Managing fiscal policy with non-Ricardian consumers in large open economies: A DSGE model for the Euro area and the U.S.

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This version: November 15, 2008. (Please do not quote)

Abstract

This paper investigates the macroeconomic effects of active fiscal policy management in interaction with a monetary policy that follows the Taylor principle. The objective is to investigate the relevance of the REP and to examine the short-run interaction of two large open economies, where a fraction of the consumers are financially constrained. According to an estimated vector autoregressive model, a positive shock in government expenditure leads to an increase in dynamic multipliers of consumption (at odds with the permanent income hypothesis). The channels are investigated in a fully microfounded dynamic stochastic general equilibrium model economy calibrated for the Euro-area (EU-12) and for the United States. The main feature of the model that we endogenize is the share of non-Ricardian consumers and we explore its implications for stability. The remaining structure contains firms that produce tradable varieties in a monopolistic competition framework, where pricing is à la Calvo that leads to price stickiness. Labor's varieties are immobile and demanded by firms in an aggregated fashion. Fiscal policy is specified as a time consistent rule. Nominal and real shocks are simulated employing impulse response functions and finally, a subset of deep parameters of the model is estimated using Bayesian techniques.

Keywords: Policy coordination; Monetary policy; Fiscal Policy; non-ricardian agents; Exchange rates; NOEM, New Open Economy Macroeconomics, DSGE models.

JEF Classification: E42; F41; F42

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1 Introduction

Fiscal policy management has re-emerged as an interesting theme in recent studies; but contrary to former times, now supranational institutions are more active than any country itself. In particular, renewed discussions are set in a new context: as the world economy has become increasingly interlinked due to the deepening of the integration process, natural actors are today supranational institutions. This is due to the fact that the establishment of economic blocs implied policies delegation with special mandate to coordinate them and because of increasing spillover effects that could not be neglected any longer.

We might think of the European Monetary Union (EMU), for instance, which advanced to a solid economic and political integration. However, looking back into that process, it does not display a straight integration path. Often, members have learned policy lessons in a rude way. Just to mention one example, the just elected President F. Mitterand, embarked alone on a Keynesian expansionary programme at a time of world recession (1981) and when France's partners were pursuing restrictive economic policies. The experiment failed, the Franc heavily depreciated, reserves vanished and the measures had to be reverted. Implementing uncoordinated policies became more and more costly. As similar experiences occurred in Europe, the countries eventually signed an agreement on limiting their abilities to set independent fiscal policies. Hence, they built consensus on bounding rules, e.g., the Maastricht Treaty —specified as a cap of three per cent of the budgetary deficit to output ratio. It was complemented with a balanced-budget guideline known as Stability and Growth Pact (SGP) in 1997. As a result, these institutions served as explicit pillars for the EMU, which once settled meant a firm background for the common currency definitively introduced in 2002.[1]

In 2005, Italy and Germany found it hard to meet the requirements of the SGP because their economic growth slowed down during the period 2000-2004 making difficult to roll-over their debt services. In order to break these tendencies in the GDP growth rates, several EMU members instrumented budgetary expansions.[2] At those times, several organizations such as the Organization for Economic Cooperation and Development (OECD), the International Monetary Found (IMF), the European Commission, *inter allia*, were concerned with tax cuts because consumers could not consider the corresponding issuance of bonds as net wealth in their portfolios. This effect is known as the Ricardian Equivalence Proposition (REP) and would imply that a present tax cut would not affect agents' permanent income because they are *exactly* compensated by the discounted (higher) future tax liabilities that the government would need in order to honor its outstanding debt.

Similarly, this phenomenon could occur in the U.S. as well, where its fiscal policy management has been recently questioned. In effect, persistent structural U.S. imbalances resulted in debt-to-output ratios that trespassed all prudent standards. Several studies pointed out that excessive consumption and government spending levels were among the most cited causes underlying trade deficits as well as fiscal deficits. Since it seems unlikely that appropriate reversals could occur in the short run (2009-2010), we think that the effects of the REP could also be verified as future tax cuts are implemented (currently under evaluation to mitigate the incipient recession of 2008).[3]

Although the REP could be regarded as a direct implication of the permanent hypothesis, it hinges on quite strong assumptions, which we very briefly summarize in the following numbered

[1] The European Commission is officially committed to enforce these agreed rules.

[2] In a currency area, member countries count with fiscal policy as a feasible policy instrument to mitigate recessions (or decelerations) of economic activity.

[3] There are at least two causes that explain the poor growth performance of the U.S.: (i) increasing world inflationary pressures (commodities, oil); and (ii) increasingly inflexible military expenses (such as those derived from the war involvements in Iraq or Afghanistan).

list items:

1. the economic agent has a horizon that extends to the *in*finite. Finite life durations, in addition, require: (a) parents who care about the utility of their children in overlapping models, saving for bequest motives, see [Barro, 1974]; (b) an individual who faces uncertainty about how long his life will last, see [Blanchard, 1985];

2. there is no uncertainty of the future income streams, meaning that insurance markets exist and effectively cover bad states of nature, (see, [Feldstein, 1988]);

3. the output —also population, in the case of pay-as-you-go social security system— does not grow enough to enable the government to rollover the debt continuously;

4. individuals are fully rational, i.e., bounded rationality is neglected;

5. borrowing differential rates is insignificant in terms of the required information to distinguish good form bad investment projects;

6. the new debt is allocated entirely in portfolios owned by home consumers (as long as the share of the debt stock held by foreigners remains constant);

7. taxes are non-distortionary, i.e., the marginal tax rate does not change during the relevant horizon.

The objective of this paper is to investigate the relevance of the REP and to examine the short-run interaction of two large open economies, where a fraction of the consumers are financially constrained (and therefore acting in a non-Ricardian way) in the framework of a fully microfounded DSGE model. The modeling strategy followed forces the separation of consumers in two types: (i) "unconstrained" consumers which have access to financial markets and able to smooth consumption; and (ii) remaining consumers face financial constraints, who in practice have no access to borrowing/lending arrangements. As a result, their ability to consume is fully determined by their disposable income (defined as total taxes subtracted from the wage income) as proposed by [Campbell & Mankiw, 1989]. Savings, commonly defined as the residual of what is not consumed, are maintained in bonds and cash solely by unconstrained consumers.[4] This separation of consumers' types has important consequences in open economies which so far, in our opinion, have not been sufficiently analyzed in the literature.

The model is suited to deal with business cycle fluctuations, but it contains parameters that must be recovered from long run datasets. In this aspect, some hint to properly calibrate the model come from the estimation of an unrestricted vector autoregression (VAR) model. We proceed to estimate a simple VAR model with classical methods employing macroeconomic aggregate data of the EU-12 that proxies the Euro area and of the U.S..[5] In particular, we recover the implied dynamic multipliers in order to calibrate parameters that match the timing of fiscal policy. Once the model is parameterized, we proceed to conduct simulation analyses comparing impulse response

[4] We acknowledge, however, that to some extent the presence of the so-called rule-of-thumb consumers are merely a shortcut that may disregard other interesting avenues of research (e.g. learning). The advantage is that it allow us to keep our model within a medium scale meanwhile it leads to valuable output in order to derive policy recommendations.

[5] The EU-12 aggregate comprises the following countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Portugal, Spain and The Netherlands. The data employed is detailed in the Data Appendix.

functions of key macroeconomic variables under nominal and real shocks (monetary demand shock, exchange rate shock, productivity shocks, markup shocks). The main feature of the model that we endogenize is the share of non-Ricardian consumers, several values of it are considered and their implications for stability are analyzed. The remaining structure of the model features firms that produce varieties in a monopolistic competition fashion. In particular, we assume that firms pricing is à la Calvo, allowing for price stickiness. The input common to all firms is an aggregate of labor's varieties.[6] Finally, we estimate a subset of parameters employing Bayesian techniques implemented with routines taken from the Dynare package. The Kalman filter and posterior distributions are simulated with the Markov chain Monte Carlo (MCMC) algorithm using the Gibbs sampler. Observable variables are those included in the estimated VAR, while the remaining variables are treated as unobserved.

The paper's structure is as follows: in Section 2 we briefly review the literature on REP; in Section 3 we present the results of a VAR specification for the Euro area (EU-12); in Section 4 we lay out a fully specified theoretical model that includes internationally tradable goods and two (large) open economies presenting consumers and firms problems and we close the model imposing equilibrium conditions; in Section 5 we present both monetary and fiscal policy rules to which the CB and the fiscal authority are committed, respectively. Section 6 we calibrate our theoretical model following the literature and includes numerical simulation exercises considering plausible real and nominal shocks; while, Section 7 estimates a subset of deep parameters of the DSGE model with Bayesian techniques. Finally Section 8 concludes with policy recommendations.

2 A brief literature review

In the theoretical macroeconomic literature [Sargent & Wallace, 1981] were among the first to tackle intertemporal aspects of monetary and fiscal policies together; however, for simplicity the literature normally assumes that fiscal policy "adjusts" by an appropriate selection of lump-sum transfers to neutralize the effects of (non-distortionary) taxes.[7] Our purpose is to consider more deeply the management of monetary and fiscal policy —conducted by two independent policy authorities— that lead to the model solution. A priori, such solution must be compatible with non-explosive sequences for both the price level and the public debt. It is crucial, then, to distinguish between active versus passive policies in the sense of [Leeper, 1991]. The former refers to the case where one policy authority pursues its objective unconstrained by the other's behavior, while the latter is consistent with a constrained behavior. For instance, [Plasmans *et al.* , 2007] assume passive fiscal policy and active monetary policy; an implicit mix frequently found in the literature, e.g., the Taylor principle. In this paper we consider additionally active fiscal policy, which enables us to generate wealth effects that shift aggregate demand. As a result we would like to assess policy impacts that are non-monetarist and non-Ricardian and discuss under which conditions the (unique) equilibrium is locally feasible, as [Leith & von Thadden, 2006].

The empirical literature on the validity of the REP seems to be inconclusive. [Becker, 1995], [Seater, 1993], [Bernheim, 1988] surveyed the evidence on the REP and came up with contradictory conclusions considering samples with aggregate data. However, further evidence that appeared in the 1990s using VARs analyses have reached a sort of consensus, giving support to basically two main findings: (i) disregarding the particular identification strategy utilized, there

[6] Without loosing generality, we may assume that capital is fixed, it does not depreciate and is normalized to one
[7] See e.g., [Plasmans *et al.* , 2007] and references therein.

is no study suggesting that consumption responds negatively to an expansionary budgetary policy (a prediction that would be supportive of the permanent income hypothesis); and (ii) that fiscal spillovers to neighbor countries occur via trade, a phenomenon not found in the former literature. The idea is that a fiscal expansion stimulates home output because of the shift of aggregate demand, leading to more domestic imports (and thus more exports and output of foreign countries). This evidence points to spillover effects solely since government imports seem to be insignificant, [Giuliodori & Beetsma, 2005], [Fatas & Mihov, 2001a], [Fatas & Mihov, 2001b], *inter allia*.

In contrast, studies that test the REP/permanent income hypothesis using samples with individual/household data, seem to offer support to the REP, e.g., [DeJuan & Seater, 1999], [Campbell & Cocco, 2007], *inter allia*.

The main reference we follow in this paper is [Galí *et al.* , 2007b]. While they focus on a closed economy, we extend the model to two (large) open economies: EU-12 and the U.S. This extension will allow us to characterize the international spillover effect as well as relative price fluctuations that would explain the pattern of spillovers. This is a novelty in the literature.

3 Assessing the effects of an expansionary fiscal policy

In this section we focus on the effects on consumption resulting from an expansionary fiscal policy. The main hypothesis is that the essential macroeconomic variables can be represented by a VAR model. In a recent paper, [Galí *et al.* , 2007b] present evidence for the U.S., suggesting that expansionary fiscal policy, say an increase of public expenditures, leads to an expansion of private consumption of nondurable goods. As we referred in the introductory section, practically all studies so far have found a positive consumption dynamic multiplier of the fiscal policy on impact and also at different (future) time horizons.

Hinging on these results, we estimate a VAR using key aggregate macroeconomic series for EU-12. The aim is to compare the aforementioned finding regarding the U.S. economy reported by [Galí *et al.* , 2007b]. Bearing in mind important aggregation concerns for the EU-12 entity during the 1990s, e.g., the unification process that took place in Germany in 1991, the implementation of the ECU, *inter allia*, we concentrated on the shorter period from 1991Q1 to 2006Q4.[8] Given the large number of data points that VAR analyses necessitate to identify estimates (recall that parameters estimates growth more than one-to-one with the number of variables), the present study is constrained to consider a very parsimonious model. Consequently, we could only produce comparable evidence of the "small" VAR model of [Galí *et al.* , 2007b].

Table 1 reports dynamic multipliers calculated from the following specification:[9]

$$\mathbf{y}_t = \Gamma_0 + \Gamma_1 \mathbf{y}_{t-1} + \Gamma_2 \mathbf{y}_{t-2} + \Gamma_3 \mathbf{y}_{t-3} + \Gamma_4 \mathbf{y}_{t-4} + \boldsymbol{\varepsilon}_t \quad (1)$$

where $\mathbf{y}_t \equiv (G_t, Y_t, C_t, PD_t)'$ and $\boldsymbol{\varepsilon}_t$ are 4×1 vectors. The former includes the following endogenous variables: government expenditure, GDP, private consumption and primary deficit, while $\boldsymbol{\varepsilon}_t$ is a disturbance vector with mean the null vector and variance-covariance matrix $\boldsymbol{\Sigma}$. In the framework of difference equations, a dynamic multiplier of (1) for one quarter effect of variable j to variable i

[8] The ECU was a basket of currencies of the European Community member states during the convergence process to adopt the Euro.

