The European Monetary Union and Imbalances Is it an anticipation story?*

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Abstract

Within an estimated model of a small open economy inside the European Monetary Union, we study the contribution of anticipated and unanticipated shock on the dynamics of international macroeconomic variables. A business cycle model featuring incomplete international financial market, price and investment adjustment cost, variable capital utilization, habit persistence, home bias and both tradable and non tradable sector creates a comprehensive framework that allows us to distinguish between possible determinants of the accumulation of international imbalances inside the EMU. Focusing only on the ability of the model to replicate the path of the current account can be misleading. Real exchange rate reaction plays a crucial role in distinguishing between different possible sources of EMU imbalances. The model, estimated using a weighted average of Ireland, Portugal and Spain, shows that expected changes in productivity can't be the major determinant of the current account deficit. Anticipated uncovered interest parity shock, interpreted as an expected decrease in the borrowing risk premium, could instead be a major source of the imbalances experienced in EMU. More than two thirds of the fluctuations of the current account can be explained with anticipated shocks: long term anticipated interest rate premium shock account for most of it.

Keywords: current account, real exchange rate, anticipated shocks, EMU
JEL Classification: E32, E43, F32, F41

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1 Introduction

...there is no simple structural relation, in our economy, between the trade balance and the terms of trade and suggests that one cannot characterize the relation between trade and prices without specifying the source of fluctuations.[1]

Significant flows of capital and diverging current account balances have characterized the European Monetary Union (EMU) member countries since its formation. Starting in 1996, a group of countries, such as Ireland, Portugal, Spain and Greece,[2] accumulated increasing current account deficits, while other countries, such as Germany, Netherlands and Austria, persistently increased the surpluses (figure 1(a)). The Great Recession revealed that the euro area countries that accumulated negative current account balances were those that suffered more from the crisis. As shown by figure 1(b), the positive correlation between current account deficit and harshness of the recent crisis seems to be specific to the European Monetary Union.[3] Therefore, it is important to understand what the sources, and possibly the peculiarities, of the EMU current account imbalances have been. The two goals of the paper are to test theoretically the plausibility of different sources of current account imbalances among EMU countries and understand the role of anticipated shock in the accumulation of international imbalances.

The idea that capitals were flowing towards catching up countries with higher current or expected productivity growth (Blanchard & Giavazzi 2002) has partially lost empirical support. Zemanek, Belke & Schnabl (2009) and Berger & Nitsch (2010) suggest that in fact capitals were flowing towards countries not only with higher per capita GDP growth but also with higher domestic distortions.[4] As in Giavazzi & Spaventa (2010) and Eichengreen (2010), we distinguish between types of current account imbalances depending on their trigger. Some are driven by growth differentials that allow surplus countries to invest in future growth of the borrowing countries and others are triggered by other factors that, instead of overcoming economic constraints, might end up creating economic fragilities. Therefore expectations play a crucial role in international flows of capitals and goods.

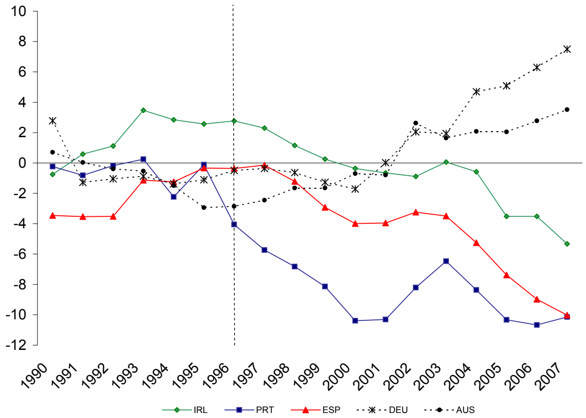
We focus on understanding the role of anticipated shock as a source of the dynamics of these international variables. As in Hoffmann, Krause & Laubach (2011), henceforth HKL, we wonder

[1] Backus, Kehoe & Kydland (1994).

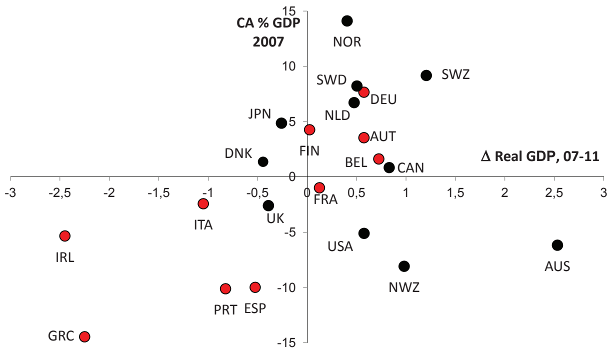
[2] From now on we will not focus on Greece given some problem on the reliability of the data.

[3] Figure 1(b) shows that the positive correlation between the current account balance of 2007 and the real GDP growth rate of the period 2007/11 is lost when we consider the other 13 developed countries that were having a similar pattern in the dispersion of the current account balances.

[4] For example relatively less flexible labor and product markets, higher level of employment protection and relatively less prudent fiscal policies. See also Schmitz & von Hagen (2009). Also Sodsriwiboon & Jaumotte (2010), Barnes, Lawson & Radziwill (2010), Barnes (2010) and Belke & Dreger (2011) focus on the dynamics and consequences of large current account deficits in the euro area but from a policy perspective.



(a) Current Account



(b) ΔGDP 2007-11 Vs. 2007 current account position

Figure 1: Current account and peculiarities

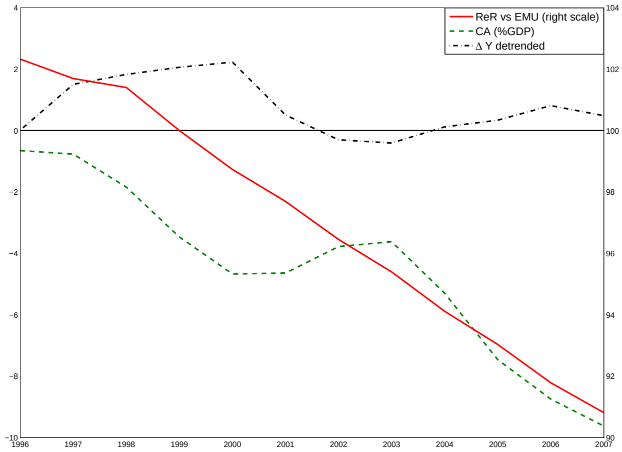
whether changes in expectations can explain the path of current account imbalances. While HKL study the role of imperfect expectation formation in the accumulation of global imbalances, we focus on the ability of anticipated shocks, in a full information set-up, in order to explain what happened in small open economies inside the EMU. Unlike HKL, we believe that in order to understand the sources of current account imbalances we need to look also at international relative prices to avoid possible miss-interpretations of the results. Relative prices, within and between countries, are crucial variables for the dynamics of international flows. The additional focus on the real exchange rate allows to differentiate between similar reactions of the current account to various types shocks.

The paper utilizes theoretical results to distinguish between different sources of current account imbalances. We want the model to reproduce the dynamics of a small set of key variables: current account, real exchange rate and output growth. Between 1996 and 2008, GDP growth above trend, current account deficit and real exchange rate appreciation were common to some EMU countries such as Ireland, Portugal and Spain (henceforth IPS, figure.[5] For this reason, in order to include a shock as a possible source of the current account deficit experienced by IPS, we claim that it is important for the model to match the sign of the experienced correlation between those variables.

Anticipated shocks were proved to be important for explaining business cycle fluctuations of some key macroeconomic variables. We are then interested in understanding the importance of anticipated shocks as a possible driver of international variable fluctuations. To address this point we follow the methodology proposed by Schmitt-Grohe & Uribe (2012) investigating the contribution of unanticipated and anticipated shocks to the unconditional variance of output growth, current

[5]Figure 2 shows the dynamics of the average current account, real exchange rate and GDP growth (detrended in a model consistent base) of a weighted average of Ireland Portugal and Spain. We used the annual HICP relative household consumption expenditure shares in the euro area totals as weights.

Figure 2: Ireland-Portugal-Spain



account and real exchange rate.

A two-sector, tradable and non tradable, New Keynesian DSGE open economy model[6] in a monetary union is constructed. Different features of open economy general equilibrium models are combined. Habit persistence in consumption, nominal and real rigidities, monopolistic competition, tradable and non tradable sector, home bias, variable capital utilization and an incomplete international financial market are characteristics of the small open economy being analyzed. We then estimate the model on IPS data and, relying on Bayesian techniques, we use carefully selected priors to reduce the short sample limitations.[7] We accordingly use the estimated model to study the reactions to structural shocks.

Unanticipated, one-year anticipated and long term anticipated (10-quarters) components are introduced for each structural shock. The importance of productivity[8], preference, investment, labor supply, monetary policy and uncovered interest parity shocks as a source of uncertainty is analyzed using a variance decomposition of the simulated model.

To check the robustness of the results we replicate the exercise with different specifications of the model. We first introduce Jaimovich and Rebelo type of preferences, we then allow for an imperfect

[6] Matheson (2010) shows that a small open economy model with a non tradable good sector fits the data better than the one-good model in a set of 3 small open economies. The model is in line with Smets & Wouters (2003), Galí & Monacelli (2005), Santacreu (2005),Galí & Monacelli (2008), Faia & Monacelli (2008), Rabanal (2009), Merola (2010), Burriel, Fernndez-Villaverde & Rubio-Ramrez (2010b).

[7] See An & Schorfheide (2007) for a discussion on Bayesian estimation in DSGE models.

[8] We analyze both sector specific shocks and shocks common to both the tradable and non tradable sectors. In addition we analyze both the impact of shocks with a persistent effect on the growth rate and shocks causing just a permanent shift in the level of technology.

information setup and we conclude with a reduced form of the model with labor as the only factor of production.

