 3.9856
cprobpm2 = 0.70191
cindpm2 = 0.10197
csadjcost2 = 4.9053
csigma2 = 0.84925
chabb2 = 0.73403
clandaw2=0.43565
cprobw2 = 0.83418
csigl2 = 2.5463
cprobp2 = 0.91585
cindw2 = 0.31701
cindp2 = 0.35211
czcap2 = 0.21957
cfc2 = 1.4162
crpi2 = 1.6271
crr2 = 0.86899
cry2 = 0.13738
crdy2 = 0.206966
cpy2 = 0.51
calfa2=.24
cbeta2=.99
ctou2=.025
ccs2=.65
cinvs2=.17
ctouk2=0.37
ctoul2=0.26
ctouc2=0.05
ctrend2=0.4
constepinf2=0.7558
conster2=0.61885
constelab2=0.0087523
constepminf2=0.41393
```

Figure 17: Dynare code

```
cEFA = 33 //  steady state value for elsticity of demand for
intermediate goods
crk1=calfa1*(ctou1+ctrend1)/cinvs1; //steady state return on capital
crk2=calfa2*(ctou2+ctrend2)/cinvs2;
ckap1=cinvs1/(ctou1+ctrend1); // kapital-output ratio
ckap2=cinvs2/(ctou2+ctrend2);
ctr1=ctouc1*ccs1+ctoul1*(1-calfa1)+ctouk1*(crk1-ctou1)*ckap1; //
proportion of transfers in output
ctr2=ctouc2*ccs2+ctoul2*(1-calfa2)+ctouk2*(crk2-ctou2)*ckap2;

model(linear);

// Flexible price model: Domestic

SF1 = SF1(+1) + rrf1 - rrf2 + EE_S1   ;
NFAF1 =  1* (1/cbeta1)*NFAF1(-1) +
((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-coilc1-cmc1))* ( EXF1 -
IMF1 - pmpyf1);
(ccs1*cf1+cinvs1*invef1+((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-
coilc1-cmc1))*EXF1)*(1-
coilc1)/(ccs1+cinvs1+((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-
coilc1-cmc1))) = (1-cmc1/cim1)*(1-coilc1)*DDF1 + (cmc1/cim1)*(1-
coilc1)*MDF1;
DDF1 = MDF1 - csubst1*( -RPMD1PF1 )-cadjc1*(DDF1-MDF1-(DDF1(-1)-MDF1(-
1))) + cbeta1*cadjc1*(DDF1(+1)-MDF1(+1)-(DDF1-MDF1));
yf1 =   (ccs1+cinvs1+((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-
coilc1-cmc1)))*(1-cmc1/cim1)*(1-coilc1)*DDF1
+(ccs1+cinvs1+((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-coilc1-
cmc1)))*(cmc1/cim1)*(1-cim1)*(1-coilc1)*MDF1  +g1 -cmy1*yf1 -coily1*yf1
;
RPMD1PF1 = cim1*RPMNOIL1PF1  ;
((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-coilc1-cmc1))*pmpyf1 =
(((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-coilc1-cmc1))-coily1-
coilc1*(ccs1+cinvs1+((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-
coilc1-cmc1))))*RPMNOIL1PF1 +
(coilc1*(ccs1+cinvs1+((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-
coilc1-cmc1))) + coily1)*(POIL-SF1+pcpyf1-pcpyf2);
pcpyf1 = (1-cmc1)*(1-coilc1)*0 + cmc1*(1-coilc1)*RPMNOIL1PF1 +
coilc1*(POIL-SF1+pcpyf1-pcpyf2);
cimpbeta1*(-RPMNOIL1PF1+SF2-pcpyf2+pcpyf1) = -(1-cimpbeta1)*( -
1*RPMNOIL1PF1) ;
EXF1=cexpbeta1*MDF2  + EE_NT1   ;
NETTRADEF1 =((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-coilc1-
cmc1))* (EXF1 - IMF1);
IMF1=(cim1*(1-
coilc1)*(cmc1/cim1)*(ccs1+cinvs1+((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinv
s1))/(1-coilc1-cmc1)))/((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-
coilc1-
cmc1)))*MDF1+(coilc1/((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-
coilc1-
cmc1)))*(ccs1*cf1+cinvs1*invef1+((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs
1))/(1-coilc1-
cmc1))*EXF1)+((cmy1+coily1)/((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/
(1-coilc1-cmc1)))*yf1;
g1=ctouc1*ccs1*((1+ctouc1)/ctouc1*taxc1+cf1)+ctoul1*(1-
calfa1)*((1+ctoul1)/ctoul1*taxl1+labf1+wf1)+ctouk1*(crk1-
```

Figure 18: Dynare code