[9] Alternative estimates with different lags lengths provided us with the information to determine that an adequate l is 4 quarters. Relevant information criteria considered were Akaike information criterion and Schwarz criterion.

can be defined as:

$$\frac{\partial \mathbf{y}_{t+1}^{(i)}}{\partial \mathbf{y}_t^{(j)}} \equiv \Gamma_1^{(i,j)}. \tag{2}$$

As in [Galí *et al.* , 2007b], we consider EU-12 aggregates of general government spending (general government spending net of military expenditures), gross domestic product, private consumption and general government budget deficit. We find that the results for EU-12 aggregates are in accordance with those reported by [Galí *et al.* , 2007b]. The dynamic multipliers of consumption and GDP are positive when expansionary fiscal policy takes place within a two years horizon. This evidence suggests that consumers in the Euro area react to increases in public expenditure increasing their consumption as well, response that is at odds with the well known REP and the neoclassical model. If the latter model would apply, consumers would have behaved differently, taking for granted that future tax slips will increase to cover the current budgetary deficit (that equals the amount in bonds that the government needs to sell today).

Which modification of the Neoclassical model would be necessary to explain this evidence? [Mankiw, 2000] suggested to introduce heterogeneous agents that behave in a myopic way because they do not have access to financial markets to smooth consumption. In practice, these agents would base their consumption in disposable income instead of permanent income. We will describe in the following section a model capable to replicate this evidence.

Table 1

	Private Consumption		**GDP**	
Quarter	Full government spending	Government spending excluding military	Full government spending	Government spending excluding military
1st	0.061 (0.04)	0.059 (-0.11)	0.047 (0.51)	0.044 (0.15)
2nd	0.148	0.143	0.139	0.132
3rd	0.177	0.168	0.206	0.196
4th	0.252 (0.09)	0.237 (0.24)	0.274 (0.31)	0.261 (-0.12)
5th	0.299	0.280	0.344	0.329
6th	0.278	0.255	0.374	0.359
7th	0.249	0.221	0.413	0.398
8th	0.198 (0.19)	0.166 (0.32)	0.434 (0.28)	0.417 (0.34)

Note: Authors' calculations for the EU-12 aggregates. Comparable figures for the U.S. estimated by [Galí *et al.* , 2007a] are in brackets (reported in Table 1, page 233).

4 The model

To begin with, we assume that there are two regions in the world economy. Each region of the world economy is populated by a continuum of economic agents "consumers" that live infinitely and that are normalized to one. Home consumer j is indexed by $j \in [0, 1]$.[10] Likewise, foreign consumers are denoted by j^* and indexed by $j^* \in [0, 1]$. Moreover, each region has an administrative authority —the national government—, which levies taxes and issue bonds with which it can purchase goods (or transfer money).

[10] We can think about dynasties of individuals that continue living through their children owing to intergenerational solidarity, to relax the problem of choosing a discrete living period. Alternatively, we may consider adding a probability of death of the representative individual, as [Blanchard, 1985].

4.1 Consumers' types

There are two types of rational consumers in both economies: (i) financially constrained consumers (myopic though fully rational) and (ii) those that can access to financial markets. Since we focus on the short run, we assume that these types contain a fixed number of agents (leading to constant shares), i.e., those constrained agents do not learn how to overcome the constraint.

All goods varieties have world markets and are indexed by: the h-index which refers to home tradable goods $h \in [0,1]$, the f-index that denotes foreign tradable varieties $f \in [0,1]$.[11] Agent j's consumption is devoted to purchase home and foreign goods. Prices are denominated in home currency, so that those prices of foreign goods are converted by the nominal exchange rate $\mathcal{E}_s$. We assume that the representative agent takes varieties' prices and nominal exchange rate, as given when choosing quantities.[12] Thus, agent j's consumption is,

$$P_s C_s^j = \int_0^1 P_{H,s}(h) C_{H,s}^j(h) dh + \int_0^1 \mathcal{E}_s P_{F,s}^*(f) C_{F,s}^j(f) df. \tag{3}$$

Individual aggregate consumption is represented by the index C_s^j, which is specified as a Constant Elasticity of Substitution (CES) function, with relevant elasticity of substitution ($\eta_c > 1$) of home and imported goods (H and F, respectively):

$$C_s^j \equiv \left[\varphi^{\frac{1}{\eta_c}} \left(C_{H,s}^j \right)^{\frac{\eta_c - 1}{\eta_c}} + (1-\varphi)^{\frac{1}{\eta_c}} \left(C_{F,s}^j \right)^{\frac{\eta_c - 1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}}, \tag{4}$$

where φ stands for the share in the consumption of home goods in terms of the total tradable goods, T. The counterpart $(1-\varphi)$ refers to the share of foreign produced goods, F, in terms of T.[13]

Notice that aggregate consumption (4) involves the consumption indices of home and foreign produced varieties. In particular, we assume that these indices are Dixit-Stiglitz aggregators of all consumed varieties with elasticity of substitution θ_h and θ_f, greater that one. The consumption indices for home and foreign tradable goods are given by:

$$C_{H,s}^j \equiv \left[\int_0^1 C_{H,s}^j(h)^{\frac{\theta_h - 1}{\theta_h}} dh \right]^{\frac{\theta_h}{\theta_h - 1}} \quad \text{and} \tag{5}$$

$$C_{F,s}^j \equiv \left[\int_0^1 C_{F,s}^j(f)^{\frac{\theta_f - 1}{\theta_f}} df \right]^{\frac{\theta_f}{\theta_f - 1}}. \tag{6}$$

The associated home and foreign tradable goods price indices (components of the aggregate CPI) are denoted by $P_{H,s}$ and $P_{F,s}$. These prices can be interpreted as minimum prices to buy one bundle of $C_{H,s}^j$ and $C_{F,s}^j$, respectively.

[11] A more general model would define an additional index for varieties such that $h \in [0,\kappa)$ along with $f \in [\kappa, 1]$. For simplicity, we assume that the 'segment' of varieties is equal to population shares of the two countries. However, it does not imply loss of generality, since it is a normalization of the range in a continuous variable.

[12] $\mathcal{E}_s$ is defined as the price of a unit of foreign currency in terms of the home currency. Notice that this definition is the inverse of the financial nominal exchange rate.

[13] When $\eta_c \to 1$, $C_s = \frac{{C_{H,s}}^{\varphi} {C_{F,s}}^{1-\varphi}}{\varphi^{\varphi}(1-\varphi)^{1-\varphi}}$. In such a case the aggregate price index is defined as $P_s = P_{H,s}^{\varphi} P_{F,s}^{1-\varphi}$. Sutherland (2004) adds realism in this specification allowing for tradable market bias. For concreteness, denote it by $(1-\omega)$, which multiplied by φ would yield $\varphi' \equiv \varphi(1-\omega)$.

They are by definition Lagrange multipliers from the problem of minimizing the expenditure necessary to buy a unit of the relevant bundle (the associated dual from the utility maximization) and have the following form:[14]

$$P_{H,s} = \left[\int_0^1 P_{H,s}(h)^{1-\theta_h} dh \right]^{\frac{1}{1-\theta_h}}, \tag{7}$$

$$P_{F,s} = \left[\int_0^1 \left(\mathcal{E}_s P^*_{F,s}(f) \right)^{1-\theta_f} df \right]^{\frac{1}{1-\theta_f}}, \tag{8}$$

where we convert foreign varieties' prices into home currency. Consequently, broader category indices are in terms of domestic currency. The aggregate CPI is representative of all goods consumed and is denoted by:

$$P_s = \left[\varphi P_{H,s}^{1-\eta_c} + (1-\varphi) P_{F,s}^{1-\eta_c} \right]^{\frac{1}{1-\eta_c}}. \tag{9}$$

4.1.1 Optimal demands

In this subsection we obtain agents' demands. In period s agent j chooses C_s^j optimally such that he minimizes a given expenditure. In particular, the intratemporal problem is to minimize $P_s C_s^j$ subject to Equation (4). Solving that problem yields aggregate levels of consumption of home tradable goods, $C_{H,s}^j$, and imported goods $C_{F,s}^j$:

$$C_{H,s}^j = \varphi \left[\frac{P_{H,s}}{P_s} \right]^{-\eta_c} C_s^j, \tag{10}$$

$$C_{F,s}^j = (1-\varphi) \left[\frac{\mathcal{E}_s P^*_{F,s}}{P_s} \right]^{-\eta_c} C_s^j, \tag{11}$$

which, combined would yield $C_{H,s}^j = \frac{\varphi}{(1-\varphi)} \left[\frac{\mathcal{E}_s P^*_{F,s}}{P_{H,s}} \right]^{\eta_c} C_{F,s}^j$.

Next, given the solutions of $C_{H,s}^j$ and $C_{F,s}^j$ obtained above, optimal demand functions of both home and imported varieties can be analogously derived. Intratemporal problems involve the minimization of the expenditure spent on: (i) home varieties, $P_{H,s} C_{H,s}^j$, subject to Equation (5) and (ii) foreign varieties $P_{F,s} C_{F,s}^j$ subject to Equation (8), which yield optimal varieties' demands:

$$C_{H,s}^j(h) = \left[\frac{P_{H,s}(h)}{P_{H,s}} \right]^{-\theta_h} C_{H,s}^j, \tag{12}$$

$$C_{F,s}^j(f) = \left[\frac{\mathcal{E}_s P^*_{F,s}(f)}{P_{F,s}} \right]^{-\theta_f} C_{F,s}^j, \tag{13}$$

Following [Benigno, 2004], the government sector also demands home tradable varieties, $G_{H,s}(h)$. We assume that the government faces the same elasticity of substitution and relative prices as agent j does, so that the relevant demand is:

$$G_{H,s}(h) = \left[\frac{P_{H,s}(h)}{P_{H,s}} \right]^{-\theta_h} G_{H,s}, \tag{14}$$

[14] Prices do not have an upper index j because consumer j is price taker.

where aggregated government purchases, $G_{H,s}$, is defined similarly as Equation (5), with a relationship between $G_{H,s}$ and G_s given by an equation similar to Equation (10). G_s is an exogenous process that is determined by the parliament and the administration based on political bases (see below).

Likewise, the government demands foreign goods in a similar fashion as Equation (13), given by:

$$G_{F,s}(f) = \left[\frac{\mathcal{E}_s P^*_{F,s}(f)}{P_{F,s}} \right]^{-\theta_f} G_{F,s}, \tag{15}$$

where $G_{F,s} = G_{F,s}(\mathcal{E}_s,\ P^*_{F,s},\ P_s, G_s)$, similarly as in Equation (11).

As we mentioned in Section 2, the government expenditure on imported goods seems to have a small impact on the foreign economy, see [Giuliodori & Beetsma, 2005]. For the foreign economy, a similar set of demands holds both for the representative consumer j^* and for the foreign government.

4.1.2 Consumer's problem: budget constraint and first order conditions

Unconstrained consumers Agent j seeks to maximize the present value of his expected lifetime utility, $\breve{U}^j_t$:

$$\breve{U}^j_t = E_t \sum_{s=t}^{\infty} \beta^{s-t} \left[U(C^j_s, bC^j_{s-1}) + L\left(\frac{M^j_s}{P_s}\right) - V\left(N^j_{H,s}, z_s\right) \right], \tag{16}$$

which depends on aggregate (current and lagged) consumption, C^j_s, real money balances, $\frac{M^j_s}{P_s}$, and work effort in terms of hours worked in the home tradable good sector, $N^j_{H,s}$. Lagged consumption is the simplest way to introduce internal habit formation in consumption.[15] In addition, liquidity services provided by real balances of money generate utility $L(.)$. Finally, disutility $V(\cdot)$ is derived from work effort —in terms of worked hours, $N^j_{H,s}$— devoted in the production of H goods.[16] Willingness to work is assumed to be affected by an *iid.* shock z_s.

It is rational for the agent to maximize its expected future utility (16) conditional upon the information available in period t, subject to the following dynamic budget constraint in real terms:

$$\begin{aligned} &\frac{(1-\tau_w)W^j_{H,s}N^j_{H,s}}{P_s} + T^j_s + \frac{(1-\tau_D)(D^j_{H,s} + D^j_{XH,s} + D^j_{MH,s})}{P_s} + \\ &\geqq C^j_s + \frac{M^j_s - M^j_{s-1}}{P_s} + \frac{1}{P_s}\left(\frac{B^j_{s+1}}{1+I_s} - B^j_s\right) + \frac{1}{P_s}\left(\frac{\mathcal{E}_{s+1}B^{*j}_{s+1}}{1+I^*_s} - \mathcal{E}_s B^{*j}_s\right). \end{aligned} \tag{17}$$

In the LHS of the budget constraint the sources of agent's real income can be found: net of tax wage income from work supplied to the home tradable goods sector, $N^j_{H,s}$, real dividends net of tax,

[15] The introduction of internal habit formation rather than external habit formation is motivated by the study of [Grishchenko, 2007]. Using long-horizon aggregate stock market returns, she found that there is strong support for internal habit formation preferences, which decays slowly over time. In addition, this feature adds realism to the model's predictions (IRFs) and help explaining asset pricing puzzles. In particular, IRFs are much alike than those obtained with an unrestricted VAR. See [Fuhrer, 2000].