Anticipated as well as unanticipated productivity shock can hardly be considered an important source of current account deficits experienced inside the EMU before the 2008 crisis.[9] On the other hand the anticipated shock in the risk premium is more likely an important source of those imbalances. Uncovered interest parity movements, in a monetary union with a fixed nominal exchange rate, can in fact be interpreted as a risk premium shock. An expected decrease in the borrowing premium seems to be plausible: agents, as soon as the monetary union became a credible agreement, have started to anticipate a future drop in the borrowing cost.

Considering the impact of all the anticipated shocks we get that news shocks account for most of the fluctuations: 54 percent of the growth rate of output, 40 percent of the real exchange rate and 86 percent of the current account. Long term anticipated risk premium shock is the most important source of the anticipated uncertainty.

The paper is organized as follows. Section 2 describes the economic environment in detail while section 3 illustrates the Bayesian estimation of the model. Section 4 analyzes which structural shock could explain the current account imbalance and investigates the importance of anticipated shocks for international variable fluctuations. Section 5 checks the robustness of the results presenting different specifications of the model analyzed. Section 6 concludes.

2 The Model

We construct a two-sector New Keynesian Dynamic Stochastic General Equilibrium (DSGE) small open economy model. The domestic economy is part of a monetary union with the foreign economy which is, for analytical simplicity, the rest of the world (henceforth RoW).

The domestic representative household consumes, saves or borrows through domestic and foreign internationally traded bonds, supplies labor and decides the level of capital to be used in production. Capital depreciates and investments are costly. The model features variable capital utilization and adjustment cost to investment in order to ensure that it generates aggregate and sectoral co-movement in presence of anticipated shock.[10] The consumption bundle is a collection of non tradables and a combination of home and foreign produced tradable goods. There is no perfect substitutability between domestic and foreign tradables but their substitutability is higher than the one between tradable and non tradable goods. We introduce home bias well-aware that the purchasing power parity will not be necessarily satisfied.

[9] Differently, considering the USA, Hoffmann et al. (2011) conclude that "global imbalances" can be largely explained with perceived change in trend growth rate. Their result is conditional on focusing just on the path of current account without trying to match a key variable as the real exchange rate.

[10] See Jaimovich & Rebelo (2008), Jaimovich & Rebelo (2009) and Schmitt-Grohe & Uribe (2012).

Within each country there are two production sectors: tradable and non tradable firms. Firms producing goods are monopolistically competitive and can adjust prices only costly. They produce employing labor and capital which are freely mobile across sectors. In addition to a unit root labor augmenting permanent shift in the level of technology we assume that each sector is characterized by persistent specific technology shocks with a unit root. This ensures that the model is able to generate permanent inflation differentials across countries and sectors.

There is a common monetary authority, the European Central Bank, that fixes the nominal interest rate. It targets the euro area inflation, for which our small open economy contributes for little above 13 percent. The assumption that the economy is small allows us to keep the model tractable and reflects the fact that the country's economy is affected by the rest of the monetary union but cannot strongly influence it. The nominal exchange rate is fixed, given the participation to a monetary union, and becomes a key mechanism through which every price movement, in both sectors, will be reflected in movements of inflation, real interest rate and real exchange rate.

Finally we allow for perfect risk sharing within countries but incomplete international financial markets. There are only two international non contingent bonds, one foreign and one domestic, implying incomplete risk sharing in-between countries. Notice that throughout the entire paper an asterisk * will characterize foreign variables, an overscript tilde$\tilde{}$will indicate detrended variables, an overscript hat$\hat{}$will define deviation from steady state and lower case variables will characterize the natural logarithm transformation.

2.1 Domestic Household

The domestic representative household maximizes the expected value of his lifetime utility

$$E_t \sum_{t=0}^{\infty} \chi_{t-1} \zeta_t U(C_t, L_t) \tag{1}$$

where E_t denotes conditional expectation at date t, U is the instantaneous utility function of the consumption index, C, and hours worked, L, and ζ_t is an intertemporal preference shock with the following law of motion:

$$\log \zeta_t = \rho_\zeta \log \zeta_{t-1} + u_t^\zeta \qquad \text{where} \qquad u_t^\zeta \sim N(0,1) \tag{2}$$

χ_t is the household's endogenous discount factor. Following Uzawa (1968) and Schmitt-Grohe & Uribe (2003) we assume that agents become more impatient the higher is the average detrended consumption, $\widehat{C_t}$.[11]

$$\chi_t = \beta_t \chi_{t-1} \qquad \text{where} \qquad \beta_t \equiv \frac{1}{1+\psi^{\beta}(\log \widetilde{C}_t - \chi^{\beta})} \tag{3}$$

The parameter ψ^{β} determines the importance of detrended average consumption and, following Ferrero, Gertler & Svensson (2008), it is set sufficiently small to avoid strong interference with the dynamics of the model.

In the baseline model we allow for a utility function separable in consumption and hours worked which accounts for an h degree of habit persistence in consumption:[12]

$$U(C_t, L_t) = \left\{ log(C_t - hC_{t-1}) - \epsilon_t^L \psi^L \frac{L_t^{1+\nu}}{1+\nu} \right\} \tag{4}$$

where ψ^L is a labor supply preference parameter, ϵ_t^L is a labor supply shock with law of motion:

$$\log \epsilon_t^L = \rho_{\epsilon^L} \log \epsilon_{t-1}^L + u_t^L \qquad \text{where} \quad u_t^L \sim N(0,1) \tag{5}$$

C_t is a composite of consumption of non tradable goods, $C_{N,t}$, and tradable goods, $C_{T,t}$ which are also a compound of domestic-made and foreign-made tradable goods :

$$C_t \equiv [\gamma_{T,t}^{\frac{1}{\eta}} C_{T,t}^{\frac{\eta-1}{\eta}} + \gamma_{N,t}^{\frac{1}{\eta}} C_{N,t}^{\frac{\eta-1}{\eta}}]^{\frac{\eta}{\eta-1}} \qquad C_{T,t} \equiv [\gamma_{h,t}^{\frac{1}{\epsilon}} C_{h,t}^{\frac{\epsilon-1}{\epsilon}} + \gamma_{f,t}^{\frac{1}{\epsilon}} C_{f,t}^{\frac{\epsilon-1}{\epsilon}}]^{\frac{\epsilon}{\epsilon-1}}$$

$\eta > 0$ is the elasticity of substitution between tradable and non tradable goods and $\epsilon > 0$ sets the substitutability between domestic and imported tradable goods. $\gamma_{T,t}$, $\gamma_{N,t}$, $\gamma_{h,t}$ and $\gamma_{f,t}$ are respectively the preference shares for tradable as a whole, non tradable, domestic tradable and foreign tradable goods.[13] Following Faia & Monacelli (2008) we also allow for a symmetric home bias, with respect to the RoW, in the share of home produced tradable goods.

Within each sector there are a continuum of different varieties of goods which are imperfectly substitutable:

$$C_{f,t} \equiv \left[\left(\tfrac{1}{1-n}\right)^{\frac{1}{\phi}} \int_n^1 C_{f,t}(i)^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}} \qquad C_{h,t} \equiv \left[\left(\frac{1}{n}\right)^{\frac{1}{\phi}} \int_0^n C_{h,t}(i)^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}}$$

$$C_{N,t} \equiv \left(\int_0^1 C_{N,t}(i)^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}}$$

[11] This feature of the model ensures the presence of a stable non-stochastic steady state independent from initial conditions with incomplete financial markets. See Schmitt-Grohe & Uribe (2003) and Bodenstein (2011) for a detailed discussion on the topic. Notice that the detrended average consumption is treated as exogenous by the representative household.

[12] In section 5.1 we present the results of the model with a utility specification that allows for different intensities of the labor wealth effect. Jaimovich & Rebelo (2009) show that models with this type of utility in the presence of anticipated shock can better match labor dynamics in the data.

[13] The shares can vary over time since they include deterministic preference shocks (see Rabanal (2009)). Those are necessary to guarantee a balance growth path when the two sectors are allowed to grow at different rates as in our framework.

where $\theta > 0$ and $\phi > 0$ are respectively the elasticity of substitution between varieties in the non tradable sector and in the tradable sector. There are two price indexes: a consumer price index (CPI), P_t, and a domestic country price index for tradable good (TPI), $P_{T,t}$:

$$P_t = [\gamma_{T,t} P_{T,t}^{1-\eta} + \gamma_{N,t} P_{N,t}^{1-\eta}]^{\frac{1}{1-\eta}} \qquad P_{T,t} = [\gamma_{h,t} P_{h,t}^{1-\epsilon} + \gamma_{f,t} P_{f,t}^{1-\epsilon}]^{\frac{1}{1-\epsilon}}$$

In appendix B we present the optimal allocation bundles in details. The representative household maximizes his utility function subject to the following budget constraint:

$$C_t + \frac{B_t}{P_t} - \frac{A_t}{P_t} + I_t \leq W_t L_t + R_{t-1}^B \frac{B_{t-1}}{P_t} - R_{t-1} \frac{A_{t-1}}{P_t} + \left(R_t^k u_t - \Psi(u_t)\right) K_{t-1}^p + \int_0^1 \Gamma_{N,t}(i) + \int_0^1 \Gamma_{h,t}(i) \quad (6)$$

where W_t is the real wage in terms of the CPI price index and $\Gamma_{j,t}(i)$ are the real profits of monopolistic firm in both the tradable and non tradable sector.[14] There is full insurance within the country but international financial markets are incomplete. The only two internationally traded assets are the domestic bond, B_t, and the foreign bond, $(-A_t)$ that give respectively a return of R_{t-1}^B and R_{t-1}.