```
ctoul)*ckapl*((l+ctoukl)/ctoukl*taxkl+rkfl*crkl/(crkl-ctoul)+kfl)-
ctrl*TRFl;
          0 =  (1-coilyl-cmyl)*( calfal*rkfl+(1-calfal)*(wfl+pcpyfl) -
(1-duma)*(1-calfal)*al - duma*al ) + coilyl*(poil-SFl+pcpyfl-pcpyf2) +
cmyl*(RPMNOIL1PFl) ;
          zcapfl =  (1/czcapl)*(rkfl*crkl/(crkl-ctoul)-taxkl)*(1-
cbetal)/ (1-cbetal+cbetal*ctoul);
          rkfl =  (wfl+pcpyfl)+labfl-kfl ;
          kfl =  kpfl+zcapfl ;
          invefl = (1/(1+cbetal))* ((  invefl(-1) +
cbetal*(invefl(1)))+(1/csadjcostl)*pkfl ) +qsl ;
          pkfl = -rrfl + bl +(1-cbetal)*(rkfl(1)*crkl/(crkl-ctoul)-
taxkl(1))+cbetal*(1-ctoul)*pkfl(1)  ;
          cfl = (chabbl/(1+chabbl))*cfl(-1) + (1/(1+chabbl))*cfl(+1)
+((csigmal-1)/(csigmal*(1+chabbl)*(1+clandawl)))*(1-
ctoull)/(1+ctoucl)*(labfl-labfl(+1)) - (1-
chabbl)/(csigmal*(1+chabbl))*(rrfl - bl+taxcl-taxcl(+1)) ;
          yfl = cfcl*( calfal*kfl+(1-calfal)*labfl )  +duma*cfcl*al
+(1-duma)*(1-cfcl*calfal)*al ;
          wfl = csigll*labfl    +(1/(1-chabbl))*cfl - (chabbl/(1-
chabbl))*cfl(-1)+taxll+taxcl  ;
          kpfl =  (1-ctoul)*kpfl(-1)+ctoul*invefl(-1) +
ctoul*(1+cbetal)*csadjcostl*qsl ;

// Sticky price model: Foreign

sl = sl(+1) + rml - rm2 + EE_Sl;
NFAl =  (1/cbetal)*NFAl(-1) +
((coilyl+cmyl+(coilcl+cmcl)*(ccsl+cinvsl))/(1-coilcl-cmcl))* ( EXl -
IMl - pmpyl);
(ccsl*cl+cinvsl*invel+((coilyl+cmyl+(coilcl+cmcl)*(ccsl+cinvsl))/(1-
coilcl-cmcl))*EXl)*(1-
coilcl)/(ccsl+cinvsl+((coilyl+cmyl+(coilcl+cmcl)*(ccsl+cinvsl))/(1-
coilcl-cmcl))) = (1-cmcl/ciml)*(1-coilcl)*DDl + (cmcl/ciml)*(1-
coilcl)*MDl;
DDl = MDl - csubstl*( -RPMDlPl )-cadjcl*(DDl-MDl-(DDl(-1)-MDl(-1))) +
cbetal*cadjcl*(DDl(+1)-MDl(+1)-(DDl-MDl));
yl =   (ccsl+cinvsl+((coilyl+cmyl+(coilcl+cmcl)*(ccsl+cinvsl))/(1-
coilcl-cmcl)))*(1-cmcl/ciml)*(1-coilcl)*DDl
+(ccsl+cinvsl+((coilyl+cmyl+(coilcl+cmcl)*(ccsl+cinvsl))/(1-coilcl-
cmcl)))*(cmcl/ciml)*(1-ciml)*(1-coilcl)*MDl  +gl -cmyl*yl -coilyl*yl
;
RPMDlPl = RPMDlPl(-1)-pinfll+PMDinfll;
PMDinfll = ciml*PMNOILINFl  + (1-ciml)*pinfll ;
((coilyl+cmyl+(coilcl+cmcl)*(ccsl+cinvsl))/(1-coilcl-cmcl))*pminfll =
(((coilyl+cmyl+(coilcl+cmcl)*(ccsl+cinvsl))/(1-coilcl-cmcl))-coilyl-
coilcl*(ccsl+cinvsl+((coilyl+cmyl+(coilcl+cmcl)*(ccsl+cinvsl))/(1-
coilcl-cmcl))))*PMNOILINFl+
(coilcl*(ccsl+cinvsl+((coilyl+cmyl+(coilcl+cmcl)*(ccsl+cinvsl))/(1-
coilcl-cmcl))) + coilyl)*(POILINF2+dS2+pinfl2);
pcinfll = (1-cmcl)*(1-coilcl)*pinfll + cmcl*(1-coilcl)*PMNOILINFl +
coilcl*(POILINF2-dSl+pinfl2)+    ETA_PCl;
PMNOILINFl = (1/(1+cbetal*cindpml))*( cbetal*PMNOILINFl(1)
+cindpml*PMNOILINFl(-1) +((1-cprobpml)*(1-
cbetal*cprobpml)/(cprobpml))*(   cimpbetal*(-RPMNOIL1P2+s2) + (1-
cimpbetal)*( -1*RPMNOIL1Pl ) )) +EE_PMl;
```

Figure 19: Dynare code