[16] $\breve{U}^j_t$ is a real-valued function, additive and separable. We assume that its components, $U(\cdot)$, $L(\cdot)$ and $V(\cdot)$, are all increasing in their arguments. Moreover, under usual assumptions, $U(\cdot)$ and $L(\cdot)$ are concave in consumption and $\frac{M^j_s}{P_s}$ $\left(U_{CC} < 0 \text{ and } L_{\frac{M^j}{P}\frac{M^j}{P}} < 0\right)$, while $V(\cdot)$ is convex in $N^j_{H,s}$, $V_{N^j_H N^j_H} > 0$.

$\frac{(1-\tau_D)}{P_s}\left(D^j_{H,s}+D^j_{XH,s}+D^j_{MH,s}\right)$, expected real returns on home-issued bonds holdings and real transfers from the government. Furthermore, the uses of resources are in the RHS: consumption, variation in the stock of money holdings in real terms and variation in the stock of riskless home and foreign bonds (without any subscript).

Following [Woodford, 2003], we assume that home asset (securities) markets are complete, thus we treat different assets comprising the portfolio as one, see [Plasmans *et al.* , 2007]. B^j_s denotes the portfolio's value at the beginning of the period, which includes bonds and shares. This greatly simplifies the algebra and it is supported by the known envelope theorem that assures that all investment alternatives should produce the same real return at the optimum. B^j_s is like a world-traded bond and it is denominated in issuer's currency, in which worldwide agents take positions to finance domestic consumption (indirectly trade deficits). The riskless (non-contingent) nominal return is denoted by I_s with one-period-maturity.

Other home financial assets are per capita nominal dividend-coupons $D^j_{H,s}$, $D^j_{XH,s}$, $D^j_{MH,s}$ and money. The government claims a tax rate τ_D to period s per capita nominal dividends.[17] Aggregate money demand, $M_s=\int_0^1 M^j_s dj$, equalized money supply which is under control of the CB, though indirectly, since the operating instrument is the nominal interest rate.

We impose that both home and foreign agents at the beginning are not indebted, i.e.:[18]

$$B^j_{-1}=\mathcal{E}_{-1}B^{*j}_{-1}=0 \qquad B^{j^*}_{-1}=\mathcal{E}_{-1}B^{*j^*}_{-1}=0. \tag{18}$$

To inquire about the implications of Equation (18), first, let us define the stock of wealth at time s in terms of each currency of home agent as $\mathcal{W}_{H,s}\equiv\frac{M^j_{s-1}+B^j_s+\mathcal{E}_sB^{*j}_s}{P_s}$ and $\mathcal{W}_{F,s}\equiv\frac{M^{*j^*}_{s-1}+\frac{B^{j^*}_s}{\mathcal{E}_s}+B^{*j^*}_s}{P^*_s}$ for foreign. Note that those assets are maintained in the portfolio for different reasons; while money facilitates transactions, bonds are used to store value and are issued to finance foreign current account deficits.[19] Initially, we can easily check that the wealth is identical across members of the different regions.[20] Moreover, recalling that asset markets are complete within the regions, thus we can predict perfect risk sharing in consumption. Consequently, we state that the problem of the agent is fully described maximizing the utility, Equation (16) subject to the budget constraint (17), given the initial conditions (18), the sequences of prices and incomes and the transversality condition. See section 4.4.

In order to solve the model, we specify the intertemporal utility function with habit formation. We propose a period constant relative elasticity risk aversion (CRRA), [21]

$$U(C^j_s)+L\left(\frac{M^j_s}{P_s},\xi_s\right)-V\left(N^j_{H,s},z_s\right)=\frac{\left(C^j_s\right)^{1-\sigma}}{(1-\sigma)\left(C^j_{s-1}\right)^{b(1-\sigma)}}+\chi\left(\frac{M^j_s}{P_s}\right)^{\varepsilon}-\frac{z_s\left(N^j_{H,s}\right)^{1+\iota}}{1+\iota} \tag{19}$$

where $\sigma>0$ is a parameter that measures agent's disposition to take risks —the greater when the agent is more risk averse— and the inverse of the intertemporal elasticity of substitution in

[17] Real home per capita dividends are given by $\frac{1}{P_s}\int_0^1\left(D^j_{H,s}+D^j_{XH,s}+D^j_{MH,s}\right)dj$.

[18] If home country has a positive stock of debt, it must add to the riskless interest rate a premium, which is a non-decreasing function of debt position; see [Schmitt-Grohe & Uribe, 2001].

[19] Shares also are used to store value; however, it likely delivers more volatility and capital gains could be non-positive. These aspects lead us to consider risk aversion of agents as crucial.

[20] To confirm that, plug Eq. (18) into $\mathcal{W}_{H,s}$ and $\mathcal{W}_{F,s}$.

[21] Note that it fulfils the requirements of (16) once innovations z_s are known.

consumption, while the parameter $b \in [0,1]$ stands for the persistence in consumption. Furthermore, ε is the elasticity of demand of money and ι is the inverse of the elasticity of substitution in exert work effort respect to real wage.

The resulting optimality conditions of the consumer problem are sufficient when budget constraint (17) is exhausted and the solution is "interior". First, representative home agents would like to smooth consumption along time as much as they can, thus initially at time s, for every positive time interval $\tau - s$, consumers equalize the marginal rate of substitution between consumption at τ and present consumption, i.e., $\beta^{\tau-s}E_s\left[U_C(C_\tau^j)\right] = U_C(C_s^j)$:[22]

$$\beta^{\tau-s}E_s\left[\frac{\left(C_\tau^j\right)^{-\sigma}}{\left(C_{\tau-1}^j\right)^{b(1-\sigma)}} + b\beta\frac{\left(C_{\tau+1}^j\right)^{1-\sigma}}{\left(C_\tau^j\right)^{b(1-\sigma)+1}}\right] = \frac{\left(C_s^j\right)^{-\sigma}}{\left(C_{s-1}^j\right)^{b(1-\sigma)}} + b\beta E_s\left[\frac{\left(C_{s+1}^j\right)^{1-\sigma}}{\left(C_s^j\right)^{b(1-\sigma)+1}}\right]. \quad (20)$$

They decide consumption *within*-period such that marginal utility of real consumption equals the marginal utility of real income:

$$\frac{\left(C_s^j\right)^{-\sigma}}{\left(C_{s-1}^j\right)^{b(1-\sigma)}} + b\beta E_s\left[\frac{\left(C_{s+1}^j\right)^{1-\sigma}}{\left(C_s^j\right)^{b(1-\sigma)+1}}\right] = \Lambda_s^j. \quad (21)$$

Second, $L_M(\cdot)$ is the household's money demand entering into utility because it enables them to purchase goods. However, given the nominal interest rate I_s, having money in pockets imply an opportunity cost: the "expected" real interest rate of bonds that the household forgo. This optimality condition is:

$$P_s\frac{L_M(\frac{M_s^j}{P_s})}{U_C(C_s^j)} = \frac{I_s}{1+I_s}E_s\left[\frac{P_s}{P_{s+1}}\right], \quad \text{or} \quad P_s\frac{\varepsilon\chi\left(\frac{M_s^j}{P_s}\right)^{\varepsilon-1}}{\left(C_s^j\right)^{-\sigma}} = \frac{I_s}{1+I_s}E_s\left[\frac{P_s}{P_{s+1}}\right]. \quad (22)$$

Third, the supply of working hours in the home economy is,

$$z_s(N_{H,s}^j)^\iota = \Lambda_s^j W_{H,s}. \quad (23)$$

If $N_s^j(i)$ denote hours supplied of the individual j to home representative firm $i \in [0,1]$, then home labor supply to sector H is consistent with a clearing-market nominal wage $W_{H,s}$. It is an index of wages paid to labor varieties (obtained by minimizing the nominal cost of producing a unit of home tradable good). labor supplies are derived from Equation (23) and the total hours worked is:

$$N_s^j = \int_0^1 N_{H,s}^j(i)di. \quad (24)$$

[22]If consumption were specified to be state dependent, $C(S_s, s)$, consumers would equalize the marginal rate of substitution between consumption at $s = \tau$ and present consumption to the appropriate discount factor, $\Psi_{H,s,\tau}(S_\tau)$, i.e., $\beta^{\tau-s}E_s\left[\frac{U_C^j(C_\tau(s_\tau))}{U_C^j(C_s)}\right] = \Psi_{H,s,\tau}(s_\tau)$. Moreover, the budget constraint is binding at any time and for all histories h_s. This result leads to [Ascari, 2004] to suggest that models were the duration of the relevant contracts is state-dependent may characterize more accurately observed data developments. At least for the Belgium economy; however, [Aucremanne & Dhyne, 2005] find that state-dependent contracts seems to be irrelevant for explaining price rigidities. Other studies were reviewed in Chapter ??, see also [Smets & Wouters, 2003].

Fourth, given information up to time s the home optimality conditions respect to B_s^j allow us to price the internationally traded bond (in foreign currency) obtaining at any time for home (likewise for bonds denominated in foreign currency):

$$\frac{1}{P_s} E_s \left[\frac{\Lambda_s^j}{1+I_s} - \beta \Lambda_{s+1}^j \right] = 0, \tag{25}$$

and replacing by the Lagrange multiplier from Equation (21), yield: $\frac{1}{P_s} U_C^j(C_s) = \beta(1+I_s) E_s \left[\frac{1}{P_{s+1}} U_C^j(C_{s+1}) \right]$, or:

$$\frac{\frac{(C_s^j)^{-\sigma}}{(C_{s-1}^j)^{b(1-\sigma)}} + b\beta E_s \left[\frac{(C_{s+1}^j)^{1-\sigma}}{(C_s^j)^{b(1-\sigma)+1}} \right]}{P_s} = \beta(1+I_s) E_s \left[\frac{\frac{(C_{s+1}^j)^{-\sigma}}{(C_s^j)^{b(1-\sigma)}} + b\beta \frac{(C_{s+2}^j)^{1-\sigma}}{(C_{s+1}^j)^{b(1-\sigma)+1}}}{P_{s+1}} \right], \tag{26}$$

from which, it can be derived the non-arbitrage condition across financial markets, at any period s:

$$E_s \left[\frac{P_s}{P_{s+1}} \frac{\frac{(C_{s+1}^j)^{-\sigma}}{(C_s^j)^{b(1-\sigma)}} + b\beta \frac{(C_{s+2}^j)^{1-\sigma}}{(C_{s+1}^j)^{b(1-\sigma)+1}}}{\frac{(C_s^j)^{-\sigma}}{(C_{s-1}^j)^{b(1-\sigma)}} + b\beta \frac{(C_{s+1}^j)^{1-\sigma}}{(C_s^j)^{b(1-\sigma)+1}}} \right] = E_s \left[\frac{P_s^*}{P_{s+1}^*} \frac{\frac{(C_{s+1}^{j^*})^{-\sigma}}{(C_s^{j^*})^{b(1-\sigma)}} + b\beta \frac{(C_{s+2}^{j^*})^{1-\sigma}}{(C_{s+1}^{j^*})^{b(1-\sigma)+1}}}{\frac{(C_s^{j^*})^{-\sigma}}{(C_{s-1}^{j^*})^{b(1-\sigma)}} + b\beta \frac{(C_{s+1}^{j^*})^{1-\sigma}}{(C_s^{j^*})^{b(1-\sigma)+1}}} \right]. \tag{27}$$

Finally, summing across individuals —in terms of home's currency— market clearing condition for the stock of global bonds is.

$$B_s^j + \mathcal{E}_s B_s^{*j^*} = 0, \qquad \text{and} \qquad \frac{B_s^{j^*}}{\mathcal{E}_s} + B_s^{j^*} = 0. \tag{28}$$

Constrained consumers Regarding the share of the households that are financially constrained, $\lambda^r \in (0,1)$, it is important to notice that they consume as much as they get in their disposable income. A representative consumer of this type, j^r, behaves as a rule-of-thumb consumer, i.e., optimizing intratemporally, but he does not so intertemporally. Technically, it means that the lagrangean for the consumer can be broken down for each period, where utility function as Equation (19) is maximized.

An expansionary fiscal policy will shift aggregate demand and output, as disposable income rises rule-of-thumb consumers will consume more, disregarding any future tax liability. If and only if the higher consumption of rule-of-thumb consumers offset the downward shift of optimizers' consumption, then aggregate consumption will go up. As a result, we would be able to replicate with our model the evidence reported in Section 3. In the following section we explore the aggregation.

Following [Coenen & Straub, 2005], [DiBartolomeo & Manzo, 2007], [DiBartolomeo *et al.* , 2007], [Galí *et al.* , 2007b], the binding budget constraint of the representative rule-of-thumb consumer, j^r(we omit it to simplify notation) can be stated as:

$$C_s^r = \frac{(1-\tau_w) W_{H,s} N_{H,s}^r}{P_s} + T_s^r, \tag{29}$$

where, a simple comparison with Equation (17) reveals that these consumers do not save: (i) there are no dividends proceeds; and (ii) they are not able smooth consumption by keeping money or bonds. As in the case of optimizing households, hours $N_{H,s}^r$ are determined by firms' labor demand and are not chosen optimally by each household given the wage $W_{H,s}$(see Section 4.3). Finally, T_s^r are transfers (if $T_s^r < 0$) or taxes paid in a lump-sum fashion (if $T_s^r > 0$).