The representative household owns physical capital k_t^p which accumulates according to

$$K_t^p = (1-\delta) K_{t-1}^p + \epsilon_t^I \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \quad (7)$$

I_t is the investment in physical capital, δ is the depreciation rate and $S()$ is an adjustment cost function. We assume that $S(Z) = S'(Z) = 0$ and $S"(Z) = \eta_k > 0$, where Z is the economy's steady state growth rate and η_k is the capital adjustment cost elasticity. ϵ_t^i is an investment specific shock that evolves according to $\log \epsilon_t^I = \rho_{\epsilon^I} \log \epsilon_{t-1}^I + u_t^{\epsilon^I}$. The household decides the capital utilization rate, u_t, that determines the amount of physical capital to be transformed in effective capital that will be rented to firms at the real rate R_t^k:

$$K_t = u_t K_{t-1}^p \quad (8)$$

$\Psi(u_t)$ in equation (6) is the cost of use of capital in units of consumption and following Christiano, Eichenbaum & Evans (2005) we assume that $\Psi(u) = 0$ and $\frac{\Psi'(u)}{\Psi"(u)} = \eta_u$ where $u = 1$.

The representative household chooses processes $\{C_t, L_t, B_t, A_t, u_t, K_t^p, I_t\}_{t=0}^{\infty}$ taking as given the set of processes $\{P_t, W_t, R_t^k, R_t, R_t^B\}_{t=0}^{\infty}$ and the initial wealth B_0 and A_0, to maximize equation (1) subject to (4),(6),(7) and (3). The necessary first order conditions are listed in the appendix B.

From now on, to lighten the notation, we introduce an indicator $j = \{N, h\}$ for the non tradable and the domestic tradable sector.

[14]Shares of the monopolistic firm i are owned by domestic residents in equal proportions and are not traded internationally.

2.2 Firms

Production in both sectors is carried out by monopolistically competitive firms owned by the household. Different production technologies with a deterministic trend characterize the two sectors while we allow for a common trend for the overall economy. Production is carried out with the use of both capital, K_t, and working hours L_t:

$$Y_{j,t} = A_{j,t} K_{j,t}^{\alpha} \left[X_t L_{j,t}\right]^{1-\alpha} \tag{9}$$
$$\tag{10}$$

where X_t is a common labor-augmenting technology process and $A_{j,t}$ are the productivity innovations for the tradable/non tradable sectors. Sector specific productivities have a trend and a first order autoregressive process:

$$A_{N,t} = (1+g^N)^t \widetilde{A}_{N,t} \tag{11}$$
$$log(\widetilde{A}_{N,t}) = \rho_{A_N} log(\widetilde{A}_{N,t-1}) + u_t^{AN} + u_t^A \tag{12}$$
$$A_{h,t} = (1+g^T)^t \widetilde{A}_{h,t} \tag{13}$$
$$log(\widetilde{A}_{h,t}) = \rho_{A_h} log(\widetilde{A}_{h,t-1}) + u_t^{Ah} + u_t^A \tag{14}$$

The labor-augmenting technology follows:

$$X_t = (1+x)^t \widetilde{X_t} \qquad \text{where} \qquad \widetilde{X_t} = u_t^X \tag{15}$$

The shocks are *i.i.d.* normally distributed $u_t^{AN} \sim N(0, \sigma_{AN}^2)$, $u_t^{Ah} \sim N(0, \sigma_{Ah}^2)$, $u_t^A \sim N(0, \sigma_A^2)$ and $u_t^X \sim N(0, \sigma_X^2)$. Notice that while the shocks to productivity, u_t^{AN} and u_t^{Ah}, have a persistent but temporary consequence, the shock u_t^X leads to a permanent shift in the level of the common labor-augmenting technology without affecting the growth rate. These assumptions provide us a model consistent based method to detrend the data when we proceed with the estimation.

Firms can change prices only costly and that implies a sluggish response of prices to shocks. We follow Rotemberg (1982) and we assume that the cost for price adjustment can be measured in terms of the output of the sector bearing the cost:

$$\frac{\psi}{2}\left(\frac{P_{j,t}(i)}{\overline{\Pi}^j P_{j,t-1}(i)} - 1\right)^2 P_{j,t} Y_{j,t} \tag{16}$$

where ψ measures the degree of price stickiness, $\overline{\Pi}^j$ denotes the steady state inflation rate in the sector considered and $Y_{j,t}$ is the aggregate demand for non tradable and home produced tradable goods.[15]

[15] The results are the same using Calvo style price stickiness. For simplicity we present here just the Rotemberg adjustment mechanism. The adjustment cost is a modified version of the general formulation of Ireland (2007) that allows us to avoid steady state effects of positive inflation rate.

Firms solve a two stage problem. In the first stage they minimize the real cost of production choosing in a perfectly competitive market the quantity of the two factors:

$$\min_{k_{j,t},L_{j,t}} W_t L_{j,t} + R_t^k K_{j,t}$$

subject to (9).

The optimality condition gives us

$$k_{j,t} = \frac{\alpha}{1-\alpha}\frac{W_t}{R_t^k} L_{j,t} \tag{17}$$

and the real marginal cost function

$$MC_{j,t} = \left(\frac{1}{1-\alpha}\right)^{1-\alpha}\left(\frac{1}{\alpha}\right)^{\alpha}\frac{W_t^{1-\alpha} R_t^{k\ \alpha}}{A_{j,t} X_t^{1-\alpha}} \tag{18}$$

In the second stage each firm (i) chooses its price $P_{j,t}(i)$ in order to maximize profits:

$$E_t\left\{\sum_{t=0}^{\infty} \upsilon_{0,t}\left[\frac{P_{j,t}(i)}{P_t} Y_{j,t}(i) - MC_{j,t} Y_{j,t}(i) - \frac{\psi}{2}\left(\frac{P_{j,t}(i)}{\overline{\pi}^j P_{j,t-1}(i)} - 1\right)^2 \frac{P_{j,t} Y_{j,t}}{P_t}\right]\right\}$$

subject to (9) and the total demand for the i non tradable/tradable good:

$$Y_{j,t}(i) \leq \left(\frac{P_{j,t}(i)}{P_{j,t}}\right)^{-\theta} Y_{j,t} \tag{19}$$

2.3 Terms of trade, UIP, real exchange rate and current account

Understanding the reactions of international relative prices and current account to shocks is one of the goals of the paper. In this section we introduce some important variables: the terms of trade, the real exchange rate, the relative price of traded and non traded goods and the current account.

We start by defining the terms of trade as the price of imported over exported goods $S_t \equiv \frac{P_{f,t}}{P_{h,t}}$. Following Faia & Monacelli (2008) the tradable price index over the price of the domestic tradables can be written as a function of the terms of trade and parameters only:

$$\frac{P_{T,t}}{P_{h,t}} = g(S_t) = [\gamma_{h,t} + \gamma_{f,t} S_t^{1-\epsilon}]^{\frac{1}{1-\epsilon}} \qquad \text{with} \quad \frac{\delta g(S_t)}{\delta S_t} > 0 \tag{20}$$

$J_t \equiv \frac{P_{T,t}}{P_{N,t}}$ is the relative price of tradable over non tradable goods. The ratio of the CPI index to the price of non tradables then can be written as:

$$\frac{P_t}{P_{N,t}} = m(J_t) = [\gamma_{T,t} J_t^{1-\eta} + \gamma_{N,t}]^{\frac{1}{1-\eta}} \qquad \text{with} \quad \frac{\delta m(J_t)}{\delta J_t} > 0 \tag{21}$$

The nominal exchange rate ε is defined as the price of foreign currency in terms of home currency.[16] Assuming that the small open economy is part of a Monetary Union, the nominal exchange rate with the rest of the world is fixed. For simplicity we set $\varepsilon = 1$. We assume that the law of one price holds $P_{f,t}(i) = \varepsilon * P^*_{f,t}(i) = P^*_{f,t}(i)\ \forall i \in [0, 1]$. However notice that the Purchasing Power Parity (PPP) will not hold given our assumption of home bias.

The real exchange rate is defined as $Q_t = \frac{P^*_t}{P_t}$. It can also be rewritten as a function of S_t, J_t and the exogenous foreign prices:

$$Q_t = \frac{S_t}{g(S_t)} \frac{J_t}{m(J_t)} \frac{P^*_t}{P_{f,t}} \qquad \text{with} \quad \frac{\delta Q_t}{\delta S_t} > 0 \ \frac{\delta Q_t}{\delta J_t} > 0 \tag{22}$$

It is important to notice that as a consequence of our assumption of imperfect financial market, the link between the real exchange rate and the ratio of international marginal utilities of consumption is broken, allowing the model to violate the risk sharing equation. [17]

We now introduce an uncovered interest parity shock building from the work of Kollmann (2001), Kollmann (2005) and Bergin (2006). In our framework the uncovered interest parity condition, remembering that our small open economy is part of a monetary union, can be derived from the two Euler conditions for the two assets:

$$E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{R^B_t}{\pi_{t+1}} \right\} = E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{R_t}{\pi_{t+1}} \right\} \tag{23}$$

Given our focus on the first order linear approximation around the steady state, equation (23) becomes $\widehat{R^B_t} = \widehat{R_t}$ which omits the nonlinearities of marginal utilities and prices. Following a standard practice in new open economy macroeconomics models we insert an exogenous "risk premium term" to account for nonlinearities transforming the previous equation in our equilibrium condition:

$$\widehat{R^B_t} = \widehat{R_t} + Risk_t \tag{24}$$

where $Risk_t = \rho_{RP} Risk_{t-1} + u^{Risk}_t$.

From the budget constraint we can write the balance of payment condition, as share of steady state GDP, Y:

$$NX_t + \frac{R^B_{t-1} B_{t-1}}{Y P_t} - \frac{R_{t-1} A_{t-1}}{Y P_t} - \frac{B_t - A_t}{Y P_t} = 0 \tag{25}$$

[16] An increase of ε is a depreciation of home currency, while a decrease in the nominal exchange rate results in an appreciation of the home currency with respect to the foreign one.