```
RPMNOIL1P2 = RPMNOIL1P2(-1)+PMNOILINF1-pinf12;
RPMNOIL1P1 = RPMNOIL1P1(-1)+PMNOILINF1-pinf11;
EX1=cexpbeta1*MD2  + EE_NT1   ;
NETTRADE1 =((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-coilc1-cmc1))*
(EX1 - IM1);
IM1=(cim1*(1-
coilc1)*(cmc1/cim1)*(ccs1+cinvs1+((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinv
s1))/(1-coilc1-cmc1)))/((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-
coilc1-
cmc1)))*MD1+(coilc1/((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(1-
coilc1-
cmc1)))*(ccs1*c1+cinvs1*inve1+((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1)
)/(1-coilc1-
cmc1))*EX1)+((cmy1+coily1)/((coily1+cmy1+(coilc1+cmc1)*(ccs1+cinvs1))/(
1-coilc1-cmc1)))*y1;
g1=ctouc1*ccs1*((1+ctouc1)/ctouc1*taxc1+c1)+ctoul1*(1-
calfa1)*((1+ctoul1)/ctoul1*taxl1+lab1+w1)+ctouk1*(crk1-
ctoul)*ckap1*((1+ctouk1)/ctouk1*taxk1+rk1*crk1/(crk1-ctoul)+k1)-
ctr1*TR1;
          mc1 = (1-coily1-cmy1)*( calfa1*rk1+(1-calfa1)*(w1+pcpy1) -
duma*a1 - (1-duma)*(1-calfa1)*a1 ) + coily1*(poil-s1+RPMNOIL1P1-
RPMNOIL1P2) + cmy1*RPMNOIL1P1 ;
          zcap1 =  (1/czcap1)*(rk1*crk1/(crk1-ctoul)-taxk1)*(1-cbeta1)/
(1-cbeta1+cbeta1*ctoul) ;
          rk1 =  (w1+pcpy1)+lab1-k1 ;
          k1 =  kp1+zcap1 ;
          inve1 = (1/(1+cbeta1))* ((  inve1(-1) +
cbeta1*(inve1(1)))+(1/csadjcost1)*pk1)+qs1;
          pk1 = -rm1+pcinf11(1)+b1  +(1-cbeta1)*(rk1(1)*crk1/(crk1-
ctoul)-taxk1(1))+cbeta1*(1-ctoul)*pk1(1) ;
          c1 = (chabb1/(1+chabb1))*c1(-1) + (1/(1+chabb1))*c1(+1) +
((csigma1-1)/(csigma1*(1+chabb1)*(1+clandaw1)))*(1-
ctoul1)/(1+ctouc1)*(lab1-lab1(+1)) - (1-
chabb1)/(csigma1*(1+chabb1))*(rm1-pcinf11(+1)-b1+taxc1-taxc1(+1)) ;
          y1 = cfc1*( calfa1*k1+(1-calfa1)*lab1 ) + duma*cfc1*a1 + (1-
duma)*(1-cfc1*calfa1)*a1  ;
          pinf11 =  (1/(1+cbeta1*cindp1))*( (cbeta1)*(pinf11(1))
+(cindp1)*(pinf11(-1)) +((1-cprobp1)*(1-
cbeta1*cprobp1)/(cprobp1))*(1/((cfc1-1)*cEFA+1))*(mc1)  )  + spinf1 -
cpy1*ETA_PC1;
          w1 =  (1/(1+cbeta1))*w1(-1)
               +(cbeta1/(1+cbeta1))*w1(1)
               +(cindw1/(1+cbeta1))*pcinf11(-1)
               -((1+cbeta1*cindw1)/(1+cbeta1))*pcinf11
               +(cbeta1/(1+cbeta1))*pcinf11(1)
               +(1-cprobw1)*(1-
cbeta1*cprobw1)/((1+cbeta1)*cprobw1*(((1+clandaw1)/(-clandaw1))*csig11-
1))*
                 (w1 - csig11*lab1 - (1/(1-chabb1))*c1 + (chabb1/(1-
chabb1))*c1(-1) -tax11-taxc1 )
               + sw1 ;
          rm1 =  crpi1*(1-crr1)*pcinf11
               +cry1*(1-crr1)*(y1-yf1)
               +crdy1*(y1-yf1-y1(-1)+yf1(-1))
               +crr1*rm1(-1)
               -.0*dS1   +.0*RPMNOIL1P2 +ms1  ;
```

Figure 20: Dynare code

```
          kp1 =  (1-ctoul)*kp1(-1)+ctoul*invel(-1) +
ctoul*(1+cbeta1)*csadjcost1*qs1 ;
          emp1 = emp1(-1)+emp1(1)-emp1+(lab1-emp1)*((1-cprobe)*(1-
cprobe*cbeta1)/(cprobe));
s1=dS1+s1(-1);
pcpy1 = pcpy1(-1)+pcinfl1-pinfl1;
pmpy1 = pmpy1(-1)+pminfl1-pinfl1;
dY1=y1-y1(-1)+ctrend1;
dC1=c1-c1(-1)+ctrend1;
dI1=invel-invel(-1)+ctrend1;
dW1=w1-w1(-1)+ctrend1;
PYINF1 = pinfl1 + constepinf1;
R1 = rm1 + constepinf1 + conster1;
dE1 = emp1 - emp1(-1) + constelab1;
PMINF1 = pminfl1+constepminf1;
PCINF1 = pcinfl1+constepinf1;

a1 = crhoa1*a1(-1)  + ea1;
b1 = crhob1*b1(-1) + eb1;
g1 = crhog1*g1(-1) + eg1;
qs1 = crhoqs1*qs1(-1) +  eqsma1 - cmaq1*eqsma1(-1) ;
eqsma1=eqs1;
ms1 = crhoms1*ms1(-1) + em1;
spinf1 = crhopinf1*spinf1(-1) + epinfma1 - cmap1*epinfma1(-1);
epinfma1=epinf1;
sw1 = crhow1*sw1(-1) + ewma1 - cmaw1*ewma1(-1) ;
ewma1=ew1;
EE_NT1 = crhont1*EE_NT1(-1) + ETA_NT1;
EE_PM1 = crhopm1*EE_PM1(-1) + ETA_PM1;
EE_S1 = crhos*EE_S1(-1) + ETA_S1;
taxk1=crhoxk1*taxk1(-1)+ ETA_K1;
taxl1=crhoxl1*taxl1(-1)+ ETA_L1;
taxc1=crhoxc1*taxc1(-1)+ ETA_C1;