Aggregation of consumers As we stated in the previous section, the economy embrace both types of consumers: optimizers and rule-of-thumb. The share of the formers in the total consumers is $1-\lambda^r$. Therefore, aggregated consumption, C_s^{aggr}, is obtained as the weighted average of the respective aggregated consumptions:

$$C_s^{aggr} \equiv \lambda^r \int_0^1 (C_s^r)^{j^r} dj^r + (1-\lambda^r) \int_0^1 C_s^j dj. \tag{30}$$

Likewise, for the number of hours worked,

$$N_{H,s}^{aggr} \equiv \lambda^r \int_0^1 \left(N_{H,s}^r\right)^{j^r} dj^r + (1-\lambda^r) \int_0^1 N_{H,s}^j dj. \tag{31}$$

Notice that we assume that each firm decides how much labor to hire (given the wage, see Section 4.3), and allocates its labor demand uniformly across households (the type does not signal any difference in the marginal productivity of labor). As a result, $N_{H,s}^r = N_{H,s}^j$, and Equation (31) reduces to $N_{H,s}^{aggr} = N_{H,s}^r = N_{H,s}^j$.

4.2 Producers and importers

Home tradable goods are produced by a large amount of firms in the home economy. Part of this production is sold at the home market and the remaining abroad as exports, HX. Suppose that there is a continuum of independent (producers) firms indexed in the $(0,1)$ interval, each of them enjoying monopolistic power on varieties produced. In addition, there are a continuum of importers and exporters, each type indexed in the $(0,1)$ interval. We assume that importer firms simply repackage and give a domestic brand to otherwise standardized goods, which they finally sell in the domestic market. Exporters shape their products so that they can be demanded by foreign importers. Importers and exporters enjoy monopolistic power, being able to set prices that maximize their profits.

In the empirical literature, e.g., [Aucremanne & Dhyne, 2005], price movements reveal different degrees of stickiness. In particular, for those varieties that are effectively traded, either exported or imported, one key determinant of the price (besides the marginal cost) is the nominal exchange rate, which easily propagates with imperfect pass-through. Stickiness may the result of multiple causes, however the implied effect is that propagation takes place imperfectly to both real and nominal variables.

We model price stickiness following [Calvo, 1983], who assume that domestic firms adjust their price infrequently and in such an event, they reset prices according to 'price signals', which follow an exogenous *iid.* Poisson process with constant probability. Hence, firms set prices in staggered 'contracts' of random duration. For instance, this probability in the home tradable goods market is $1-\varphi_H^{(i)}$, meaning that firm i would be able to announce a new price with probability $1-\varphi_H^{(i)}$; otherwise, the old price, remains in effect (e.g., instrumented in a contract). Hence, this firm i will not be able to adjust its price on its market with probability $\varphi_H^{(i)}$. This probability is the so-called Calvo price parameter.[23]

[23] So that the average duration of a price contract, i.e. the average duration between two subsequent price adjustments is $\frac{1}{1-\varphi_H^{(i)}}$ periods, since $0 < \varphi_H^{(i)} < 1$. For example, a Calvo price parameter equal to 0.75 implies an average duration of 4 periods.

As $\varphi_H^{(i)} \to 0$, firm j in the final goods sector sets its prices each period, which is the flexible price case.

To analyze the maximization problem of the producer, notice that the law of large numbers can be applied since the number of firms is large, so that we drop the Calvo price parameter's upper index i. If firm i of type $m = \{H,\, XH,\, MF\}$ gets to announce a new contract in period t, at that time it chooses a price to maximize the value of its discounted profit stream over states of nature in which that price holds.[24] Thus, domestic firm i of type m solves:

$$\max_{\{\mathbf{P}_{m,t}(i)\}} E_t \left\{ \sum_{a=0}^{\infty} \mathbf{\Delta}_{t,t+a}(i,j)(\boldsymbol{\varphi}_m)^a \left[[\mathbf{P}_{m,t}(i)]' \, \mathbf{Y}_{m,t+a}(i) - TC_{m,t+a}(i) \left([\mathbf{Y}_{m,t+a}(i)]' \, \boldsymbol{\iota}_m \right) \right] \right\}, \quad (32)$$

subject to relevant demand functions.[25] In Equation (32), the (nominal) discount factor from t to $t+a$, applied by firm i to the stream of future profits, results from (25) for home assets as $\Delta^j_{t,t+a}(i) = \beta^a \frac{E_t[\Lambda^j_{t+a}]}{\Lambda^j_t}$ with β the households' discount factor and $\frac{E_t[\Lambda^j_{t+a}]}{\Lambda^j_t}$ the household j's marginal utility of nominal wealth, $\mathbf{P}_{m,t}(i)$ is the appropriate vector of relevant prices of home produced goods in sector m and $TC_{m,t+a}(i)(\cdot)$ is the (nominal) total cost of production at period $t+a$ of firm i of domestic type m, which is a function of firm i's total output during period t. Moreover, $\boldsymbol{\iota}_m$ is the unity vector consisting of an appropriate number of ones which equals the number of markets and $(\boldsymbol{\varphi}_\mathbf{m})^a$ is the vector of Calvo probabilities for price vector $\mathbf{P}_{m,t}(i)$ remaining unchanged for producer i of domestic type m. Entries of this vector correspond to elements of relevant prices $P_{H,t}(i)$, $P_{XH,t}(i)$ and $P_{MF,t}(i)$ and $\boldsymbol{\varphi}_m \equiv [\varphi_H,\, \varphi_{XH},\, \varphi_{MF}]'$.

Solving Equation (32) subject to relevant demands (as e.g. (33)), we obtain the following optimality condition (see [Plasmans *et al.* , 2007], Subsection 8.1.1 and Appendix I):

$$\breve{\mathbf{P}}_{m,t}(j,i) = \begin{bmatrix} \frac{\theta_h}{(\theta_h - 1)} \frac{E_t \sum_{a=0}^{\infty} (\varphi_H \beta)^a \frac{\Lambda_{t+a}(i)}{\Lambda_t(i)} \left[MC_{H,t+a}(y_{H,t+a}(j))(P_{H,t+a})^{\theta_h} Y_{H,t+a} \right]}{E_t \sum_{a=0}^{\infty} (\varphi_H \beta)^a \frac{\Gamma_{t+a}(i)}{\Gamma_t(i)} \left[Y_{H,t+a}(P_{H,t+a})^{\theta_h} \right]} \\ \\ \frac{\theta_f^*}{\left(\theta_f^* - 1\right)} \frac{E_t \sum_{a=0}^{\infty} (\varphi_{XH} \beta)^a \frac{\Lambda_{t+a}(i)}{\Lambda_t(i)} \left[MC_{XH,t+a}\left(y^*_{H,t+a}(j)\right)\left(P^*_{H,t+a}\right)^{\theta_f^*} Y^*_{H,t+a} \right]}{E_t \sum_{a=0}^{\infty} (\varphi_{XH} \beta)^a \frac{\Lambda_{t+a}(i)}{\Lambda_t(i)} \left[Y^*_{H,t+a}\left(P^*_{H,t+a}\right)^{\theta_f^*} \right]} \\ \\ \frac{\theta_f}{(\theta_f - 1)} \frac{E_t \sum_{a=0}^{\infty} (\varphi_{MF} \beta)^a \frac{\Lambda_{t+a}(i)}{\Lambda_t(i)} \left[MC_{MF,t+a}(y_{F,t+a}(j))(P_{F,t+a})^{\theta_f} Y_{F,t+a} \right]}{E_t \sum_{a=0}^{\infty} (\varphi_{MF} \beta)^a \frac{\Lambda_{t+a}(i)}{\Lambda_t(i)} \left[Y_{F,t+a}(P_{F,t+a})^{\theta_f} \right]} \end{bmatrix}, \quad (34)$$

where firm j's prices $\breve{\mathbf{P}}_{m,t}(j,i)$ of domestic type m are aggregated over consumers as it is done for wages in [Plasmans *et al.* , 2007], Equation (102) in Appendix B.2, resulting in vectors $\breve{\mathbf{P}}_{m,t}(i)$.[26]

Since any domestic price at period t, $P_{m,t}(i)$, is assumed to be a CES aggregator of the predetermined price $\{P_{m,t-1}(i)\}$ and the newly set price $\breve{P}_{m,t}(i)$ according to Calvo in (34), this domestic

[24] Notice that prices quoted by consumption importers are invoiced in the domestic currency and exporters in the foreign currency.

[25] For example, under equilibrium, the domestic aggregate optimal demand of good i, becomes:

$$y_{H,t+a}(i) = \left(\frac{p_{H,t}(i)}{P_{H,t+a}} \right)^{-\theta_h} Y_{H,t+a}, \quad (33)$$

taking equilibrium conditions into account.

[26] Notice that as $\varphi_m \to 0$, the relevant firms reset their prices each period (the flexible price case) and a particular firm j of type m sets its price as a (monopolistic) markup over its marginal cost, i.e. then $\breve{P}_{m,t}(i) \to \frac{\theta_m}{(\theta_m - 1)} MC_{m,t}(i)$ with $MC_{m,t}(j) \equiv MC_{m,t}\left(Y_{m,t}(j)\right)$.

price index for a typical domestic company i of type m can be written as:

$$(P_{m,t}(i))^{1-\theta_n} = \varphi_m (P_{m,t-1}(i))^{1-\theta_n} + (1-\varphi_m)\left(\breve{P}_{m,t}(i)\right)^{1-\theta_n}, \tag{35}$$

where the n-subscript stands for h, f and f^*. It can be shown that three different Phillip curves can be derived if Equation (34) is rewritten in terms of appropriate inflation rates.[27]

4.3 Staggered wage setting

The labor market presents monopolistic competition where firms are wage takers. This implies that the labor suppliers learned that they have special abilities and these can be substituted imperfectly. In this framework, forward-looking agents set nominal wages in staggered wage contracts and then they supply all the working time in a analogous way as it was described for prices in the previous section. More specifically, we assume that the fraction of wages that are kept sticky according to Calvo staggered wage setting behavior is φ_W. Hence, in any period in which household j is able to reset its wage contract, it maximizes the expected discounted sum of agent j's utility flows with respect to wage rates W_t^j, subject to its total supply of labor (specifically, we refer to Equation (80) in Subsection 8.2.2 and Appendix K in [Plasmans *et al.* , 2007]):

$$\breve{W}_t^j = \frac{\varrho_L}{(\varrho_L - 1)} \frac{E_t \sum_{a=0}^{\infty} (\beta\varphi_W)^a \left[(W_{t+a})^{\varrho_L} L_{t+a} \left(L_{t+a}^j\right)^{\iota}\right]}{E_t \sum_{a=0}^{\infty} (\beta\varphi_W)^a \left[(W_{t+a})^{\varrho_L} L_{t+a} (1-\tau_t^w) \Lambda_t^j\right]}, \tag{36}$$

which might be simplified since $\Lambda_t^j = \Lambda_t$ because of complete assets markets and therefore also the labor supply L_{t+a}. As a result all signaled agents set the same wage $\breve{W}_t^j = \breve{W}_t$.

Since any (domestic) wage at period t, W_t, is assumed to be determined by the CES aggregator of the predetermined wage W_{t-1} and the (common) newly set wage of all signaled agents, $\breve{W}_t$. According to the Calvo wage setting, the wage index is:

$$(W_t)^{1-\gamma} = \varphi_W (W_{t-1})^{1-\gamma} + (1-\varphi_W)\left(\breve{W}_t\right)^{1-\gamma}. \tag{37}$$

4.4 Equilibrium conditions

Equilibrium condition for the labor market, given the assumption of no migration, is as follows (similarly for the foreign country):

$$N_s = \int_0^1 N_{H,s}^{aggr}(i)di. \tag{38}$$

Regarding the bonds issued by the government, those denominated in home currency are used to finance public expenditures, while those denominated in foreign currency is the counterpart amount of the accumulated previous net trade balances, $\sum_{k=0}^{s} NX_{s-k}$, where NX_s is defined as exports minus imports at period s.

We can state the bond equilibrium condition as follows:

$$B_{g,s} = (1-\lambda^r)\left(\int_0^1 B_s^j dj + \mathcal{E}_s \int_0^1 B_s^{*j^*} dj^*\right). \tag{39}$$

[27] By exploiting the recursive form of the infinite summations and log-linearizing w.r.t. the steady state values.

Resource constraints for home and foreign economy are:

$$Y_{H,s} = \varphi \left[\frac{P_{H,s}}{P_s} \right]^{-\eta_c} \left(C_s^{aggr} + G_s \right) + (1 - \varphi) \left[\frac{P_{H,s}}{\mathcal{E}_s P_s^*} \right]^{-\eta_c} \left(C_s^{aggr*} + G_s^* \right), \tag{40}$$

$$Y_{F,s} = \varphi \left[\frac{P_{F,s}^*}{P_s^*} \right]^{-\eta_c} \left(C_s^{aggr*} + G_s^* \right) + (1 - \varphi) \left[\frac{\mathcal{E}_s P_{F,s}^*}{P_s} \right]^{-\eta_c} \left(C_s^{aggr} + G_s \right). \tag{41}$$

5 Fiscal and Monetary policy

So far the model is a simplified version of [Plasmans *et al.* , 2007] extended with the two types of consumers and with active fiscal policy. In this section, we comment on the assumed fiscal and monetary policies followed by the home country. Similarly, the foreign economy is subject to same restrictions and rules.