[17] If we were in a model with perfect financial and insurance market with constant nominal exchange rate the risk sharing condition would be $\zeta \frac{U^*_{C,t}}{U_{C,t}} = \frac{P^*_t}{P_t}$ where $\zeta = Q_0 \frac{U_{C,0}}{U^*_{C,0}} = 1$. This equation states that a benevolent social planner would allocate consumption across countries in a way that the marginal benefit from an extra unit of consumption equals its marginal costs. With a time separable preferences and CRRA utility function we would have a positive correlation between the relative consumption and the real exchange rate. The data shows that this is not always the case and this goes under the name of Backus-Smith puzzle (Backus, Kehoe & Kydland 1993). Corsetti, Dedola & Leduc (2010) provide a complete overview of the literature, from the work of Cole & Obstfeld (1991) to most recent models.

where nx_t denotes the real value of net exports as a ratio to Y and it is equal to

$$NX_t = \frac{J_t}{g(S_t)m(J_t)} \frac{(Y_{h,t} - C_{h,t} - S_t C_{f,t})}{Y} \tag{26}$$

We finally define the current account as the net change in real bond holding (scaled with Y):

$$CA_t = \frac{(B_t - A_t)}{P_t Y} - \frac{(B_{t-1} - A_{t-1})}{P_t Y} \tag{27}$$

2.4 Equilibrium in a Small Open Economy

In equilibrium we will have that firms meet the demand at selected prices clearing the market in both sectors. The following condition must hold:

$$Y_{N,t} = C_{N,t} + \tfrac{\psi}{2}(\tfrac{\pi_{N,t}}{\overline{\pi}_N} - 1)^2 Y_{N,t} \tag{28}$$

$$Y_{h,t} = C_{h,t} + C^*_{h,t} + \tfrac{\psi}{2}(\tfrac{\pi_{h,t}}{\overline{\pi}_h} - 1)^2 Y_{h,t} \tag{29}$$

Real GDP aggregates tradable and nontradable production weighted by the relative prices:

$$Y_t = \frac{P_{h,t}}{P_t} Y_{h,t} + \frac{P_{N,t}}{P_t} Y_{N,t} + I_t \tag{30}$$

Total labor supply must be equal to labor demand and the same holds for effective capital supply and demand which gives:

$$L_t = L_{N,t} + L_{h,t} \tag{31}$$

$$K_t = K_{N,t} + K_{h,t} \tag{32}$$

To complete the model we introduce a monetary policy rule. Our small open economy is part of the European Monetary Union and we assume that the European Central Bank follows a simple Taylor rule with the union price index as a target:

$$R_t = R_{t-1}^{\rho_r} \left(\frac{\Pi_t^{EMU}}{\Pi^{EMU}} \right)^{(1-\rho_r)\rho_\pi} \tag{33}$$

where Π^{EMU} is the union inflation rate. $\Pi^{EMU} = \Pi_t^{\gamma_{ips}} (\Pi_t^*)^{1-\gamma_{ips}}$ where γ_{ips} is the relative economic size of our domestic economy in the monetary union.

2.5 Anticipated shocks

During the exposition we showed that the model is driven by nine sources of innovations: preference shocks; tradable, non tradable and common to both sectors technology shocks; permanent shifts in level of productivity; investment specific shocks; labor supply shocks; monetary policy and uncovered interest parity innovations;

For each of these shocks we introduce unanticipated, one-year anticipated and long term anticipated (10-quarters) components.[18] The choice of one year anticipation comes from the fact that we learned from Schmitt-Grohe & Uribe (2012) that anticipation close to one year can account for more than 35% of the variance of output growth. We also introduce long term expected shocks because we want to understand the importance of agents anticipation in the first quarter of 1996 of the euro implementation happening 3 years later.

Following closely the cited paper, if $x_t = \rho_x x_{t-1} + u_t^x$ identifies a general exogenous process, we assume that the error terms follows the structure:

$$u_t^x = u_{0,t}^x + u_{4,t-4}^x + u_{10,t-10}^x \tag{34}$$

where, for example, $u_{4,t-4}^x$ is a realization of the shock today that was learned one year ahead. For a full and detailed exposition of this method of introducing anticipated shocks we cross-refer to section 3 of Schmitt-Grohe & Uribe (2012).

2.6 Detrending Equilibrium Conditions

The system of equilibrium conditions of the model is non stationary. The deterministic trends included in both the sector productivities and the labor-augmenting technology make some variable of the model growing as time elapses. To be able to use standard solution techniques, we need to de-trend the model.

We define $Z_t = \frac{X_t}{X_{t-1}}$ to be the growth rate of the real aggregate variable and $Z_t^j = \frac{X_t A_{j,t}}{X_{t-1} A_{j,t-1}}$ to be the sector specific growth rate. In appendix C the full list of detrended equilibrium conditions is available but, for instance, the production in the two sectors can be made stationary by defining new variables:

$$\widetilde{Y}_{N,t} = \frac{Y_{N,t}}{X_t(1+g^N)^t} = \widetilde{A}_{N,t} Z_t^{-\alpha} \widetilde{K}_{N,t}^{\alpha} L_{N,t}^{1-\alpha} \tag{35}$$

and

$$\widetilde{Y}_{h,t} = \frac{Y_{h,t}}{X_t(1+g^h)^t} = \widetilde{A}_{h,t} Z_t^{-\alpha} \widetilde{K}_{h,t}^{\alpha} L_{h,t}^{1-\alpha} \tag{36}$$

where $\widetilde{K}_{j,t} = \frac{K_{j,t}}{X_{t-1}}$ and $\widetilde{A}_{j,t}$ is defined by equations 12 and 14.

3 Model Estimation

We rely on Bayesian techniques to estimate a subset of key parameters of the model for which there is both theoretical and empirical controversy. The main advantage of using Bayesian methods, with respect to classical ones, is that a meaningful set of priors allows to reduce the problem of short sample data. Two are the main purposes of the estimation procedure: finding the values of the elasticities and understanding the role of anticipated shocks in the EMU business cycle. For

[18] We just exclude monetary policy shocks because it is hard to think of anticipated shocks to the policy rule which are not already included in the anticipated borrowing risk premium shock.

the remaining parameters we use standard calibration methods, which is the same as assigning infinitely tight priors, because we are confident with the values previously assigned in the literature. Furthermore this simplifies the comparison of our results with previous studies.

In this section we start by describing the data used to estimate the model and the set of calibrated parameters. Following, we present the prior distribution and compare it with the estimated posterior. Those values are then used in the next section for the impulse-response analysis.

3.1 Data

Given our interest in the European Monetary Union we should be looking at data starting in January 1, 1999. Instead we consider the first quarter of 1996 as the first observation. Following Rabanal (2009) we assume that agents started to act as if they were in the EMU around 1996. We argue that this choice is even conservative, if something. On December 15-16, 1995, during the Madrid meeting, the European Council decided the name of the future common currency, the euro, and the timeline of the transition to a single currency. Given our interest in estimating the importance of anticipation on the behavior of agents, we argue that setting the first quarter 1996 as a starting point should be considered as a safe choice.

We pick the last quarter of 2007, the beginning of the Great Recession as the end of our sample. We claim that it is important to focus on the pre-crisis period to understand why imbalances were actually accumulated without being influenced by the peculiarities of the crisis episode. Linking the sources of the accumulating imbalances before the crisis and the reaction of the economy (and of current account) during the crisis is an interesting future question which will not be addressed in this paper. So we focus on the period between 1996:1 to 2007:4.

As shown in figure 1(a) Ireland, Portugal and Spain experienced a similar dynamics of the current account. Notice that following the construction of our model we should present the current account position only vis-a-vis the rest of the monetary union. Even if these data are not readily available, we claim that the analysis for Spain and Portugal would not be significantly different. Using intra EU-12 trade balances as a proxy for intra euro area current account, as suggested by Ahearne, Schmitz & von Hagen (2008), the picture doesn't change. Concerning Ireland we are aware of the importance of extra EMU trade (UK and USA), but we still include it in the analysis because more that 40 per cent of the inflows of capital (share of FDI by partner countries) are coming from the EMU partners. During the period under consideration IPS experienced similar dynamics of real exchange rate (with respect to EMU countries) and output growth. Accordingly throughout the estimation we focus on a weighted average of these 3 countries using European Central Bank HCPI as weights.

We estimate the model using quarterly frequency for nine time series: growth rate of real GDP, growth rate of non tradable real output, change in the average weekly hours worked, growth rate of real consumption, growth rate of real investment, current account as a fraction of GDP, non tradable HICP inflation, the real exchange rate within EMU partners and 3-month money market interest rates for euro area countries. Following Beltran & Draper (2008) we also include in the estimation

Table 1: Observable Variables and Model counterparts

Observable variable	Model counterpart	Adjusting factor
Real GDP growth IPS	$\Delta\widetilde{y}_t$	z
Non tradable real GDP growth IPS	$\Delta\widetilde{y}_{N,t}$	z + g^{NT}
Real consumption growth IPS	$\Delta\widetilde{c}_t$	z
Real Investment growth IPS	$\Delta\widetilde{I}$	z
Current account ($\%GDP$)	$\Delta\widetilde{ca}_t$	z
3-month money market interest rate	r_t	$log(r_{SS})$
NT HICP inflation IPS	$\widetilde{\pi}_{N,t}$	$\pi_{IPS} - g^{NT}$
Δ Real exchange rate w/EMU partners	$\Delta\widetilde{q}_t$	$\pi_{EMU} - \pi_{IPS} + g^{NT}$
Change avg weekly hours worked	ΔL_t	
EMU(-IPS) T HICP inflation	$\widetilde{\pi}_{f,t}$	$\pi_{EMU} - g^{T*}$
EMU(-IPS) HICP inflation	$\widetilde{\pi}^*_t$	π_{EMU}
EMU(-IPS) Real foreign consumption growth	$\widetilde{c}^*_t$	z^*

3 time series coming from the exogenous foreign economy block, after having subtracted the IPS group, as unrestricted autoregression: HICP EMU(-IPS) inflation, foreign tradable HICP EMU(-IPS) inflation and foreign growth rate of real consumption. We assume that foreign observables are generated by the following processes:

$$\Pi^*_t = \rho_{\pi^*}\Pi^*_{t-1} + u^{\Pi^*} \qquad \Pi^*_{T,t} = \rho_{\pi^*_T}\Pi^*_{T,t-1} + u^{\Pi^*_T} \qquad \text{and} \qquad c^*_t = \rho_{c^*}c^*_{t-1} + u^{c^*}$$

where u^{Π^*}, $u^{\Pi^*_T}$ and u^{c^*} are independent and identically distributed random errors. Details on the data are available in appendix A.