// Flexible price model: Foreign

SF2 = -SF1;
(ccs2*cf2+cinvs2*invef2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-
coilc2-cmc2))*EXF2)*(1-
coilc2)/(ccs2+cinvs2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-
coilc2-cmc2))) = (1-cmc2/cim2)*(1-coilc2)*DDF2 + (cmc2/cim2)*(1-
coilc2)*MDF2;
DDF2 = MDF2 - csubst2*( -RPMD2PF2 )-cadjc2*(DDF2-MDF2-(DDF2(-1)-MDF2(-
1))) + cbeta2*cadjc2*(DDF2(+1)-MDF2(+1)-(DDF2-MDF2));
yf2 =   (ccs2+cinvs2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-
coilc2-cmc2)))*(1-cmc2/cim2)*(1-coilc2)*DDF2
+(ccs2+cinvs2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-coilc2-
cmc2)))*(cmc2/cim2)*(1-cim2)*(1-coilc2)*MDF2  +g2 -cmy2*yf2 -coily2*yf2
;
RPMD2PF2 = cim2*RPMNOIL2PF2  ;
((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-coilc2-cmc2))*pmpyf2 =
(((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-coilc2-cmc2))-coily2-
coilc2*(ccs2+cinvs2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-
coilc2-cmc2))))*RPMNOIL2PF2 +
```

Figure 21: Dynare code

```
(coilc2*(ccs2+cinvs2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-
coilc2-cmc2))) + coily2)*(POIL-SF2+pcpyf2-pcpyf1);
pcpyf2 = (1-cmc2)*(1-coilc2)*0 + cmc2*(1-coilc2)*RPMNOIL2PF2 +
coilc2*(POIL-SF2+pcpyf2-pcpyf1);
cimpbeta2*(-RPMNOIL2PF2+SF1-pcpyf1+pcpyf2) = -(1-cimpbeta2)*( -
1*RPMNOIL2PF2) ;
EXF2=cexpbeta2*MDF1  + EE_NT2   ;
NETTRADEF2 =((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-coilc2-
cmc2))* (EXF2 - IMF2);
IMF2=(cim2*(1-
coilc2)*(cmc2/cim2)*(ccs2+cinvs2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinv
s2))/(1-coilc2-cmc2)))/((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-
coilc2-
cmc2)))*MDF2+(coilc2/((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-
coilc2-
cmc2)))*(ccs2*cf2+cinvs2*invef2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs
2))/(1-coilc2-
cmc2))*EXF2)+((cmy2+coily2)/((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/
(1-coilc2-cmc2)))*yf2;
g2=ctouc2*ccs2*((1+ctouc2)/ctouc2*taxc2+cf2)+ctoul2*(1-
calfa2)*((1+ctoul2)/ctoul2*taxl2+labf2+wf2)+ctouk2*(crk2-
ctou2)*ckap2*((1+ctouk2)/ctouk2*taxk2+rkf2*crk2/(crk2-ctou2)+kf2)-
ctr2*TRF2;
          0 =  (1-coily2-cmy2)*( calfa2*rkf2+(1-calfa2)*(wf2+pcpyf2) -
(1-duma)*(1-calfa2)*a2 - duma*a2 ) + coily2*(poil) + cmy2*(RPMNOIL2PF2)
;
          zcapf2 =  (1/czcap2)*(rkf2*crk2/(crk2-ctou2)-taxk2)*(1-
cbeta2)/ (1-cbeta2+cbeta2*ctou2);
          rkf2 =  (wf2+pcpyf2)+labf2-kf2 ;
          kf2 =  kpf2+zcapf2 ;
          invef2 = (1/(1+cbeta2))* ((  invef2(-1) +
cbeta2*(invef2(1)))+(1/csadjcost2)*pkf2 ) +qs2 ;
          pkf2 = -rrf2 + b2 +(1-cbeta2)*(rkf2(1)*crk2/(crk2-ctou2)-
taxk2(1)) +cbeta2*(1-ctou2)*pkf2(1) ;
          cf2 = (chabb2/(1+chabb2))*cf2(-1) + (1/(1+chabb2))*cf2(+1)
+((csigma2-1)/(csigma2*(1+chabb2)*(1+clandaw2)))*(1-
ctoul2)/(1+ctouc2)*(labf2-labf2(+1)) - (1-
chabb2)/(csigma2*(1+chabb2))*(rrf2 - b2+taxc2-taxc2(+1)) ;
          yf2 = cfc2*( calfa2*kf2+(1-calfa2)*labf2 )  +duma*cfc2*a2
+(1-duma)*(1-cfc2*calfa2)*a2 ;
          wf2 = csigl2*labf2    +(1/(1-chabb2))*cf2 - (chabb2/(1-
chabb2))*cf2(-1)+ taxl2+taxc2 ;
          kpf2 =  (1-ctou2)*kpf2(-1)+ctou2*invef2(-1) +
ctou2*(1+cbeta2)*csadjcost2*qs2 ;

// Sticky price model: Foreign

(ccs2*c2+cinvs2*inve2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-
coilc2-cmc2))*EX2)*(1-
coilc2)/(ccs2+cinvs2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-
coilc2-cmc2))) = (1-cmc2/cim2)*(1-coilc2)*DD2 + (cmc2/cim2)*(1-
coilc2)*MD2;
DD2 = MD2 - csubst2*( -RPMD2P2 )-cadjc2*(DD2-MD2-(DD2(-1)-MD2(-1))) +
cbeta2*cadjc2*(DD2(+1)-MD2(+1)-(DD2-MD2));
y2 =   (ccs2+cinvs2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-
coilc2-cmc2)))*(1-cmc2/cim2)*(1-coilc2)*DD2
```

Figure 22: Dynare code