5.1 Fiscal policy

In this section, we present a simplified structure of the government of the home economy. The government levies taxes from dividends, τ_D, and from the wage bill, τ_w.However, it is not bounded by genuine resources: it can issue bonds and sell them to the agents and provide money for transactions. In any period s, the outstanding bonds stock or/and money increase (decrease) if expenditures are higher than tax proceeds. Expenditures of the government are explained by purchases of goods, which are sold by firms. The government, faces the following nominal budged constraint, GBC henceforth:

$$\begin{aligned} \tau_t^w \left[\int_0^1 W_{H,s}^j N_{H,s}^j dj \right] + \int_0^1 \left(M_s^j - M_{s-1}^j \right) dj + \frac{1}{(1+I_s)} \left(\int_0^1 B_{s+1}^j dj - \int_0^1 B_s^j dj \right) \\ + \frac{1}{(1+I_s)} \left(\int_0^1 B_{s+1}^{j*} dj - \int_0^1 B_s^{j*} dj \right) \geq \int_0^1 T_s^j dj + P_{H,s} G_s. \end{aligned} \tag{42}$$

Equation (42) includes on the left hand side labor revenues, money creation and net domestic and foreign borrowing, while on the right hand side outlays of government revenues (transfers and goods purchases) are considered. In particular, we assume that the government do not disfavor any type of consumers, so we assume the transfers are the same, $T_s^j = (T_s^r)^{j^r} \Rightarrow T_s = T_s^r$ (by aggregation, see Equation (30)).

Abstracting from different government levels, we assume that transfers (taxes is negative) are set according to the following tax rule:

$$T_s = \left(\frac{\int_0^1 B_s^j dj}{P_s} \right)^{\phi_1} \left(\frac{P_{H,s} G_s}{P_s} \right)^{\phi_2} (Y_{H,s})^{\phi_3}, \tag{43}$$

where, taxes react to outstanding domestic public debt, real domestic public expenditure and (possibly) also to domestic output volumes when $\phi_3 \neq 0$. Stability cannot be taken from granted, because Equation (43) interacts with the GBC, therefore we must assume $\phi_2 > 0$ to rule out an explosive path of GBC. Intuitively, the larger ϕ_1, the faster the government debt returns to its steady state value. Moreover, the ϕ_2 parameter indicates how the government consumption is initially financed. It is worth considering boundary values of ϕ_1, meaning that the budgetary expansion is fully financed with: (a) taxes if $\phi_2 = 1$ or (b) deficit spending if $\phi_2 = 0$.

As regards the public expenditure, the stream $g_s \equiv \left(\frac{G_s - G^{ss}}{Y^{ss}}\right)$, i.e., the deviations of expenditure from its steady state, which is normalized by the steady state GDP), evolves exogenously according to the following AR(1) process:

$$g_s = \rho_g g_{s-1} + \xi_{g,s}, \tag{44}$$

where $0 < \rho_g < 1$ and $\xi_{g,s}$ represents an *iid.* shock with constant variance $\sigma^2_{\xi_g}$. [28]

5.2 Monetary policy

Designing monetary policy rules concerns the choice of (a) the monetary policy instruments, (b) the variables to be targeted and (c) their targeted values. In theory, a Central Bank (CB) can define different monetary policy instruments to be targeted as, e.g., (i) interest rate targeting, (ii) exchange rate targeting and (iii) money supply targeting. In the literature, variables that are often targeted are: (1) real output (gap), (2) (changes in) prices, (3) (changes in) exchange rates, (4) (changes in) interest rates, (5) a combination of real output and prices in the form of nominal GDP.

[Kydland & Prescott, 1977] claim that monetary policy effectiveness depends, not only on policy actions undertaken, but also on the public perception about these actions and its expectations about future actions. Consequently, policy is more effective when future actions are predictable, so that a monetary authority can commit itself to a certain course of policies. As [Atoian *et al.* , 2004] argue, commitment permits the CB to distribute 'policy medicine' over time. For example, when the CB wishes to offset inflation that will result from a supply shock, under commitment, it can raise interest rates moderately provided that it maintains higher rates for a period of time. In contrast, in the case of lack of commitment, a higher initial rate increase will be necessary because of the public doubts that the CB will sustain this interest rate increase.

[Atoian *et al.* , 2004] also argue that optimal commitment does not need to take the form of a reaction function with fixed coefficients. In general, an optimal commitment rule has the form of a state-contingent plan that presents the instrument setting as a function of the history of exogenous shocks. However, optimal commitment is not practical because, first, as noted by [Woodford, 2003], it is not feasible to provide an advance listing of all relevant contingencies and, second, it is difficult for the public to distinguish between discretion and a complicated contingency rule. Both problems are avoided when the CB commits to a rule with fixed coefficients.

Which form should such a rule with fixed coefficients take? Since most CBs use a short-term interest rate as their control variable, we are focusing on rules that relate this short-term interest rate to economic conditions. The most famous and widely used examples of simple (short-term) interest rate rules are those proposed by John Taylor. The **standard Taylor rule** (see [Taylor, 1993b]), which relates the interest rate target to inflation and output (gap) in a log-linearized form, is:

$$r_{t,t+1} = \lambda_0 + \lambda_1 \pi_t^{(4)} + \lambda_2 y_t + \varepsilon_{rt}, \tag{45}$$

where $\pi_t^{(4)} \equiv \sum_{j=0}^{3} \pi_{t-j}$ and y_t are annualized domestic inflation and (logarithmic) deviations of domestic output w.r.t. their respective steady state values, which are assumed to be the target variables of the home monetary authority. [Taylor, 1993a] assigns coefficient values consistent

[28] Alternatively, an endogenous expenditure rule could be considered, for instance, one that includes cyclical GDP in Equation (44) .

with an accurate description of Federal Reserve policy for quarterly data and domestic annualized inflation: $\lambda_1 = 1.5$ and $\lambda_2 = 0.5$. The intuition for the value of the former reaction parameter is that the CB must raise the interest rate by more than any increase in inflation in order to raise the real rate of interest, cool the economy and move inflation back toward its target. This refers to the so-called "lean against the wind" policy advocated by Taylor.

Moreover, [Taylor, 1999] suggests an alternative that allows for interest-rate smoothing, which may be added to (45):

$$r_{t,t+1} = (1 - \lambda_3)\, r^d_{t,t+1} + \lambda_3 r_{t-1,t} + \varepsilon^I_{rt}, \tag{46}$$

where we assume that the smoothing procedure follows an $AR(1)$ process with smoothing parameter λ_3 and $r^d_{t,t+1}$ stands for the CB's desired interest rate that comes from the standard rule (45).[29]

[McCallum, 1997] argues that the policymakers' reaction is more accurate if it is based on lagged and not on current values of output and inflation. In response, [Taylor, 1999] suggests an alternative form of his rules where lagged values of output and inflation replace the current values in (45). In contrast, [Clarida *et al.* , 2000], *inter allia*, argue that rules in which the CB reacts to forward-looking variables are optimal in the case of a quadratic objective function of the monetary authorities, which will also be utilized in this paper. The difference between backward-looking, contemporaneous and forward-looking monetary rules relates primarily to the information set of the monetary policymakers. For instance, in the case of a contemporaneous rule, the current inflation rate, on which the CB is assumed to have adequate information, is targeted.

An interesting alternative to the rules above, is one that chooses policy reaction values which minimize the present value of the CB's loss function (a weighted linear combination of variances of the targeted variables and the instrument). This interesting exercise is done in [Plasmans *et al.* , 2007], however, it is beyond the scope of this paper.

5.3 Shocks driving the economy

We consider several shocks, all of them characterized as exogenous processes. They have similar structure as Equation (44) and their introduction in the model is motivated because they are useful to drive the set of endogenous variables of the economy. We take into account the following shocks:

1. productivity shocks, ε_{ys}, which can interpreted as an expansion of the (efficient) production function;
2. monetary policy shock, ε^I_{rs}, which can be interpreted as a unexpected increase in the demand of money by the public;
3. willingness to work shock, z_s, which affects the Euler condition through disincentives to additional working hours;
4. expansionary budgetary policy shock, $\xi_{g,s}$, which spreads over to the whole economy, shifting demand of rule-of-thumb consumers.

These shocks are considered as unexpected by the agents. Moreover, in general, they have AR(1) structure that facilitates the modeling of the degree of persistency (it could be an interesting

[29] We calibrated $\lambda_3 = 0.75$ throughout all exercises. This assumption allows us to interpret that the CB's interest rate that actually prevails now will have no-effect in the 4-quarters ahead interest rate.

exercise to estimate this persistency). For example, whilst a permanent shock is consistent with a ρ-parameter equal to one, a purely temporary shock is with $\rho = 0$.

Formally, exogenous processes are gathered in the vector $\boldsymbol{\xi}_t$, that follows the following AR structure:

$$\boldsymbol{\xi}_s = \boldsymbol{\rho}\boldsymbol{\xi}_{s-1} + \mathbf{v}_s, \tag{47}$$

where $\mathbf{v}_s$ are innovations, i.e., *iid* with mean zero vector and diagonal variance-covariance matrix $\boldsymbol{\Sigma}_{\mathbf{v}}$. Formally,where $\boldsymbol{\xi}_s \equiv (\varepsilon_{ys},\ \varepsilon^{I}_{rs},\ z_s,\ \xi_{g,s})'$, $\boldsymbol{\rho} \equiv \mathbf{diag}(\rho_A, \rho_{\varepsilon^I_r}, \rho_z, \rho_g)$, and $\mathbf{v}_s \equiv (v_{\varepsilon_y}, v_{\varepsilon^I_r}, v_z, v_g)$. Likewise, the foreign economy has symmetric exogenous processes.

6 Calibration and simulation methodology

A rational expectations (RE) equilibrium is then a set of processes of the endogenous variables that satisfy both first order conditions (from corresponding optimal problems) and equilibrium conditions at all dates $s \geq 0$ given the exogenous processes included in the vector $\boldsymbol{\xi}_{t+s}$.

The non linear DSGE model containing both economies, can be specified as an implicit multivariate function as the most compact manner:

$$E_s\left[F_\theta(\mathbf{y}_{s+1}, \mathbf{y}_s, \mathbf{y}_{s-1}, \mathbf{v}_s)\right] = \mathbf{0}, \tag{48}$$

where $\mathbf{y}_s \in \Lambda \subseteq \mathbb{R}^n$ is the set of endogenous variables, while $\mathbf{v}_s$ are structural innovations defined above. The function $F_\theta : \Lambda^3 \times \mathbb{R}^8 \longrightarrow \Lambda$ is real in $\mathbb{C}^2$ parameterized by the real vector $\boldsymbol{\theta} \in \boldsymbol{\Theta} \subseteq \mathbb{R}^p$ where p is the dimension of the parameter space that include deep parameters.

Assuming the existence of a non linear stochastic difference equation (unique, stable and invariant) of the form:

$$\mathbf{y}_s = \mathbf{H}_\theta(\mathbf{y}_{s-1}, \mathbf{v}_s), \tag{49}$$

that solves (48) where $\mathbf{H}_\theta$ is a collection of policy and transition functions. Repeated substitution of Equation (49) into (48) provides a system where $\mathbf{y}$ and $\mathbf{v}$ are included in the information set at time s. Given that we know the exact form (our hypothesized model) of F_θ, our unknown is $\mathbf{H}_\theta$.

The model (48) has a solution at a fixed point that is known as the deterministic ($E_s[\mathbf{v}_s] = \mathbf{0}$) steady state. Formally,

$$F_\theta(\mathbf{y}^*(\boldsymbol{\theta}), \mathbf{y}^*(\boldsymbol{\theta}), \mathbf{y}^*(\boldsymbol{\theta}), \mathbf{0}) = \mathbf{0}, \tag{50}$$

where $\mathbf{y}^*(\boldsymbol{\theta}) = \mathbf{H}_\theta(\mathbf{y}^*(\boldsymbol{\theta}), \mathbf{0})$. The steady state is a crucial element to solve our model given the fact that we use local approximation methods. That means that Jacobians and Hessians, etc. that arise because of the Taylor expansion of (48) are evaluated at $\mathbf{y}^*(\boldsymbol{\theta})$.

The model is log-linearized around the steady state (first order approximation, i.e., $\hat{\mathbf{y}}_s \equiv \mathbf{y}_s - \mathbf{y}^*(\boldsymbol{\theta})$) and reshuffled in a linear state space system as suggested by [Sims, 2002] using a guess policy function:

$$\mathbf{B}_1\hat{\mathbf{y}}_s + \mathbf{B}_2\hat{\mathbf{y}}_{s-1} + \mathbf{C}\mathbf{v}_s + \mathbf{D}\boldsymbol{\eta}_s = \mathbf{0}, \tag{51}$$

since we solve (51) with his rational expectation algorithm. It is primarily based on the systematic perturbation of the policy function around the steady state. Note that $\boldsymbol{\eta}_s$ contains expectational errors (so that we drop the expectation operator).