Table 1 list the 12 observable variables and their model counterpart. Notice that the third column identifies the adjusting factor between the data and the model generated data that corresponds to the detrending factor. In fact x and g^j are the coefficient estimates on time when we fit a linear trend to the natural logarithm of the trending variable. To clarify, we obtain x fitting a linear trend to $ln(Y_t)$ using an ordinary least square regression:

$$\widetilde{y}_t = logy^{data}_t - x_0 - xt = u^X_t \tag{37}$$

If we were in a deterministic world x would be the difference between the growth rate of the output in the real data and in the model:

$$\Delta y^{data}_t - \Delta\widetilde{y}_t = x \tag{38}$$

3.2 Calibrated parameters

Table (2) summarizes the values and the sources of the calibrated parameters. We follow the estimation results of Smets & Wouters (2003) for different parameters. v, the inverse elasticity of work effort with respect to the real wage, is set equal to 1. The depreciation rate, δ, is 0.025 per quarter, implying a 10 per cent annual depreciation of capital. The monetary policy has a high degree of interest rate smoothing, $\rho_r = 0.94$, and strongly reacts to deviation of inflation from the target level, $\rho_\pi^{EMU} = 1.658$.

The discount factor is endogenous and following Ferrero et al. (2008) we arbitrarily set $\chi^\beta = -100$ and then calibrate $\psi = 1.0174 \cdot 10^{-4}$ in order to ensure the steady state value of the discount factor equal to 0.99. In this way we ensure that the endogeneity of the discount factor does not significantly influence the medium term dynamics of the model.

As in Faia & Monacelli (2008) we set the elasticities of substitution between varieties in the same sector, θ and ϕ, equal to 7.5 implying a steady state markup of 15 percent. Using the log linearized version of the pricing equations we get that the elasticities of inflation with respect to the real marginal cost are respectively $\frac{\theta-1}{\psi}$ and $\frac{\phi-1}{\psi}$. We can compare those with the slope of the Phillips curve we would get using a Calvo approach, $\frac{(1-p)(1-\beta p)}{p}$ where p is the probability of not being able to reset prices. Assuming as in Angeloni, Aucremanne, Ehrmann, Gal, Levin & Smets (2006) that $p = 0.75$ it implies that the price stickiness parameter, ψ, is around 76.

For the share of tradable and non tradable goods in the consumption basket, $\gamma_{N,t}$ and $\gamma_{T,t}$, we use Eurostat HCPI item weights data. In the IPS the average share of tradable goods for the period 1996:2007 is 65.6 per cent. This number is slightly lower when instead we consider the entire euro area, $\gamma_{T,t}^* = 60.6$ per cent. Focusing on the tradable good sector we find that the share of imported goods is around 33.9 per cent for the IPS countries.

The last parameter we calibrate, γ_{ips}, is the weight of Ireland Portugal and Spain on the average EMU inflation. We calibrate it using Eurostat HCPI country weights and we set the parameter to 13.4 per cent.

3.3 Prior Distributions

Some structural parameters are central for shaping the responses of the model to shocks. For some of those, a wide range of values, provided by empirical and theoretical studies, fail to give us a precise and reliable calibration. Therefore we perform a Bayesian estimation using values found by previous studies as references for priors. Table 3 summarizes the prior of the parameters that we use in the estimation.

The elasticity of substitution between home and foreign produced tradable, the trade elasticity ϵ, is a parameter for which the literature provides a large range of estimates. On one side there are microeconomic and trade studies that, using disaggregated data, estimate large values. The highest value is found by Broda & Weinstein (2006) that claims that the elasticity is decreasing over time and it ranges between 6.8 and 4, when we consider three-digit goods. On the other side the international macroeconomic literature, which relies on aggregated data, finds much lower values. Taylor (1999) estimates a long run elasticity of 0.39. Empirical literature was recently enriched with theoretical studies that showed that implied low trade elasticity could help explaining the Backus

Table 2: Calibrated Parameteres

Par	Value	Description	Source
v	1	Inverse elasticity of labor supply	Smets & Wouters (2003)
χ	-10000	Discount factor, arbitrary parameter	Ferrero et al. (2008)
ψ^{β}	$1.011 \cdot 10^{-5}$	Spillover effect of avgerage detrended consumption on discount factor	Steady-state of $\beta = 0.99$
ψ^{L}	11.9783	Labor supply preference parameter	Ensures $L^{ss} = 0.236$, Eurostat 96/07
θ	7.5	Elasticity between non tradables	Faia & Monacelli (2008)
ϕ	7.5	Elasticity between tradables	Faia & Monacelli (2008)
ψ	75.73	Price stickiness	Faia & Monacelli (2008)
δ	0.025	Depreciation of capital	Smets & Wouters (2003)
$\gamma_{T,t}$	0.656	Proportion of goods in IPS HICP	Eurostat 1996-2007
$\gamma^{*}_{T,t}$	0.606	Proportion of goods in EMU HICP	Eurostat 1996-2007
$\gamma_{f,t}$	0.3	Degree of openess	Eurostat 1996-2007
$\frac{IM}{Y}$	0.339	Average share of Imports on GDP	Eurostat 1996-2007
γ_{ips}	0.134	Average weight of IPS wrt EMU	Eurostat 1996-2007
ρ_r	0.94	AR interest rate	Smets & Wouters (2003)
ρ_{π}^{EMU}	1.658	Taylor rule inflation	Smets & Wouters (2003)

and Smith puzzle[19] (Corsetti, Dedola & Leduc (2008) and Benigno & Thoenissen (2008)) and the volatility of the real exchange rate (Thoenissen (2011)).[20] We use both field findings to limit the prior distribution with boundaries: 0.36 as the lower bound and 6.8 as the upper bound. Then we use a normal distribution with mean 1.5 (the most used value in calibrated exercise) and standard deviation of 1.

The other central parameter is the elasticity of substitution between tradable and non tradable goods, η. Although the range of values suggested by previous studies is non trivial, there is more consensus on its value. Mendoza (1991), focusing on a set of industrialized countries, finds a value of 0.74 while Stockman & Tesar (1995) estimate a lower elasticity of 0.44. Rabanal & Tuesta Retegui (2007) in a model made to understand the role of the non tradable goods for the dynamics of the real exchange rate estimate the parameter to be 0.13. Combining this information we set a gamma prior distribution with mean 0.5 and standard deviation 0.1.

We include three further parameters in the estimation: consumption habit, capital adjustment cost elasticity and capital utilization rate elasticity. Following the fact that habit in consumption choices can only take values between zero and one, we set a beta prior distribution with mean 0.5 and standard deviation of 0.1. Following Smets & Wouters (2003) we assume that the capital adjustment cost elasticity, η_k, is normally distributed with mean 4 and a wide standard deviation of 1.5. Finally, for the capital utilization rate elasticity we define a variable $\overline{\eta}_v$ such as $\eta_v = \frac{1-\overline{\eta}_v}{\overline{\eta}_v}$ and estimate the new variable assuming a beta distribution with mean 0.5 and standard deviation

[19]Backus et al. (1993)

[20]The list of cited studies is far from being complete. It has the purpose of giving a sense of the extremes of those estimates and some reference.

0.1.

For the set of priors on the autoregressive component and the volatilities of shocks we follow a common practice in the estimated DSGE models. The autoregressive coefficients of anticipated and unanticipated shocks are assumed to be beta distributed with prior mean of 0.7. The standard deviation of shocks have a gamma distribution with mean 0.7 and standard deviation of 0.3. As presented previously, we focus on unanticipated, four-quarters anticipated and ten-quarters anticipated shocks. For all these anticipation length we assign the same prior.