```
+(ccs2+cinvs2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-coilc2-
cmc2)))*(cmc2/cim2)*(1-cim2)*(1-coilc2)*MD2  +g2 -cmy2*y2 -coily2*y2
;
RPMD2P2 = RPMD2P2(-1)-pinfl2+PMDinfl2;
PMDinfl2 = cim2*PMNOILINF2  + (1-cim2)*pinfl2 ;
((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-coilc2-cmc2))*pminfl2 =
(((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-coilc2-cmc2))-coily2-
coilc2*(ccs2+cinvs2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-
coilc2-cmc2))))*PMNOILINF2 +
(coilc2*(ccs2+cinvs2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-
coilc2-cmc2))) + coily2)*(POILINF2+pinfl2);
pcinfl2 = (1-cmc2)*(1-coilc2)*pinfl2 + cmc2*(1-
coilc2)*PMNOILINF2+coilc2*(POILINF2+pinfl2)+   ETA_PC2;
PMNOILINF2 = (1/(1+cbeta2*cindpm2))*( cbeta2*PMNOILINF2(1)
+cindpm2*PMNOILINF2(-1) +((1-cprobpm2)*(1-
cbeta2*cprobpm2)/(cprobpm2))*(   cimpbeta2*(-RPMNOIL2P1+s1) + (1-
cimpbeta2)*( -1*RPMNOIL2P2 ) )) +EE_PM2;
RPMNOIL2P1 = RPMNOIL2P1(-1)+PMNOILINF2-pinfl1;
RPMNOIL2P2 = RPMNOIL2P2(-1)+PMNOILINF2-pinfl2;
EX2=cexpbeta2*MD1  + EE_NT2   ;
NETTRADE2 = ((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-coilc2-
cmc2))* (EX2 - IM2);
IM2=(cim2*(1-
coilc2)*(cmc2/cim2)*(ccs2+cinvs2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinv
s2))/(1-coilc2-cmc2)))/((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-
coilc2-
cmc2)))*MD2+(coilc2/((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(1-
coilc2-
cmc2)))*(ccs2*c2+cinvs2*inve2+((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2)
)/(1-coilc2-
cmc2))*EX2)+((cmy2+coily2)/((coily2+cmy2+(coilc2+cmc2)*(ccs2+cinvs2))/(
1-coilc2-cmc2)))*y2;
g2=ctouc2*ccs2*((1+ctouc2)/ctouc2*taxc2+c2)+ctoul2*(1-
calfa2)*((1+ctoul2)/ctoul2*taxl2+lab2+w2)+ctouk2*(crk2-
ctou2)*ckap2*((1+ctouk2)/ctouk2*taxk2+rk2*crk2/(crk2-ctou2)+k2)-
ctr2*TR2;
          mc2 = (1-coily2-cmy2)*( calfa2*rk2+(1-calfa2)*(w2+pcpy2) -
duma*a2 - (1-duma)*(1-calfa2)*a2 ) + coily2*(poil) + cmy2*RPMNOIL2P2 ;
          zcap2 =  (1/czcap2)*(rk2*crk2/(crk2-ctou2)-taxk2)*(1-cbeta2)/
(1-cbeta2+cbeta2*ctou2) ;
          rk2 =  (w2+pcpy2)+lab2-k2 ;
          k2 =  kp2+zcap2 ;
          inve2 = (1/(1+cbeta2))* ((  inve2(-1) +
cbeta2*(inve2(1)))+(1/csadjcost2)*pk2)+qs2;
          pk2 = -rm2+pcinfl2(1)+b2  +(1-cbeta2)*(rk2(1)*crk2/(crk2-
ctou2)-taxk2(1))+cbeta2*(1-ctou2)*pk2(1) ;
          c2 = (chabb2/(1+chabb2))*c2(-1) + (1/(1+chabb2))*c2(+1) +
((csigma2-1)/(csigma2*(1+chabb2)*(1+clandaw2)))*(1-
ctoul2)/(1+ctouc2)*(lab2-lab2(1)) - (1-
chabb2)/(csigma2*(1+chabb2))*(rm2-pcinfl2(+1)-b2+taxc2-taxc2(1)) ;
          y2 = cfc2*( calfa2*k2+(1-calfa2)*lab2 ) + duma*cfc2*a2 + (1-
duma)*(1-cfc2*calfa2)*a2  ;
          pinfl2 =  (1/(1+cbeta2*cindp2))*( (cbeta2)*(pinfl2(1))
+(cindp2)*(pinfl2(-1)) +((1-cprobp2)*(1-
cbeta2*cprobp2)/(cprobp2))*(1/((cfc2-1)*cEFA+1))* (mc2)  )  + spinf2 -
cpy2*ETA_PC2;
          w2 =  (1/(1+cbeta2))*w2(-1)
```

Figure 23: Dynare code