Second, Equation (51) is rewritten after applying the QZ factorization as:[30]

[30] Matrices $\mathbf{Q}'$ and $\mathbf{Z}'$ are unitary matrices (with $\mathbb{R}$ or $\mathbb{C}$ numbers), while $\boldsymbol{\Omega}$ and $\boldsymbol{\Lambda}$ are upper triangular.

$$\mathbf{Q}'\mathbf{\Lambda}\mathbf{Z}'\hat{\mathbf{y}}_s + \mathbf{Q}'\mathbf{\Omega}\mathbf{Z}'\hat{\mathbf{y}}_{s-1} + \mathbf{C}\mathbf{v}_s + \mathbf{D}\boldsymbol{\eta}_s = \mathbf{0}.$$

Third, generalized eigenvalues of $\mathbf{B}_1$ and $\mathbf{B}_2$ are reorganized in $\mathbf{\Lambda}$ and $\mathbf{\Omega}$ in increasing order from the left to the right ($\mathbf{Q}'$ and $\mathbf{Z}'$ are reorganized accordingly). Redefining transformed variables as $\check{\mathbf{y}}_s \equiv \mathbf{Z}'\hat{\mathbf{y}}_s$ and premultiplying the system by $\mathbf{Q}$ results in the following upper triangular system:

$$\mathbf{\Lambda}\check{\mathbf{y}}_s + \mathbf{\Omega}\check{\mathbf{y}}_{s-1} + \mathbf{QC}\mathbf{v}_s + \mathbf{QD}\boldsymbol{\eta}_s = \mathbf{0},$$

where $\check{\mathbf{y}}_s \equiv (\check{\mathbf{y}}_{1s}, \check{\mathbf{y}}_{2s})'$(similarly for other matrices), with the block $\mathbf{\Lambda}_{12}$ has been zeroed out (corresponding to forward-looking variables $\check{\mathbf{y}}_{2s}$). We refer to [Sims, 2002] for the details in solving the following step, the fourth, where $\check{\mathbf{y}}_{2s}$ is solved iterating forwardly, and then (once $\check{\mathbf{y}}_{2s}$ is known) $\check{\mathbf{y}}_{1s}$ is solved iterating backwardly. The critical issue arises in solving $\check{\mathbf{y}}_{1s}$ because it involves expectational errors $\mathbf{QD}\boldsymbol{\eta}_s$ and exogenous shocks errors $\mathbf{QC}\mathbf{v}_s$. Uniqueness of the solution requires the following necessary and sufficient condition: $\mathbf{Q}_1\mathbf{D} = \Phi\mathbf{Q}_2\mathbf{D}$, which if satisfied means that expectational errors that work as loading factors are neutralized, yielding the following solution:

$$\hat{\mathbf{y}}_s = \Xi_0\hat{\mathbf{y}}_{s-1} + \Xi_1\mathbf{v}_s, \tag{52}$$

where $\Xi_0 \equiv \mathbf{Z}\mathbf{\Lambda}_{11}^{-1}\left[\mathbf{\Omega}_{11}(\mathbf{\Omega}_{12} - \Phi\mathbf{\Omega}_{22})\right]\mathbf{Z}'$ and $\Xi_1 \equiv \begin{bmatrix} \mathbf{\Lambda}_{11}^{-1} & -\mathbf{\Lambda}_{11}^{-1}(\mathbf{\Lambda}_{12} - \Phi\mathbf{\Lambda}_{22}) \\ \mathbf{0} & \mathbf{I} \end{bmatrix} \begin{bmatrix} (\mathbf{Q}_1 - \Phi\mathbf{Q}_2)\,\mathbf{C} \\ \mathbf{0} \end{bmatrix}$.

Note that Equation (52) is nothing more than a SVAR, which allow us to calculate IRFs as well as variance decompositions for $\mathbf{v}_s$ are *conditional* on the proposed calibration. The model is solved with the set of routines called Dynare, see [Juillard, 2005a].

Why the IRFs are so important for policymaking? They reveal to policymakers the propagation mechanism (also the channel of transmission) working after the occurrence of a shock. Likewise, variance decompositions deliver the relative impact in aggregates variability. With our parameterized model, policy makers can figure out how interventions in different regimes (scenarios) will affect expected paths of sensible variables within an arbitrary probability confidence interval. This is valuable information for Euro area and the U.S. policy makers.

We will replicate the result of the positive multiplier of consumption for expansionary fiscal policy illustrated in Table 1. Moreover, we explore the ranges of λ^r (and the presence of a threshold) that yields model solutions displaying negative dynamic multipliers of aggregate private consumption.

Bearing in mind that the parameterization is very important in the numerical simulation experiment, we first describe those parameters chosen before analyzing the effects of shocks 1, 2 and 4, mentioned in the previous section.

6.1 Calibration

The simulation exercise is conditional on the calibration assumed. In particular, we take as usual in the literature a quarter as the unit of time in which decisions are made. Beginning with share of rule-of-thumb consumers we assume that $\lambda^r = \lambda^{r*} = 0.6$ a value that seems reasonable in light of the evidence suggested by [Mankiw, 2000] (afterwards we assume that all parameters are symmetric across countries). Regarding parameters that affect the utility function, Equation (19), we set the elasticity of wages with respect to hours, ι, equal to 1/3. Although, the suggested value for the U.S. is 0.20 ([Rotemberg & Woodford, 1998], [Galí *et al.* , 2007b]) we consider a higher value to maintain symmetry and because it is expected higher value for the euro area. Moreover, the risk aversion parameter σ, is assumed equal to 1.5 as is fairly standard in the literature. The habit persistence parameter, b, is assumed equal to 0.5, e.g. higher values (0.7) is assumed in [Smets & Wouters, 2007]. The elasticity of money demand, χ, is assumed to be equal to 2/3. The willingness to postpone consumption or the discount factor, β, is set to 0.99 in accordance with a long run (annual) nominal interest rate of 4%. The returns-to-scale parameter of the production function, ψ_H, is set to 0.98. As the price and wage observed stickiness depend on the Calvo parameter (see Sections 4.2 and 4.3), we assume that on average all wages and prices are reviewed once a year, so $\varphi_H = \varphi_{XH} = \varphi_{MF} = \varphi_W = 0.75$. Regarding the elasticity of substitution of home and foreign goods we assume $\eta_c = 1.8$; and the degree of home bias is assumed to be $\varphi = 0.5$. For the AR(1) processes we assume the following persistence parameters: (i) productivity, ρ_A, equal to 0.95; and (ii) the government spending, ρ_g, equal to 0.85.

Monetary policy rules are assumed to be based on the Taylor principle. Therefore, the reaction parameter to inflation, λ_1, is set equal to 1.5, with no inertia, i.e., $\lambda_0 = 0$, the corresponding reaction parameter to output gap, λ_2, is set equal to 0.5. The smoothing parameter, λ_3, is assumed 0.8, consistent with a monetary policy that has full effect after 5 quarters.

As regards as the fiscal rule parameters, we set $\phi_1 = 0.1$, $\phi_2 = 0.1$ and $\phi_3 = 0.05$. The assumed value for ϕ_2 implies that only 10% of the expansionary shock is financed with taxes.

Finally, a log-linearized form of Equation (29), needs the following steady-state parameters: $\frac{(WN^r)^{ss}}{C^{ss}} = \frac{Y^{ss}}{C^{ss}} = \frac{1}{0.77}$, which are calibrated considering data from the euro area.

6.2 Numerical simulations

6.2.1 Productivity shock

The simulation of an unexpected shock in productivity of one standard deviation (SD) will raise consumption of fully rational consumers, while decreasing consumption of rule-of-thumb consumers, see Figure 1. Given that the latter goes down more deeply, it leads to a negative response of aggregated consumption. While for the same reasons (mirrored) aggregated consumption in the foreign economy is boosted. Consumption of foreign rule-of-thumb consumers goes up because they are able to consumer more with their salaries (especially imports from home that are substantially cheaper). Notice that this expenditure switching effect is so strong because of in the economy all goods are fully tradable, while the labor force is locked in the corresponding country. For an analysis of the adjustment process in the presence of non-tradable goods, see [Plasmans *et al.* , 2007].

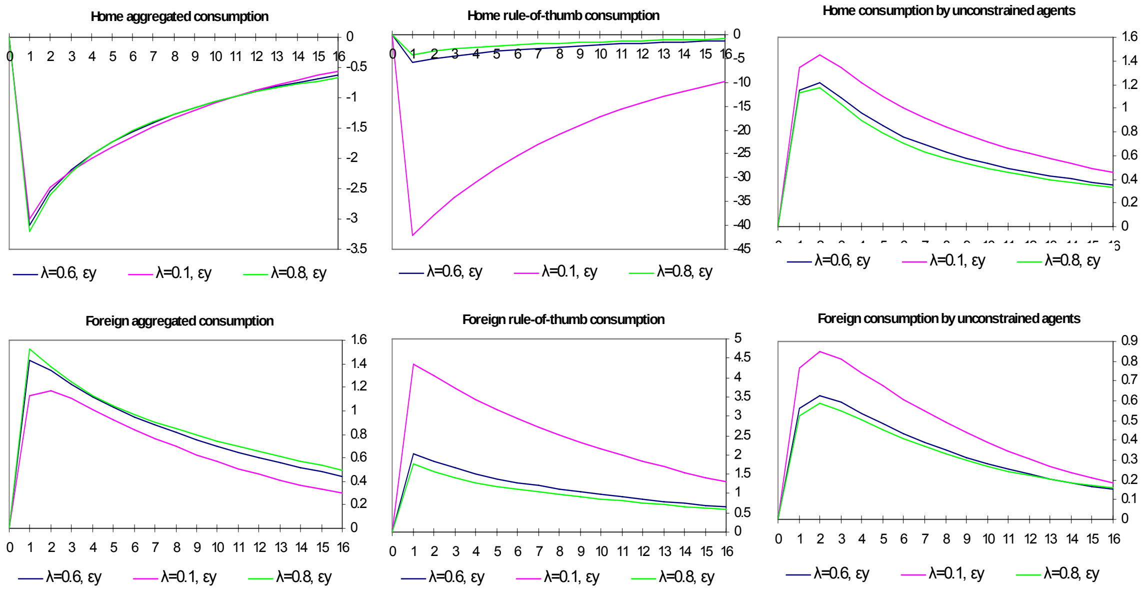

Figure 1: Productivity inprovement shock (simple Taylor rule)

6.2.2 Money demand shock

In Figure 2 we report a negative and purely temporary shock in the demand of money and its effects on consumption (resulting from an exogenous shift to the left of the money demand). The immediate effect occurs in the money market as the nominal rate of interest goes down (in the first round the central bank does not react). As a result, consumption goes temporarily up no matter consumers' types because it becomes more attractive to postpone saving and to consume more at the present time. Given the tradability of the goods, foreign financially unconstrained consumers foresee a temporary opportunity to consume more because of the expansionary effect of the foreign output resulting from higher exports to the home country. However, foreign rule-of-thumb consumers react consuming less on impact because of the drop in the disposable income due to higher foreign taxes to cover the issuance of bonds to cover the trade deficit.

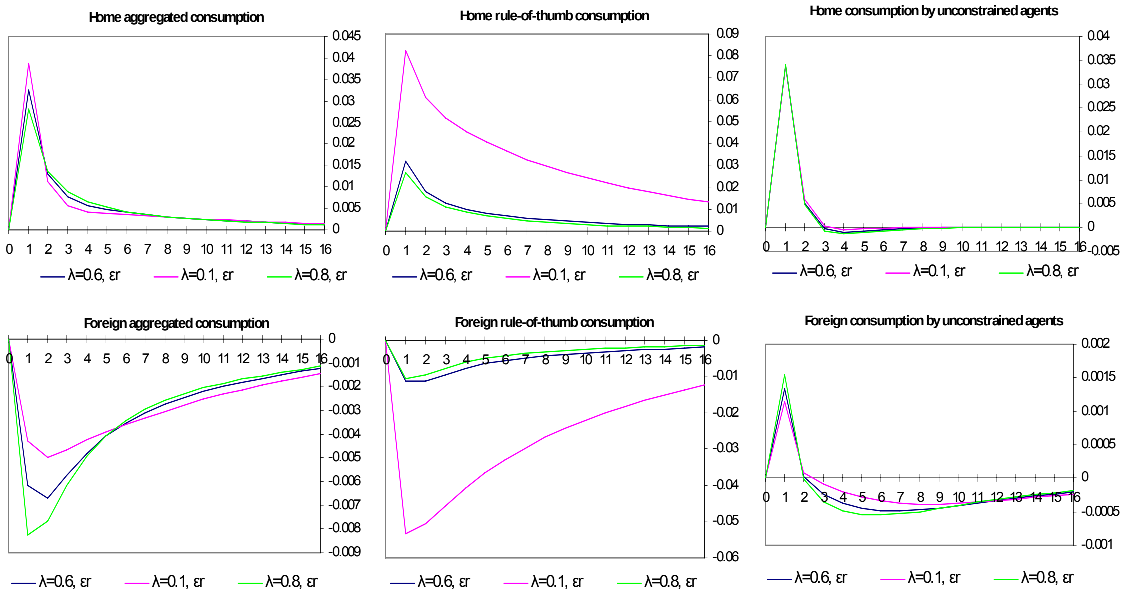

Figure 2: Temporary negative Monetary shock (simple Taylor rule)

6.2.3 Public expenditure shock

In our opinion, the most interesting case to analyze concerns expansionary fiscal policy in the home country which is illustrated by IRFs of Figures 3 and 4. Despite these figures look like similar, the IRFs displayed are slightly different since they resulted from monetary Taylor rules (45) and (46). Conditional on the calibration we proposed, in Figure 3 we observe that a positive impact on consumption occurs as a result of expansionary policy. This result last a few quarters (approximately two quarters or more for $\lambda^r > 0.6$) becoming negative afterwards. This behavior is the result of the relatively large weight of rule-of-thumb consumers in the economy that overturn the negative adjustment of consumption (according the REP) in response of future liabilities of the government. Such an example shows that it is likely that the argument of [Mankiw, 2000] us truly applicable and, therefore, worth considering it. For parameterization where $\lambda^r < 0.45$ the response of aggregate consumption in the home economy remains negative within four years. On the other hand, large values of λ^r lead to model indeterminacy ([Blanchard & Kahn, 1980] conditions do not hold). Therefore, the critical question that arises is which estimate of λ^r is supported by the data of the U.S. and of the euro area?