Table 3: Prior and Posterior Distribution

			Prior			Posterior	
		Distr.	Mean	St. Dev	Mean	Lower	Upper
Estimated Parameters							
η	T Vs NT	*Gamma*	0.500	0.1	1.2284	1.0462	1.3700
ϵ	home VS foreign	*Norm*	1.500	0.5	2.0974	1.9675	2.2312
h	habit formation	*Beta*	0.500	0.1	0.9421	0.9294	0.9529
$\overline{\eta}_v$	Utilization rate elast	*Beta*	0.500	0.1	0.3468	0.2320	0.4842
η_k	Capital adj cost elast	*Norm*	4.000	1.5	5.1000	4.2521	5.8973
AR Coefficients							
ρ_{A_h}	T Techn	*Beta*	0.7	0.1	0.7754	0.7174	0.8490
ρ_{A_N}	NT Techn	*Beta*	0.7	0.1	0.4754	0.4108	0.5319
ρ_ζ	Preference	*Beta*	0.5	0.1	0.5345	0.4176	0.6472
$\rho_{\epsilon_r b}$	Risk Prem	*Beta*	0.7	0.1	0.4847	0.3904	0.5606
ρ_{ϵ_I}	Invest	*Beta*	0.7	0.1	0.5301	0.4335	0.6197
ρ_{ϵ_L}	Labor	*Beta*	0.7	0.1	0.5632	0.4491	0.7018
Standard Deviation							
$\sigma_{u^A_{0,t}}$	Common Techn	*Gamma*	0.7	0.3	0.0815	0.0326	0.1279
$\sigma_{u^{Ah}_{0,t}}$	T Techn	*Gamma*	0.7	0.3	0.2468	0.1761	0.3161
$\sigma_{u^{An}_{0,t}}$	NT Tech	*Gamma*	0.7	0.3	0.1977	0.1224	0.2784
$\sigma_{u^\zeta_{0,t}}$	Preference	*Gamma*	1	0.5	0.1085	0.0396	0.1727
$\sigma_{u^{Risk}_{0,t}}$	Risk Prem	*Gamma*	0.7	0.3	0.1342	0.0575	0.2042
$\sigma_{u^I_{0,t}}$	Invest	*Gamma*	0.7	0.3	0.5451	0.4049	0.6869
$\sigma_{u^L_{0,t}}$	Labor	*Gamma*	0.7	0.3	0.1069	0.0250	0.1830
$\sigma_{u^r_{0,t}}$	Int rate	*Gamma*	0.7	0.3	0.2461	0.2053	0.2844
$\sigma_{u^X_{0,t}}$	Trend shock	*Gamma*	0.7	0.3	0.0086	0.0063	0.0111
$\sigma_{u^A_{4,t}}$	Ant Common Techn	*Gamma*	0.7	0.3	0.0852	0.0363	0.1353
$\sigma_{u^{Ah}_{4,t}}$	Ant Ah	*Gamma*	0.7	0.3	0.1233	0.0531	0.1957
$\sigma_{u^{An}_{4,t}}$	Ant An	*Gamma*	0.7	0.3	0.1393	0.0558	0.2223
$\sigma_{u^\zeta_{4,t}}$	Ant ζ	*Gamma*	1	0.5	0.0966	0.0330	0.1580
$\sigma_{u^I_{4,t}}$	Ant I	*Gamma*	0.7	0.3	0.3099	0.1968	0.4058
$\sigma_{u^L_{4,t}}$	Ant L	*Gamma*	0.7	0.3	0.1789	0.0371	0.3169
$\sigma_{u^{Risk}_{4,t}}$	Ant Risk Prem	*Gamma*	0.7	0.3	0.1180	0.0514	0.1808
$\sigma_{u^X_{4,t}}$	Ant Trend shock	*Gamma*	0.7	0.3	0.0076	0.0052	0.0102
$\sigma_{u^A_{10,t}}$	Ant Common Techn	*Gamma*	0.7	0.3	0.0917	0.0449	0.1374
$\sigma_{u^{Ah}_{10,t}}$	Ant Ah	*Gamma*	0.7	0.3	0.1409	0.0595	0.2168
$\sigma_{u^{An}_{10,t}}$	Ant An	*Gamma*	0.7	0.3	0.1291	0.0572	0.2006
$\sigma_{u^\zeta_{10,t}}$	Ant ζ	*Gamma*	1	0.5	0.1028	0.0381	0.1614
$\sigma_{u^I_{10,t}}$	Ant I	*Gamma*	0.7	0.3	0.2978	0.1985	0.4041
$\sigma_{u^L_{10,t}}$	Ant L	*Gamma*	0.7	0.3	0.1801	0.0588	0.2981
$\sigma_{u^{Risk}_{10,t}}$	Ant Risk Prem	*Gamma*	0.7	0.3	0.1708	0.1150	0.2298
$\sigma_{u^X_{10,t}}$	Ant Trend shock	*Gamma*	0.7	0.3	0.0076	0.0052	0.0101

3.4 Posterior Distribution

Table 3 presents the posterior distribution mean, standard deviation and 90 percent posterior intervals for the estimated parameters. The statistics are computed using the last 40 percent of 1.4 million draws generated with a random walk Metropolis Hastings chain algorithm.

The estimated posterior mean of the elasticity of substitution between home and foreign produced tradable goods, ϵ, is 2.1 which is almost twice η, 1.23, the elasticity of substitution between tradable and non tradable goods. Figure 3 shows the prior and posterior density function of the two elasticities. A trade elasticity of roughly 2, although it is still below the value found by trade theorist, is much closer to microeconomic estimates than previous macroeconomic studies. One of the reasons why this value is higher has to do we our focus on peculiar area: the European Monetary Union. Not surprisingly, following the reasoning of Lubik & Schorfheide (2006), in a monetary union with a higher satisfaction of the law of one price, home and foreign tradable output are more responsive to movements in relative prices.

Focusing on more standard parameters, the elasticity of capital utilization, 0.35, and capital adjustment cost, 5.1, are consistent with other studies. Habit formation in consumption is estimated to be 0.94, which is only slightly higher than the value found by Burriel, Fernndez-Villaverde & Rubio-Ramrez (2010a) for Spain in a similar timespan.

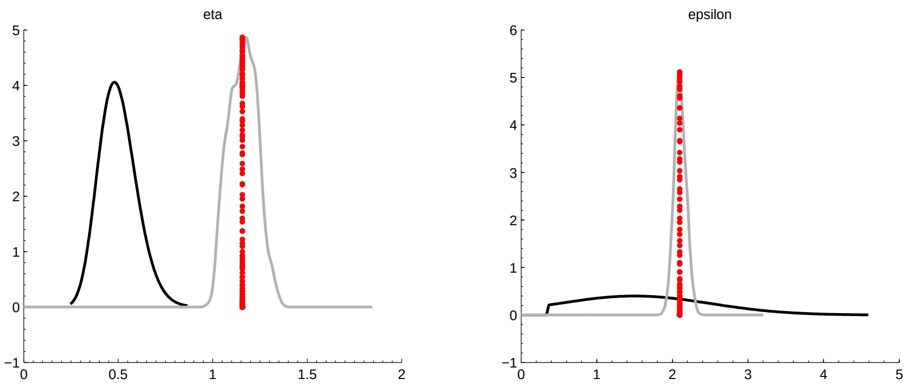


Figure 3: Prior and Posterior density

The autoregressive parameters of the innovation processes are not very persistence. This could be due to the fact that the model is able to endogenously generate a sufficient degree of persistence with respect to the data without the need to rely on strong autoregressive shocks. The estimated process for the productivity shock is more persistent in the tradable, 0.76, than in the non tradable sector, 0.48.

Tradable and non tradable sectors are mostly driven by sector specific shocks and not by innovations that hit both sectors contemporaneously and equally. Innovations common to both sectors are estimated to have a significantly smaller standard deviations than sector specific shocks: 0.081 the unanticipated component, 0.085 the one year ahead component and 0.092 the ten quarters ahead innovation. In the tradable and non tradable home sectors, the sum of the two standard deviations of the anticipated shock is slightly bigger than the one of the unanticipated innovation. Notice, and we will see it more clearly in the next section, that anticipated innovations, in particular the ten-quarters anticipation, play an important role for almost all shocks.

4 Which structural shock can explain current account imbalances?

Ireland, Portugal and Spain, during the period under investigation, were accumulating current account deficit, experiencing real exchange rate appreciation and growing slightly above trend (figure 2).[21] The goal of the paper is to investigate which structural shock, anticipated or unanticipated, can reproduce a similar pattern of those three key variables. We start by looking at the impulse response to different shocks and we claim that to be considered a major source of the imbalances the shocks need to induce a reaction of current account, real exchange rate and GPD growth similar to the one presented in figure 2. We then try to understand the role played by anticipated shocks for the volatility of those three variables. In order to disentangle the importance of each shock, we decompose the variance of international and domestic variables in the amount of information that each unanticipated and anticipated innovation adds.

4.1 Impulse Response

We study the dynamics of the model in response to a wide range of possible shocks for the estimated parametrization. For every shock we consider the unanticipated component but we also allow for the possibility that agents learn in advance about the shock that will come true only in the future. In this section we look at the baseline model with separable utility function and complete information in which agents perfectly forecast the future. Later we relax these two assumptions: in section 5.1 we show how the results change when we use a preference specification that allows us to control for the wealth elasticity of labor supply and in section 5.2 we assume imperfect information and slow learning by agents of the true technology process.

Sector specific technology, common productivity, permanent shift in the level, investment cost, monetary policy, risk premium, preferences and labor supply are the shocks we consider in our specification. For each shock we try to understand if it could be considered a possible source of the current account imbalance experienced by Ireland, Portugal and Spain.

As in Giavazzi & Spaventa (2010) and Eichengreen (2010), we have in mind a distinction between types of current account imbalances depending on their trigger. Some are driven by growth differentials that allow surplus countries to invest in future growth of the borrowing countries and others are triggered by other factors. We would define good, or intertemporal efficient, imbalances

[21] Notice that periods in which the current account deficit increase coincides with periods in which the output grows above trend. In fact, during 2002 and 2003 GDP was growing below trend and IPS were experiencing a reduction in the deficit.

resulting from a deeper financial integration that allows countries with better growth prospect to borrow from abroad in order to undertake profitable investments and to increase their consumption due to the anticipated wealth effect. In a way it is like saying that good imbalances are the ones that come from borrowing using future growth as collateral. If we believe in this definition, it is not difficult to understand why we think of anticipated productivity shocks as the main source of good imbalances. In this section we want to theoretically test if the imbalances experienced by the IPS inside the EMU could be driven by unanticipated as well as anticipated productivity shocks.

We first present, in detail, the response of the model to an unanticipated shock in technology. This will allow us to highlight the forces behind the movements of the variables that will characterize also all other shocks. Then, we focus on the reaction of output growth, current account and real exchange rate to all considered shocks trying to understand which shock could generate a picture similar to figure 2.

Figure 4 shows a one standard deviation unanticipated shock in the tradable sector. Consumption and investment co-move resulting in output growing above trend. Tradable marginal costs of production decrease and due to the stickiness of prices and the imperfect substitutability of goods, tradable firms have excessive production. This pushes their prices and the demand for labor and capital down. Wages and cost of capital decrease generating a reduction in the marginal costs also in the non tradable sector. As a result prices go down in both sectors and the real exchange rate depreciates. Home produced tradable goods are now also internationally more competitive through a term of trade depreciation.[22] The current account deteriorates due to the fact that the increase in wealth, resulting in increase in consumption and investment, exceeds the increase in exports due to the gained comparative advantages. However, notice that a sectoral Balassa-Samuelson effect is still active: non tradable goods become relatively more expensive than tradable goods. Everything works in a very similar fashion when the shock is specific to the non tradable sector. The differences are that now the non tradable goods will become relatively cheaper with respect to the tradable goods and that, given the smaller weight of the non tradable sector in the economy, the increase in exports will exceed the increase in wealth, turning current account in surplus. We conclude that unanticipated sector specific productivity shock (but also a common shock to both sectors, for the same reasoning) leads to terms of trade and real exchange rate depreciation.