```
+(cbeta2/(1+cbeta2))*w2(1)
                 +(cindw2/(1+cbeta2))*pcinfl2(-1)
                 -((1+cbeta2*cindw2)/(1+cbeta2))*pcinfl2
                 +(cbeta2/(1+cbeta2))*pcinfl2(1)
                 +(1-cprobw2)*(1-
cbeta2*cprobw2)/((1+cbeta2)*cprobw2*(((1+clandaw2)/(-clandaw2))*csigl2-
1))*
                   (w2 - csigl2*lab2 - (1/(1-chabb2))*c2 + (chabb2/(1-
chabb2))*c2(-1) -taxl2-taxc2)
                 + sw2 ;
           rm2 =   crpi2*(1-crr2)*pcinfl2
                 +cry2*(1-crr2)*(y2-yf2)
                 +crdy2*(y2-yf2-y2(-1)+yf2(-1))
                 +crr2*rm2(-1)
                 +ms2;
           kp2 =  (1-ctou2)*kp2(-1)+ctou2*inve2(-1) +
ctou2*(1+cbeta2)*csadjcost2*qs2 ;
s2=dS2+s2(-1);
pcpy2 = pcpy2(-1)+pcinfl2-pinfl2;
dY2=y2-y2(-1)+ctrend2;
dC2=c2-c2(-1)+ctrend2;
dI2=inve2-inve2(-1)+ctrend2;
dW2=w2-w2(-1)+ctrend2;
PYINF2 = pinfl2 + constepinf2;
R2 = rm2 + constepinf2 + conster2;
dL2 = lab2 - lab2(-1) + constelab2;
PMINF2 = pminfl2+constepminf2;
PCINF2 = pcinfl2+constepinf2;
dS1=-dS2;

a2 = crhoa2*a2(-1)  + ea2;
b2 = crhob2*b2(-1) + eb2;
g2 = crhog2*g2(-1) + eg2;
qs2 = crhoqs2*qs2(-1) +  eqsma2 - cmaq2*eqsma2(-1) ;
eqsma2=eqs2;
ms2 = crhoms2*ms2(-1) + em2;
spinf2 = crhopinf2*spinf2(-1) + epinfma2 - cmap2*epinfma2(-1);
epinfma2=epinf2;
sw2 = crhow2*sw2(-1) + ewma2 - cmaw2*ewma2(-1) ;
ewma2=ew2;
EE_NT2 = crhont2*EE_NT2(-1) + ETA_NT2;
EE_PM2 = crhopm2*EE_PM2(-1) + ETA_PM2;
pmpy2 = pmpy2(-1)+pminfl2-pinfl2;
taxk2=crhoxk2*taxk2(-1)+ ETA_K2;
taxl2=crhoxl2*taxl2(-1)+ ETA_L2;
taxc2=crhoxc2*taxc2(-1)+ ETA_C2;

POILINF2 = poil-poil(-1) + constepoil;
poil = crhopoil*poil(-1) + 100*ETA_POIL + 100*ETA_POILma(-1);
ETA_POILma=ETA_POIL;

end;

DSGE_steadystate;
steady;
```

Figure 24: Dynare code

```
check;

shocks;
var ea1; stderr 0.02;
var eb1; stderr 0.02;
var eg1; stderr 0.02;
var eqs1; stderr 0.02;
var em1; stderr 0.02;
var epinf1; stderr 0.02;
var ew1; stderr 0.02;
var ETA_PC1; stderr 0.02;
var ETA_PM1; stderr 0.02;
var ETA_POIL; stderr 0.02;
var ETA_NT1; stderr 0.02;
var ETA_S1; stderr 0.02;
var ea2; stderr 0.02;
var eb2; stderr 0.02;
var eg2; stderr 0.02;
var eqs2; stderr 0.02;
var em2; stderr 0.02;
var epinf2; stderr 0.02;
var ew2; stderr 0.02;
var ETA_PC2; stderr 0.02;
var ETA_PM2; stderr 0.02;
var ETA_NT2; stderr 0.02;
var ETA_K1; stderr 0.02;
var ETA_K2; stderr 0.02;
var ETA_L1; stderr 0.02;
var ETA_L2; stderr 0.02;
var ETA_C1; stderr 0.02;
var ETA_C2; stderr 0.02;
end;

//exercise 2: estimation

estimated_params;
// PARAM NAME, INITVAL, LB, UB, PRIOR_SHAPE, PRIOR_P1, PRIOR_P2,
PRIOR_P3, PRIOR_P4, JSCALE
// PRIOR_SHAPE: BETA_PDF, GAMMA_PDF, NORMAL_PDF, INV_GAMMA_PDF

// home specific parameters
stderr ea1,0.7347,0.025,2,INV_GAMMA_PDF,0.1,2;
stderr eb1,0.6314,0.025,5,INV_GAMMA_PDF,0.1,2;
stderr eg1,0.3776,0.025,2,INV_GAMMA_PDF,0.1,2;
stderr eqs1,0.5653,0.025,10,INV_GAMMA_PDF,0.1,2;
stderr em1,0.1627,0.025,2,INV_GAMMA_PDF,0.1,2;
stderr epinf1,0.1817,0.01,2,INV_GAMMA_PDF,0.1,2;
stderr ew1,0.1804,0.01,2,INV_GAMMA_PDF,0.1,2;
stderr ETA_PC1,0.2345,0.01,10,INV_GAMMA_PDF,0.1,2;
stderr ETA_PM1,0.5545,0.01,10,INV_GAMMA_PDF,0.1,2;
stderr ETA_POIL,0.1734,0.01,10,INV_GAMMA_PDF,0.1,2;
stderr ETA_NT1,2.696,0.01,10,INV_GAMMA_PDF,1,2;
stderr ETA_S1,0.1098,0.01,10,INV_GAMMA_PDF,.1,2;
crhoa1,.9913 ,.01,.9999,BETA_PDF,0.75,0.150;
crhob1,.7382,.01,.9999,BETA_PDF,0.75,0.150;
crhog1,.9173,.01,.9999,BETA_PDF,0.75,0.150;
```

Figure 25: Dynare code