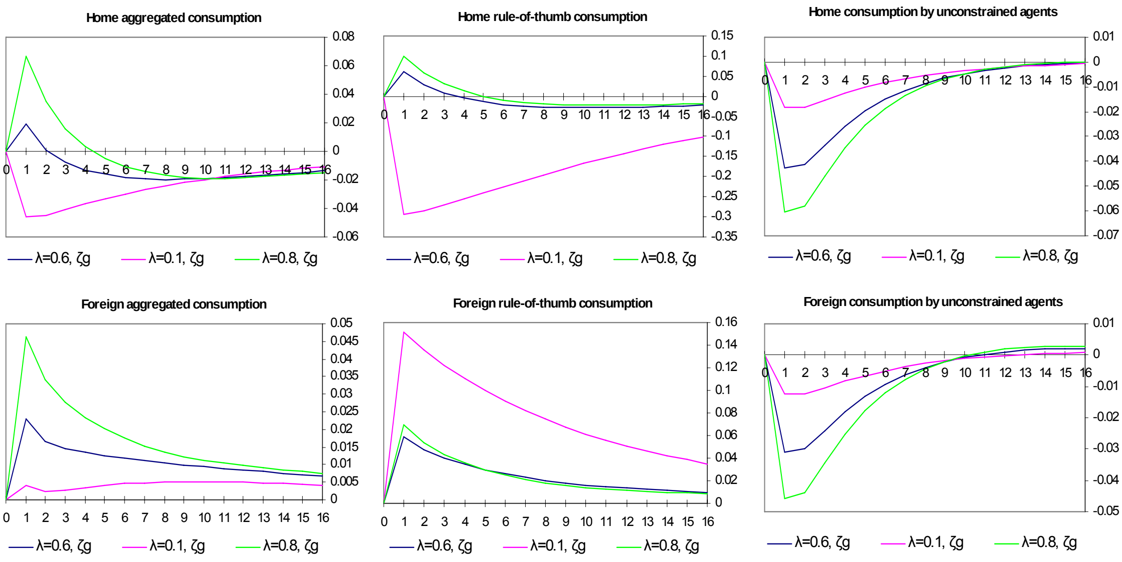

Figure 3: Government spending shock in the home country (simple Taylor rule)

Figure 4 does not provide us with surprising results, as we might expect, because at increasing values of λ^r the link between aggregate demand and consumption looses, thereby changes of monetary policy do not show up. Indeed, it is the case that adding smoothing to the Taylor rule as in (46), would make little difference in the (marginal reduction of) consumption fluctuations.

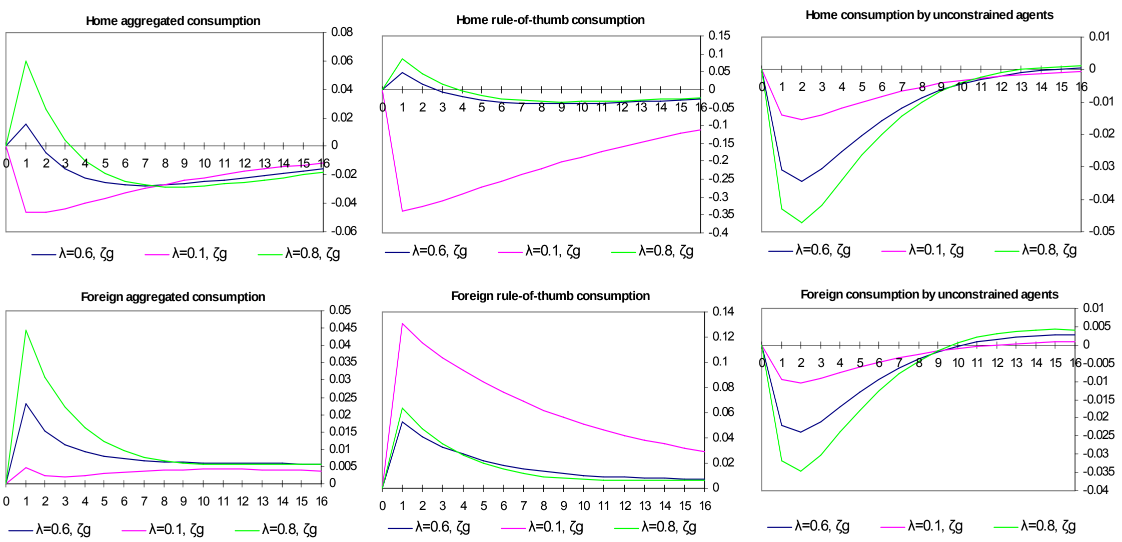

Figure 4: Government spending shock in the home country (Taylor rule with smoothing)

7 Estimation

In this section, we describe the data considered for the construction of observable variables. Besides, in next subsection, we estimate the deep parameters of the model using Bayesian techniques. All computations are performed with the DYNARE set of routines, [Juillard, 2005b].

7.1 Data

We estimate our model for the EU-12 and for the U.S. economies. According to very recent figures, it is quite reasonable to consider these economies as symmetric in terms of GDP and openness.

For the Euro area data, we considered relevant aggregates for EU-12, which are publicly available from Eurostat on a quarterly basis. To obtain a dataset with homegeneous frequency we interpolated series of military expenses because they are available on an annual frequency from the SIPRI database. In particular, the interpolation method used is the one suggested by [Chow & Lin, 1971]. As a result, our sample runs from 1991Q1 to 2006Q4.

All series are corrected from seasonality, deflated by the corresponding CPI index and translated into per capita terms dividing by total population in the working age (16 to 65 years old) from OECD statistical compendium. Finally, all series are taken in terms of deviations from their respective trends, as obtained by applying the Hodrick-Prescott filter with smoothing parameter λ equal to 1600.

Variables used for estimation are per capita private consumption, per capita government expenditure and per capita GDP. Per capita government expenditure net of military expenditure gave similar estimation results. For a detailed description of these variables, their construction, units, etc. refer to Table A.1 in the Data appendix.

As for the U.S. economy, relevant data series were selected trying to match similar aggregated series available for the Euro area. Further details are summarized in Table A.2. in the Data appendix.

7.2 Data into the DSGE model and the likelihood function

Given the solution of the model from Equation (52) a direct estimation approach would maximize its likelihood function with respect to θ and $vech(\mathbf{\Sigma}_v)$; however, we must acknowledge that not all variables included into $\hat{\mathbf{y}}_s$ are observed. To include data, a partition of the vector $\hat{\mathbf{y}}_s$ into observed and unobserved variables is needed, so that $\hat{\mathbf{y}}_s \equiv (\hat{\mathbf{y}}_s^o, \hat{\mathbf{y}}_s^{uno})'$. In our model, $\hat{\mathbf{y}}_s^{o\prime}$ is 6×1 Then, a state-space representation is derived from (52) which includes a measurement equation:

$$\begin{aligned} \hat{\mathbf{y}}_s &= \Xi_0 \hat{\mathbf{y}}_{s-1} + \Xi_1 \mathbf{v}_s, \\ \hat{\mathbf{y}}_s^o &= \Upsilon \hat{\mathbf{y}}_s + \boldsymbol{\epsilon}_s, \end{aligned} \tag{53}$$

where Υ is a $6 \times n$ binary matrix that selects the observed variables from $\hat{\mathbf{y}}_s$, $\boldsymbol{\epsilon}_s$ is a measurement error that is assumed to be *iid* with mean zero vector and variance $\mathbf{\Sigma}_\epsilon$. More explicitly, our specific measurement equation is:

$$\begin{pmatrix} Y^o_{H,s} \\ C^{aggr,o}_s \\ G^o_s \\ Y^o_{F,s} \\ C^{aggr*,o}_s \\ G^o_s \end{pmatrix} = \begin{bmatrix} ... & 1 & 0 & 0 & 0 & 0 & 0 & ... \\ ... & 0 & 1 & 0 & 0 & 0 & 0 & ... \\ ... & 0 & 0 & 1 & 0 & 0 & 0 & ... \\ ... & 0 & 0 & 0 & 1 & 0 & 0 & ... \\ ... & 0 & 0 & 0 & 0 & 1 & 0 & ... \\ ... & 0 & 0 & 0 & 0 & 0 & 1 & ... \end{bmatrix}_{(6\times n)} \begin{pmatrix} \vdots \\ Y^{uno}_{H,s} \\ C^{aggr,uno}_s \\ G^{uno}_s \\ Y^{uno}_{F,s} \\ C^{aggr*,uno}_s \\ G^{uno}_s \\ \vdots \end{pmatrix}_{n\times 1} + \underset{6\times 1}{\boldsymbol{\epsilon}_s}, \qquad (54)$$

where the first entry of $\hat{\mathbf{y}}^o_s$ in (54) correspond to the LHS of the GDP identity, or domestic resource constraint, Equation (40); while the second an third entries link observed (aggregate) home tradable consumption and observed government expenditures to RHS of (40). Symmetrically, 4th to 6th entries of $\hat{\mathbf{y}}^o_s$ correspond the variables included in the foreign resource constraint (41).

Denoting the sample as $\hat{Y}^o_T \equiv \{\hat{\mathbf{y}}^o_1, \hat{\mathbf{y}}^o_2, \hat{\mathbf{y}}^o_3, ..., \hat{\mathbf{y}}^o_T\}$, the density of $\hat{Y}^o_T$ conditional on the parameters (likelihood) can be written as:

$$\begin{aligned} \mathcal{L}(\theta, vech(\mathbf{\Sigma}_v), vech(\mathbf{\Sigma}_\epsilon); \hat{Y}^o_T) &= p(\hat{Y}^o_T \mid \theta, vech(\mathbf{\Sigma}_v), vech(\mathbf{\Sigma}_\epsilon)), \\ &= p(\hat{\mathbf{y}}^o_0 \mid \theta, vech(\mathbf{\Sigma}_v), vech(\mathbf{\Sigma}_\epsilon)) \\ &\quad \times \prod_{s=1}^{T} p(\hat{\mathbf{y}}^o_s \mid Y^o_{s-1}, \theta, vech(\mathbf{\Sigma}_v), vech(\mathbf{\Sigma}_\epsilon)), \qquad (55) \end{aligned}$$

which includes a marginal density (involving the distribution of the initial condition) $p(\hat{\mathbf{y}}^o_0 \mid \theta, vech(\mathbf{\Sigma}_v), vech(\mathbf{\Sigma}_\epsilon))$ and a conditional density. Given our linearized model (53) and our definition of $\boldsymbol{\epsilon}_s$, it follows that $\hat{\mathbf{y}}^o_0 \sim \mathbf{N}(E_\infty[\hat{\mathbf{y}}^o_s], V_\infty[\hat{\mathbf{y}}^o_s])$.[31] Concerning the second factor, the conditional density involves the evaluation of $\hat{\mathbf{y}}^o_s \mid Y^o_{s-1}$ which is not directly observable since $\hat{\mathbf{y}}^o_s$ depends on other unobserved endogenous variables given by the model; however, it is at hand the following identity:

$$p(\hat{\mathbf{y}}^o_s \mid Y^o_{s-1}, \theta, vech(\mathbf{\Sigma}_v), vech(\mathbf{\Sigma}_\epsilon)) \equiv \int_\Lambda p(\hat{\mathbf{y}}^o_s \mid \hat{\mathbf{y}}_s, \theta, vech(\mathbf{\Sigma}_v), vech(\mathbf{\Sigma}_\epsilon)) p(\hat{\mathbf{y}}_s \mid Y^o_{s-1}, \theta, vech(\mathbf{\Sigma}_v), vech(\mathbf{\Sigma}_\epsilon)) d\hat{\mathbf{y}}_s,$$

where the density of $\hat{\mathbf{y}}^o_s \mid Y^o_{s-1}$ depends on the mean of the density of $\hat{\mathbf{y}}^o_s \mid \hat{\mathbf{y}}_s$ where the relevant weight is the density of $\hat{\mathbf{y}}_s \mid Y^o_{s-1}$. The former density is directly given by the measurement Equation (53), while $\hat{\mathbf{y}}_s \mid Y^o_{s-1}$ is computed by the Kalman filter.

7.3 Bayesian estimation: the likelihood meets prior densities

Bayesian estimation and evaluation techniques have been particularly successful in estimation of not only small DSGE models but also medium to large-scale New Keynesian models. The estimation procedure combines a likelihood function (55) derived from our model with the specification of a prior distribution for $\boldsymbol{\theta} \equiv (\boldsymbol{\theta}, vech(\mathbf{\Sigma}_v), vech(\mathbf{\Sigma}_\epsilon))'$. As a result, the state-space representation can be translated to form the posterior distribution.