[22]As we will see later the high elasticity of substitution between tradables and between tradables and non tradables make sure that the mechanism presented by Corsetti et al. (2008), for which a productivity increase could generate a terms of trade appreciation, does not play a role in this framework.

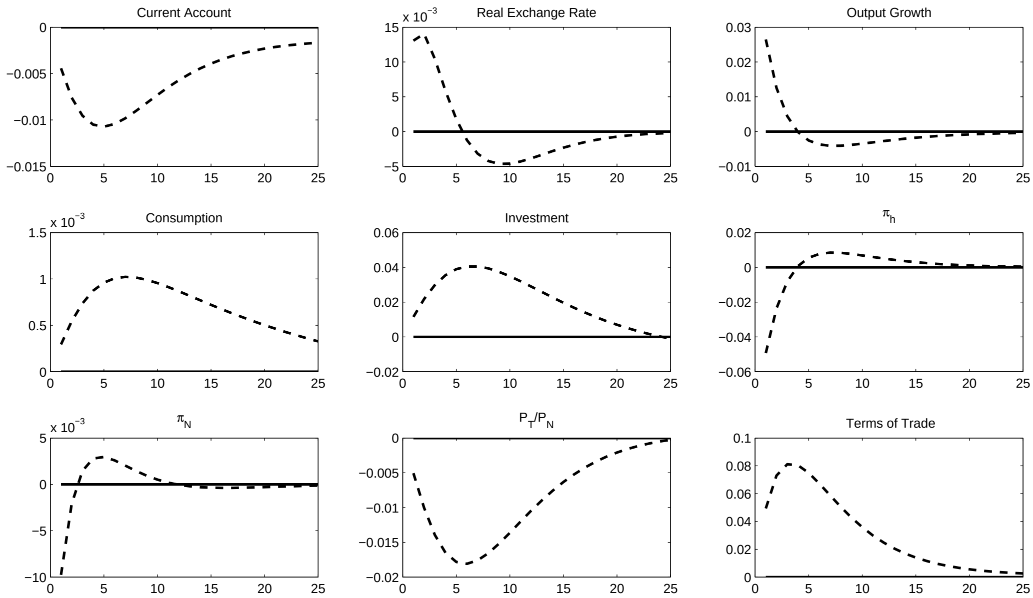


Figure 4: Impulse response to an unanticipated tradable sector technology shock

With the underlining forces in mind, we now focus on output growth, current account and real exchange rate. Figure 5 summarizes the responses of those three variables to a one standard deviation shock to all possible productivity innovation included in the model. The left column of the picture shows the responses to unexpected shocks while the right column focuses on long term anticipated shocks. Starting from the first line and moving vertically we look at a sector specific shock in the tradable and non tradable sector, a common shock in both sectors and a permanent shift in the level of technology. As we can see, none of the productivity shock considered can reproduce the correlation between the responses of those variables, needed to replicate figure 2.

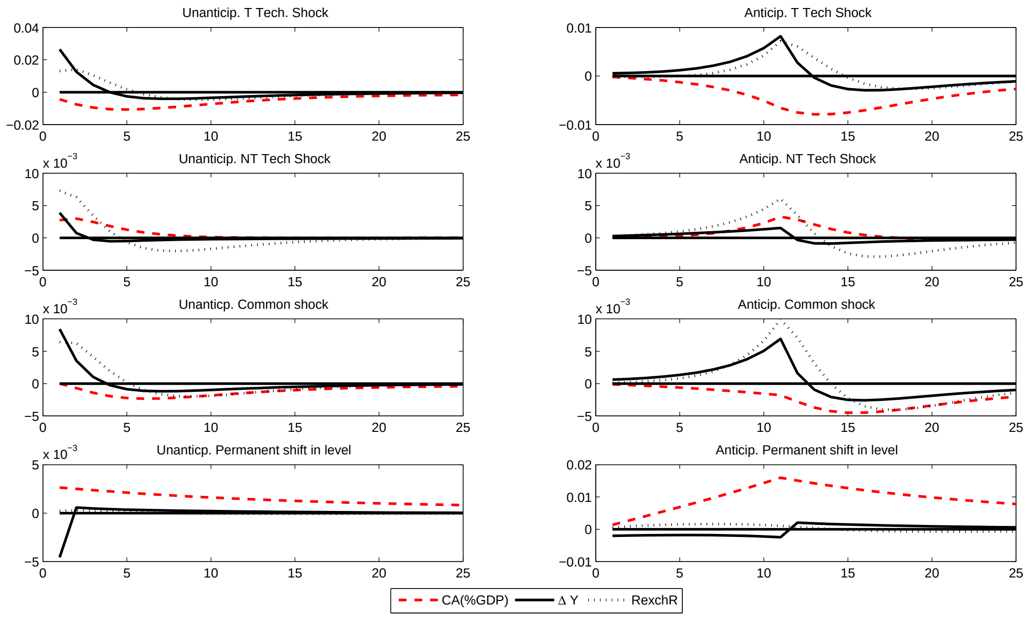


Figure 5: Impulse response of CA, GDP and RER to technology shocks

The main problem comes from the inability of the model to generate a real exchange rate appreciation as a response to just a positive technology shock. In fact, for the estimated parametrization, we cannot rely on a low price elasticity of tradable goods that induce, through market clearing, a strong wealth effect that pushes the increase in demand above the increase in supply of goods. As shown by Corsetti et al. (2008) the most important parameter governing the wealth effect is the elasticity of substitution between domestic and foreign tradable goods. We show in figure 6, that keeping the calibration and estimation of the other parameters fixed, the model is unable to generate a real exchange rate appreciation, as a response to an unanticipated common technology shock, for any value of the elasticity in the range considered as plausible by previous studies. An increase in the efficiency of production in our framework always leads to a decrease in the marginal cost (expected in the case of anticipated shock) that pushes prices down. Being part of a monetary union implies that the nominal exchange rate is fixed. Because of that all the movements go directly to the real exchange rate and the terms of trade. On the other hand notice from the same picture that the range of parameters for which the current account becomes negative in response to a positive technology shock (common to both sectors) is pretty wide. Current account reacts positively when goods are more substitutable and it reacts negatively if they are complement goods. As shown by Corsetti et al. (2008), in the presence of a marginal cost advantage with highly substitutable tradable good, exports increase more than imports generating a surplus, while, in the case of complement goods, the wealth effect increases consumption more than production generating current account deficit.

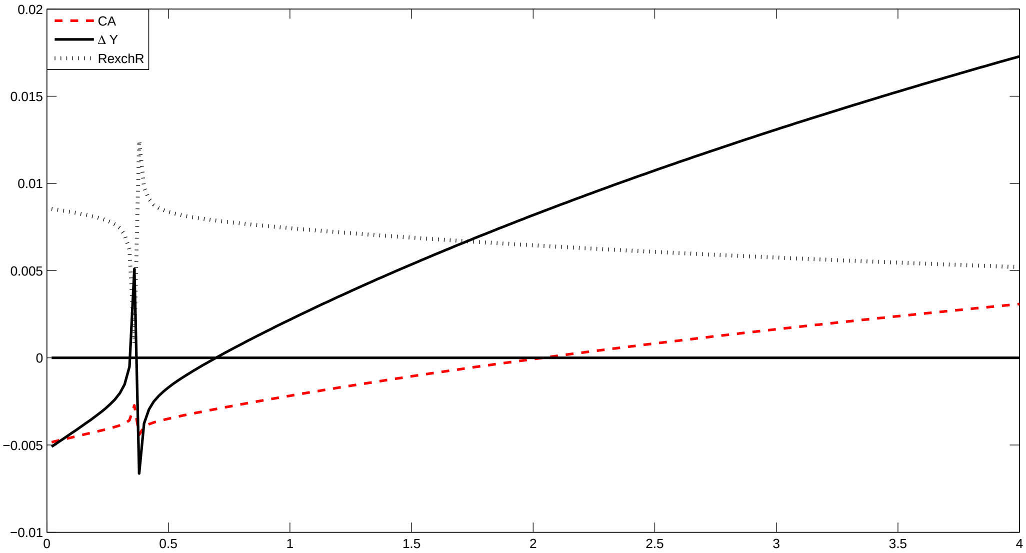


Figure 6: Response of CA,GDP and RER to a common technology shock with varying ϵ

Figure 7 summarizes the dynamics of the model in response to a drop in the risk premium, (RP_t), an increase in household preferences for consumption, (ϵ^{ζ_t}), a positive increase of investment technology, ϵ^I and finally a labor supply shock, ϵ_t^L. Investment shock, as the productivity shock just considered, does not generate a real exchange rate appreciation. Labor supply moves current account and real exchange in the right direction but induces output growing below trend. Leaving aside the preference shock, due to the lack of clear interpretation, the most interesting results seem to come from the anticipated drop in the risk premium: current account deteriorates, real exchange rate appreciates and output grows slightly above trend. The interesting pattern is that current account starts to deteriorate and stays persistently in deficit position. The real exchange rate keeps appreciating until the risk premium shock realizes.