```
crhoqs1,.9002,.01,.9999,BETA_PDF,0.75,0.150;
crhoms1,.3121,.01,.9999,BETA_PDF,0.25,0.150;
crhopinf1,.9452,.01,.9999,BETA_PDF,0.75,0.150;
crhow1,.9744,.001,.9999,BETA_PDF,0.75,0.150;
cmap1,.8663,0.01,.9999,BETA_PDF,0.75,0.15;
cmaw1,.8958,0.01,.9999,BETA_PDF,0.75,0.15;
cmaq1,.8535,.01,.9999,BETA_PDF,0.75,0.15;
crhopm1,.936,.01,.9999,BETA_PDF,0.75,0.150;
crhopoil,.99,.01,.9999,BETA_PDF,0.75,0.150;
crhont1,.9876,.01,.9999,BETA_PDF,0.75,0.150;
cmy1,.046,.01,.9999,NORMAL_PDF,0.06,0.010;
cmc1,.0834,.01,.9999,NORMAL_PDF,0.06,0.010;
cim1,.85,.01,.9999,BETA_PDF,0.7,0.10;
coilc1,.0037,.0001,.9999,NORMAL_PDF,0.00625,0.0010;
coily1,.0021,.0001,.9999,NORMAL_PDF,0.00625,0.0010;
cimpbeta1,.297,.0001,.9999,BETA_PDF,0.4,0.10;
cexpbeta1,.753,.0001,.9999,BETA_PDF,0.4,0.10;
csubst1,2.8061,.0001,5.,NORMAL_PDF,1.5,0.5;
cadjc1,3.797,.0001,10.,NORMAL_PDF,4.0,1.0;
cprobpm1,0.6873,0.1,0.95,BETA_PDF,0.75,0.05;
cindpm1,0.2064,0.01,0.99,BETA_PDF,0.5,0.15;
csadjcost1,7.9672,2,15,NORMAL_PDF,4,1.5;
csigma1,1.02,0.25,3,NORMAL_PDF,1.5,0.375;
chabb1,0.7176,0.001,0.99,BETA_PDF,0.7,0.1;
clandaw1,0.4942,0.001,5.0,NORMAL_PDF,0.5,0.15;
cprobw1,0.7624,0.3,0.95,BETA_PDF,0.75,0.05;
csig11,2.976,0.25,10,NORMAL_PDF,2,0.75;
cprobp1,0.74,0.1,0.95,BETA_PDF,0.66,0.05;//cprobp1,0.8829,0.5,0.95,BETA
_PDF,0.75,0.05;
cindw1,0.3797,0.01,0.99,BETA_PDF,0.5,0.15;
cindp1,0.1431,0.01,0.99,BETA_PDF,0.5,0.15;
cprobe,0.7505,0.1,0.95,BETA_PDF,0.5,0.15;
czcap1,0.2530,0.01,1,NORMAL_PDF,0.2,0.075;
cfc1,1.185,1.0,3,NORMAL_PDF,1.25,0.125;
crpi1,1.7357,1.0,3,NORMAL_PDF,1.5,0.25;
crr1,0.9073,0.5,0.975,BETA_PDF,0.75,0.1;
cry1,0.1095,0.001,0.5,NORMAL_PDF,0.125,0.05;
crdy1,0.2166,0.001,0.5,NORMAL_PDF,0.125,0.05;
constepinf1,0.6097,0.1,2.0,NORMAL_PDF,0.625,0.1;//20;
constepminf1,0.4492,0.1,2.0,NORMAL_PDF,0.625,0.1;//20;
constepoil,0.0,-1.0,2.0,NORMAL_PDF,0.0,0.1;//20;
conster1,0.6097,0.1,2.0,NORMAL_PDF,0.625,0.1;//0.20;
constelab1,-0.0745,-1.0,1.0,NORMAL_PDF,0.0,.10;
ctrend1,0.44,0.1,0.8,NORMAL_PDF,0.4,0.10;

// foreign specific parameters
stderr ea2,0.4472,0.025,2,INV_GAMMA_PDF,0.1,2;
stderr eb2,0.8416,0.025,5,INV_GAMMA_PDF,0.1,2;
stderr eg2,0.5693,0.025,2,INV_GAMMA_PDF,0.1,2;
stderr eqs2,0.5441,0.025,10,INV_GAMMA_PDF,0.1,2;
stderr em2,0.2397,0.025,2,INV_GAMMA_PDF,0.1,2;
stderr epinf2,0.1695,0.01,2,INV_GAMMA_PDF,0.1,2;
stderr ew2,0.2224,0.01,2,INV_GAMMA_PDF,0.1,2;
stderr ETA_PC2,0.1766,0.01,10,INV_GAMMA_PDF,0.1,2;
stderr ETA_PM2,1.0044,0.01,10,INV_GAMMA_PDF,0.1,2;
stderr ETA_NT2,1.735,0.01,10,INV_GAMMA_PDF,1,2;
crhoa2,.9915 ,.01,.9999,BETA_PDF,0.75,0.150;
```

Figure 26: Dynare code