[31] Construction of the likelihood for an AR(1) and AR(p) processes are derived in [Hamilton, 1994] Ch.5, Sections 2 and 3, respectively. In case $\hat{y}^o_0$ contains variables with unit roots, the initialization assumes an infinite $V_\infty[\hat{\mathbf{y}}^o_s]$, which is known as diffuse Kalman filter.

The idea behind the Bayesian principle is to look for a parameter vector which maximizes the posterior density, given the prior and the likelihood based on the data. Formally, the posterior density $p(\boldsymbol{\theta}|\hat{\mathbf{y}}^o)$ is related to the prior and the likelihood as follows:

$$p(\boldsymbol{\theta}|\hat{\mathbf{y}}^o) = \frac{p(\hat{\mathbf{y}}^o|\boldsymbol{\theta})\, p(\boldsymbol{\theta})}{p(\hat{\mathbf{y}}^o)} \propto p(\hat{\mathbf{y}}^o|\boldsymbol{\theta})\, p(\boldsymbol{\theta}) = L(\boldsymbol{\theta}|\hat{\mathbf{y}}^o)\, p(\boldsymbol{\theta})), \tag{56}$$

where $p(\boldsymbol{\theta})$ is the prior density of the parameter vector, $\mathcal{L}(\boldsymbol{\theta}|\hat{\mathbf{y}}^o)$ is the likelihood of the data and $p(\hat{\mathbf{y}}^o) = \int_\Theta p(\hat{\mathbf{y}}^o|\boldsymbol{\theta})\, p(\boldsymbol{\theta})\, d\boldsymbol{\theta}$ is the unconditional data density, which, since it does not depend on the parameter vector to be estimated, can be treated as a proportionality factor and accordingly can be disregarded in the estimation process. Assuming *iid* priors, the logarithm of the posterior is given by the sum of the log likelihood of the data and the sum of the logarithms of the prior distributions:

$$\ln(p(\boldsymbol{\theta}|\hat{\mathbf{y}}^o)) = \ln(\mathcal{L}(\boldsymbol{\theta}|\hat{\mathbf{y}}^o)) + \sum_{\iota=1}^{N} \ln(p(\theta_i)). \tag{57}$$

The latter term can be directly calculated from the specified prior distributions of the estimated parameters. For the computation of the log likelihood of the data the Kalman filter is applied to the DSGE model solution (the state-state representation) for the number of periods, T, provided by the data $\hat{\mathbf{y}}^o$.

The (multivariate) posterior distribution for our DSGE model would not exist in closed form; however, it can be approximated through a gaussian density providing the sample size grows.[32] Following [Tierney & Kadane, 1986], the posterior is understood as a kernel of unknown form, $\mathcal{K}(\boldsymbol{\theta}) \equiv \mathcal{K}(\boldsymbol{\theta}, Y_T^o)$, given that (one of) its mode is assumed to be known, $\boldsymbol{\theta}^*$, thaking logs and approximating the kernel using a 2^{nd} order Taylor expanssion, yields:

$$\log \mathcal{K}(\boldsymbol{\theta}) \approx \log \mathcal{K}(\boldsymbol{\theta}^*) - \frac{1}{2}(\boldsymbol{\theta} - \boldsymbol{\theta}^*)' \left[H(\boldsymbol{\theta}^*)\right]^{-1} (\boldsymbol{\theta} - \boldsymbol{\theta}^*),$$

where $H(\boldsymbol{\theta}^*)$ is minus the inverse of the hessian of the model evaluated at the posterior mode. Consequently, the gaussian posterior would be:

$$p(\boldsymbol{\theta}^*) \approx (2\pi)^{T/2} \left|H(\boldsymbol{\theta}^*)\right|^{-1/2} \exp\left\{-\frac{1}{2}(\boldsymbol{\theta} - \boldsymbol{\theta}^*)' \left[H(\boldsymbol{\theta}^*)\right]^{-1} (\boldsymbol{\theta} - \boldsymbol{\theta}^*)\right\},$$

which enables us to approximate posterior moments, as derived by [Kass *et al.* , 1989] and [Tierney *et al.* , 1989].

The whole point is that the asymptotic approximation ($T \to \infty$) makes sense if and only if the true posterior does not differ from the hypothetized gaussian. More exact results for our sample range can be derived via simulation given its non-standard shape, employing an approximation method around the optimum that generates a (large) sample of draws using the Markov-Chain Monte Carlo (MCMC) algorithm. This is useful to characterize the shape of the posterior distribution, from which inference can be drawn. The Metropolis-Hastings algorithm is implemented using a jumping distribution to visit areas that are not at the tails of the posterior. The validity of the "jump" is assessed via acceptance-rejection instrumented with the Metropolis-Hastings algorithm, where proposal draws that are accepted (rejected) are included (excluded) in Markov chain. The researcher establishes the ratio of acceptance. The simulation is considered large enough when pooled moments converge to within moments of the chain, see [Brooks, 1998].

[32] As the sample enlarges, the choice of the prior density would not affect the posterior.

7.4 Estimation results

The aim of this section is to provide estimates of the deep parameters of our model supported by data. In particular, we focus attention on estimates of fiscal and monetary rules parameters to shed light on the local determinacy, see [Leith & von Thadden, 2006].

The strategy employed starts from a parameter space with a minimum dimension and, subsequently, it is expanded so that the information contained in the series is fully exploited. Further, in the estimation we tried prior distributions for all deep parameters aiming at obtaining estimates of the parameter vector with the largest dimension. However, in the extreme, the estimated full dimension parameter vector proved to make the log likelihood function (multidimensional mode) not maximum. We have two options: (i) to increase the number of series (which can only be added if the number of shocks is higher, otherwise we could not solve it due to stochastic singularity), or (ii) to reduce the parameter space to be estimated. We chose the second alternative. Regarding the first one, recall that in Section 5.3 we specified exogenous shocks, which we judged adequate. Adding more shocks could be an interesting extension, though this is potentially troublesome if they are not motivated by economic theory (shocks should help to identify data series).

Bearing these considerations in mind, we report in Table 2 Bayesian estimates arising from the maximization of the posterior distribution of our DSGE model. Relevant information we specified includes:

1. the prior densities;
2. prior lower and upper bounds (not shown); and
3. Prior means and SDs.

Consider Table 2, starting with density types, the Beta density is chosen to represent parameters bounded within the (0,1) interval, whilst the inverted Gamma density for parameters whose expected values are strictly positive and larger than one (and posibly unbounded from above). In addition, the bounds were set considering economic theory as well as estimates from previous related studies. Finally, prior means and prior SDs are taken from the related literature.

Table 2

Log data density is 520.98.

					Post mean 90% conf. interval	
Parameters	Prior mean	Prior SD	Density	Post mean	lower	upper
ι	$\frac{1}{3}$	0.05	β	0.3167	0.2363	0.3950
φ	0.60	0.15	β	0.5016	0.4315	0.5676
ρ_A	0.75	0.15	β	0.3996	0.2162	0.5741
α	0.50	0.15	β	0.2574	0.1394	0.3816
α^*	0.50	0.15	β	0.4813	0.3922	0.5774
ϕ_1	0.10	0.025	β	0.0402	0.0316	0.0479
ϕ_2	0.25	0.15	β	0.4934	0.2262	0.7649
ϕ_3	0.05	0.015	β	0.0583	0.0307	0.0876
λ_1	1.50	0.25	inv Γ	1.5001	1.0594	2.0066
λ_1^*	1.50	0.25	inv Γ	1.7102	1.1173	2.2830
λ_2	0.50	0.15	β	0.7415	0.5850	0.8966

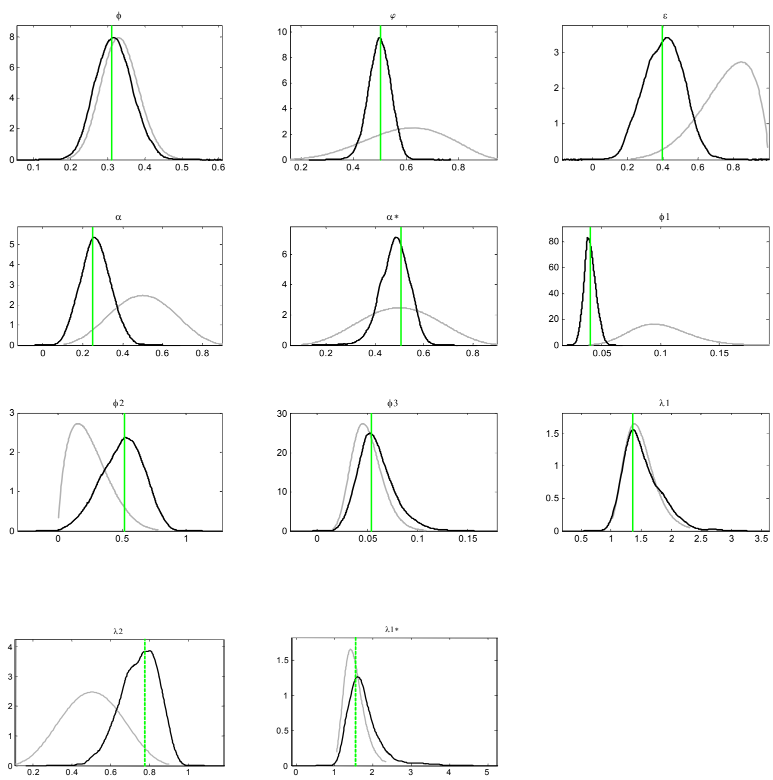

Figure 4: Estimates of deep parameters

8 Conclusions

This paper investigates fiscal and monetary policies and how they can interact in order to better stabilize large economies. Stabilization is potential and depends on the specific model setup. We examined a fully microfounded model focusing attention on the short-run interaction of two large open economies, where a fraction of the consumers are financially constrained (and therefore acting in a non-ricardian way). We argued that the separation of consumers' types has important consequences in open economies which have not been sufficiently analyzed in the literature.

Firstly, we estimated a small VAR model specification with minimum structure. We were able to capture in a parsimonious way very interesting results both for the EU-12 aggregate and the U.S. We could unambiguously confirm the same pattern found by [Galí *et al.* , 2007b] for the EU-12 aggregate: private consumption reacts positively to an unexpected government expenditure shock. This result is at odds with the suggested result from the permanent income hypothesis.

Taking into account these consumption developments, we accomplished a classical numerical simulation analysis with our model, where parameters calibrated resemble the EU-12 and the U.S. economies and we ask under which conditions we are able to generate developments of consumption as those predicted by the VAR. We find that we need more than 50% of rule-of-thumb consumers in both economies to reproduce the IRFs of VAR, a similar figure was proposed by [Mankiw, 2000]. Different shares of non-ricardian consumers were considered and its implications for stability analyzed, confirming that if the share of rule-of-thumb consumers increase to such an extent that become dominant, the model's solution becomes indeterminate, an issue also shown by [Galí *et al.* , 2007b].

The analysis of IRFs allows us to conclude that the monetary policy design may have little influence in the channel of transmission that matters for consumption fluctuations. The same pattern emerges when considering monetary demand and productivity shocks (therefore we did not show these results). Critically, active fiscal policy will shape aggregate consumption fluctuations — with source in whatsoever shock— through the transfer's channel together with disposable income fluctuations.

We also estimated a subset of deep parameters assuming that the rule-of-thumb share is 0.6 (we obtained similar IRFs as from the estimated VAR). Other deep parameters (relatively less important) were calibrated because otherwise the parameter space of the log-likelihood function becomes too large. In total we estimated 11 deep parameters using Bayesian techniques resulting all of them display well-behaved posterior distributions (narrower that priors and centered around the mode). Estimates are inside the (local) determinacy regions.

For future research agenda, we acknowledge that the current model need to be extended to take into account the stock of physical capital to endow conclusions with more realism. Moreover, different taxation regimes should be analyzed focusing more on how the disposable income is generated and varies with changes in transfers or in tax proceedings. Meanwhile, the presented model assumed that these channels were shut down.

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A Data Appendix

Table A.1

Variables for EU 12 (BE, DE, IE, GR, ES, FR, IT, LU, NL, AT, PT, FI)	
Description	Source and series' name
Government expenditure divided by lagged GDP trend	Eurostat: "na-p3_s13"
Government expenditure net of military expenses divided by lagged GDP trend	Eurostat: "na-p3_s13"; SIPRI database
Government revenues divided by lagged GDP trend	Eurostat: "gov_q_ggnfa", SA adj
Government deficit divided by lagged GDP trend	Constructed
GDP over working age population, in logs	Eurostat, "na-b1gm", OECD: "POPT"
Private consumption over working age population, in logs	Eurostat: "na-p3"; OECD: "POPT"

Note: Countries abbreviations are Belgium, Germany, Ireland, Greece, Spain, France, Italy, Luxemburg, The Netherlands, Austria, Portugal, Finland, respectively.

Table A.2

Variables for U.S.	
Description	Source and series' name
Government expenditure divided by lagged GDP trend	FRED II: “GCEC1”
Government expenditure net of military expenses divided by lagged GDP trend	FRED II: “GCEC1”; SIPRI database
Government revenues divided by lagged GDP trend	Constructed
Government deficit divided by lagged GDP trend	FRED II: “TGDEF”
GDP over population older than 16 years old, in logs	FRED II: "GDP", "CNP16OV"
Private consumption over working age population, in logs	FRED II: “PCECC96”, "CNP16OV"