```
crhob2,.7164,.01,.9999,BETA_PDF,0.75,0.150;
crhog2,.9963,.01,.9999,BETA_PDF,0.75,0.150;
crhoqs2,.9770,.01,.9999,BETA_PDF,0.75,0.150;
crhoms2,.1694,.01,.9999,BETA_PDF,0.25,0.150;
crhopinf2,.8243,.01,.9999,BETA_PDF,0.75,0.150;
crhow2,.9329,.001,.9999,BETA_PDF,0.75,0.150;
cmap2,.7804,0.01,.9999,BETA_PDF,0.75,0.15;
cmaw2,.8805,0.01,.9999,BETA_PDF,0.75,0.15;
cmaq2,.8277,.01,.9999,BETA_PDF,0.75,0.15;
crhopm2,.9851,.01,.9999,BETA_PDF,0.75,0.150;
crhont2,.9969,.01,.9999,BETA_PDF,0.75,0.150;
crhos,.9899,.01,.9999,BETA_PDF,0.5,0.150;
cmy2,.0547,.01,.9999,NORMAL_PDF,0.05,0.010;
cmc2,.0717,.01,.9999,NORMAL_PDF,0.05,0.010;
cim2,.5936,.01,.9999,BETA_PDF,0.7,0.10;
coilc2,.0053,.0001,.9999,NORMAL_PDF,0.00625,0.0010;
coily2,.0043,.0001,.9999,NORMAL_PDF,0.00625,0.0010;
cimpbeta2,.7681,.0001,.9999,BETA_PDF,0.4,0.1;
cexpbeta2,.2185,.0001,.9999,BETA_PDF,0.4,0.1;
csubst2,1.8287,.0001,9.9999,NORMAL_PDF,1.5,0.5;
cadjc2,0.7336,.0001,10.,NORMAL_PDF,4.0,1.0;
cprobpm2,0.6032,0.1,0.95,BETA_PDF,0.75,0.05;
cindpm2,0.1038,0.01,0.99,BETA_PDF,0.5,0.15;
csadjcost2,3.738,2,15,NORMAL_PDF,4,1.5;
csigma2,1.2178,0.25,3,NORMAL_PDF,1.5,0.375;
chabb2,0.6626,0.001,0.99,BETA_PDF,0.7,0.1;
clandaw2,0.4377,0.001,5.0,NORMAL_PDF,0.5,0.15;
cprobw2,0.8184,0.3,0.95,BETA_PDF,0.75,0.05;
csigl2,2.7773,0.25,10,NORMAL_PDF,2,0.75;
cprobp2,0.74,0.1,0.95,BETA_PDF,0.66,0.05;//cprobp2,0.90,0.5,0.95,BETA_P
DF,0.75,0.05;
cindw2,0.4535,0.01,0.99,BETA_PDF,0.5,0.15;
cindp2,0.3307,0.01,0.99,BETA_PDF,0.5,0.15;
czcap2,0.2290,0.01,1,NORMAL_PDF,0.2,0.075;
cfc2,1.3876,1.0,3,NORMAL_PDF,1.25,0.125;
crpi2,1.87,1.0,3,NORMAL_PDF,1.5,0.25;
crr2,0.8182,0.5,0.975,BETA_PDF,0.75,0.1;
cry2,0.1033,0.001,0.5,NORMAL_PDF,0.125,0.05;
crdy2,0.2332,0.001,0.5,NORMAL_PDF,0.125,0.05;
constepinf2,0.7041,0.1,2.0,NORMAL_PDF,0.625,0.1;//20;
constepminf2,0.5133,0.1,2.0,NORMAL_PDF,0.625,0.1;//20;
conster2,0.6298,0.1,2.0,NORMAL_PDF,0.625,0.1;//0.20;
constelab2,0.023,-1.0,1.0,NORMAL_PDF,0.0,.10;
ctrend2,0.40,0.1,0.8,NORMAL_PDF,0.4,0.10;

// parameters from the extension of the model
cpy1,0.50,0.1,2.0,NORMAL_PDF,0.5,0.25;
cpy2,0.50,0.1,2.0,NORMAL_PDF,0.5,0.25;
crhoxk1,.7,.1,.9999,BETA_PDF,0.85,0.150;
crhoxl1,.7,.1,.9999,BETA_PDF,0.85,0.150;
crhoxc1,.7,.1,.9999,BETA_PDF,0.85,0.150;
crhoxk2,.7,.1,.9999,BETA_PDF,0.85,0.150;
crhoxl2,.7,.1,.9999,BETA_PDF,0.85,0.150;
crhoxc2,.7,.1,.9999,BETA_PDF,0.85,0.150;
stderr ETA_K1,0.001,0.0001,1,INV_GAMMA_PDF,0.001,2;
stderr ETA_K2,0.001,0.0001,1,INV_GAMMA_PDF,0.001,2;
stderr ETA_L1,0.001,0.0001,1,INV_GAMMA_PDF,0.001,2;
```

Figure 27: Dynare code

```
stderr ETA_L2,0.001,0.0001,1,INV_GAMMA_PDF,0.001,2;
stderr ETA_C1,0.001,0.0001,1,INV_GAMMA_PDF,0.001,2;
stderr ETA_C2,0.001,0.0001,1,INV_GAMMA_PDF,0.001,2;

end;


//stoch_simul(nomoments,irf=20) y1 c1 invel w1 rm1 lab1 s1 pcinfl1
NETTRADE1;


varobs PYINF1 R1 PCINF1 NETTRADE1   PYINF2  R2  PCINF2  NETTRADE2
POILINF2    dC1   dI1   dY1 dE1 dW1 dC2 dI2 dY2 dL2 dW2 dS1 PMINF1
PMINF2;

//estimation(optim=('MaxIter',10),datafile=DSGE_data, mode_check,
mh_replic=0, mh_nblocks=2,mh_jscale=0.25);
//estimation(datafile=DSGE_data, mode_check,
mh_nblocks=2,mh_jscale=0.25);
estimation(lik_init=2,datafile=DSGE_data, mode_check, mh_replic=150000,
mh_nblocks=2,mh_jscale=0.25);
```

Figure 28: Dynare code