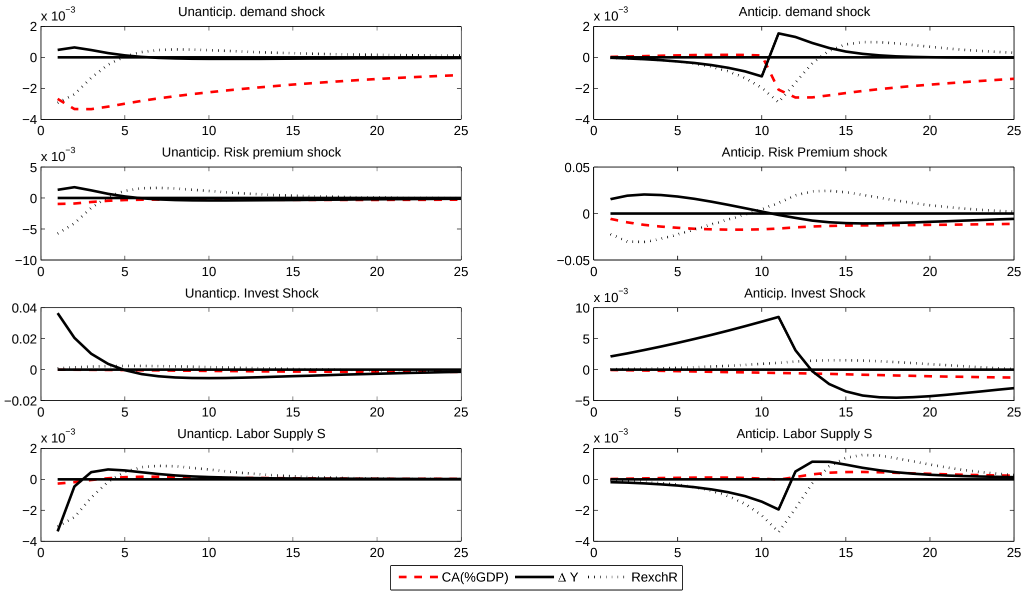


Figure 7: Demand vs interest rate vs investment

An anticipated drop in risk premium can be plausibly interpreted, from a model perspective, as an expected decrease in the "risk free rate" that the IPS had to pay on domestic borrowing. Figure 8 shows that this is a plausible assumption: the 3 months Euro Inter Bank offered rate shows a strong and persistent decrease. If at least some of this decrease was coming from following anticipated shocks, which in our opinion is a sensible assumption, we could easily replicate the path of the output growth, current account and real exchange rate experienced by Ireland Portugal and Spain. In fact, if in 1996 agents in Ireland, Portugal and Spain were expecting that the introduction of a common currency would decrease persistently the cost of borrowing the path of current account balance, real exchange rate and output would have followed a similar path to the one experienced in reality.

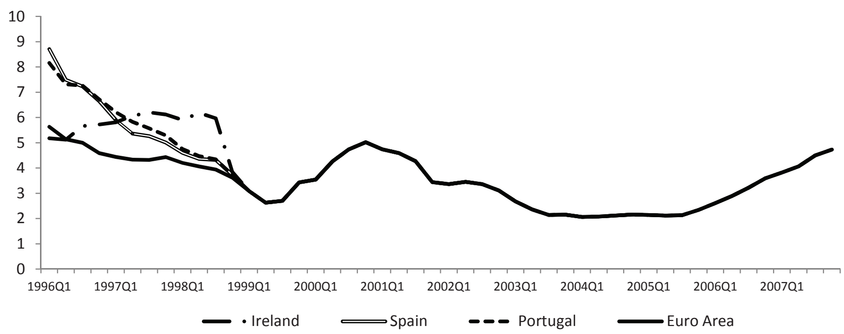


Figure 8: 3 months interest rate

4.2 The importance of anticipated shocks

Anticipated shocks were proved to be important for explaining business cycle fluctuations. We are now interested in understanding the importance of anticipated shocks for a set of international variables crucial for external imbalances. Following the methodology proposed by Schmitt-Grohe & Uribe (2012), we investigate the importance of unanticipated and anticipated shocks on output growth, current account and real exchange rate.

Table 4 presents the contribution of all shocks to the variance of those three variables. Summing up the impact of all anticipated shocks we get that news shock account for 54 percent of output growth fluctuations, 40 percent of real exchange rate variability and 86 percent of current account movements.

Anticipated innovations explain the majority of the output cycle, although we get a value below the 70 percent found by Schmitt-Grohe & Uribe (2012). On the other hand, the main difference with respect to their result is that we find three main components generating those fluctuations: risk premium shocks, 34 percent, investment specific shocks, 31 percent, and productivity shocks, 18 percent. Productivity is mainly driven by shocks in the tradable sector and in particular by the unanticipated component.

The role of anticipated shocks is somewhat reduced when we consider real exchange rate fluctuations. The major anticipated component playing a role is the 10-quarters anticipated drop in the risk premium. Unanticipated components are the main driving forces of the swings in international relative prices. It is not surprising that almost 10 percent of the cycle is explained by the shocks in the exogenous processes governing foreign prices. Unanticipated monetary policy shocks also explain an important fraction of the fluctuations. Notice although, that in our framework the difference between risk premium shocks and monetary policy shocks is not well defined and then it is hard to economically interpret the result.

The most striking result is that only two shocks can explain almost all current account fluctuations: 10-quarters anticipated permanent shifts in the level of productivity and 10 quarters anticipated shock in the risk premium. Permanent productivity jumps account for a little more than 10 percent, with pretty much the same contribution of unanticipated and anticipated innovations. Investment, labor and preference shocks, once we include risk premium, explain a minor fraction of current account fluctuations.

Even if these results are not conclusive, they point in the same direction of the impulse-response analysis. Anticipated long run fluctuations in the risk premium, for the estimated SOE, are probably the most important sources of the current account imbalance experienced inside the IPS.

Table 4: Unconditional Variance Decomposition

Shock	Δy	ca/gdp	Δq
$u_{0,t}^{A}$	0.0091	0.002	0.0152
$u_{4,t}^{A}$	0.0135	0.0062	0.0149
$u_{10,t}^{A}$	0.0153	0.0113	0.0169
Σu^{A}	0.0379	0.0195	0.0470
$u_{0,t}^{AH}$	0.0955	0.0397	0.0651
$u_{4,t}^{AH}$	0.0131	0.0135	0.0052
$u_{10,t}^{AH}$	0.0197	0.0291	0.0086
Σu^{AH}	0.1283	0.0823	0.0789
$u_{0,t}^{AN}$	0.0016	0.0003	0.0198
$u_{4,t}^{AN}$	0.0022	0.0008	0.0142
$u_{10,t}^{AN}$	0.0013	0.0003	0.0071
Σu^{AN}	0.0051	0.0014	0.0411
$u_{0,t}^{X}$	0.0021	0.0041	0
$u_{4,t}^{X}$	0.0041	0.0541	0.0002
$u_{10,t}^{X}$	0.0063	0.2273	0.0003
Σu^{X}	0.0125	0.2855	0.0005
$u_{0,t}^{\zeta}$	0.0001	7.60E-03	3.00E-03
$u_{4,t}^{\zeta}$	0.0009	0.0053	0.0017
$u_{10,t}^{\zeta}$	0.0008	0.0045	0.0016
Σu^{ζ}	0.0018	0.0174	0.0063
$u_{0,t}^{L}$	0.0012	0	0.0035
$u_{4,t}^{L}$	0.0069	0.0003	0.0129
$u_{10,t}^{L}$	0.0014	0.0002	0.0024
Σu^{L}	0.0095	0.0005	0.0188
$u_{0,t}^{I}$	0.2084	0.0053	0.0006
$u_{4,t}^{I}$	0.0532	0.0026	0.0001
$u_{10,t}^{I}$	0.0529	0.0052	0.0001
Σu^{I}	0.3145	0.0131	0.0008
u_{t}^{r}	0.0976	0.0786	0.3967
$u_{0,t}^{Risk}$	0.0008	0.0003	0.0127
$u_{4,t}^{Risk}$	0.0197	0.0123	0.0569
$u_{10,t}^{Risk}$	0.3284	0.4857	0.2519
Σu^{Risk}	0.3489	0.4983	0.3215
$u_{t}^{\Pi_{T}*}$	0.0005	0.0002	0.0212
$u_{t}^{\Pi*}$	0.0007	0.0002	0.0666
u_{t}^{c*}	0.0426	0.003	0.0004
Σu^{*}	0.0438	0.0034	0.0882

5 Robustness checks

In this section we investigate the robustness of the results checking if they still hold for different specifications of the model. We first introduce Jaimovich and Rebelo type of preferences, which allow us to control for the wealth elasticity of the labor supply, and then, we weaken the assumption of perfect information of agents, researching if the result presented by Hoffmann et al. (2011) hold also for the EMU experience. We conclude with a reduced form of the model with labor as the only factor of production to allow the comparison with previous studies in which capital didn't play any role. For all three specifications of the model the results of the paper are robust.

5.1 Jaimovich and Rebelo preferences

Often, in theoretical models, an expected permanent shock in technology leads to a reduction in hours worked. Agents in fact anticipate the increase in wealth and increase the demand of normal goods such as leisure and consumption. The reaction of the labor dynamics is in contrast with the empirical evidence. To understand the role played by the wealth effect and to make sure that our results are not driven by the wrong behavior of the labor supply we substitute our utility function (equation 4) with the non separable specification introduced by Jaimovich & Rebelo (2009). This utility specification enables us to control the wealth elasticity of the labor supply. In particular we rely on the specification proposed by Hoffmann et al. (2011) that includes habit persistence in consumption choices and explicitly allows for a trend in the growth rate:

$$U(C_t, L_t) = \frac{\left\{(C_t - h\overline{C}_{t-1}) - \epsilon_t^L \psi^L L_t^{1+\nu} \Omega_t\right\}^{1-\sigma} - 1}{1-\sigma} \tag{39}$$

where

$$\Omega_t = (C_t - h\overline{C}_{t-1})^{\mu} \Omega_{t-1}^{1-\mu} (Z_t)^{1-\mu} \tag{40}$$

Utility depends on consumption at time t, C_t, a weighted component of average past consumption, $h\overline{C}_{t-1}$, and hours worked L_t. Notice that past average consumption is perceived as external by the maximizing household which does not take into account the effects of his decision on the accumulation of average consumption. Ω_t controls the wealth effect on labor supply through the parameter $\mu \in [0, 1]$. By just changing μ we can account for two important classes of utility function used in the business cycle literature: King, Plosser & Rebelo (1988) types of preferences (KPR henceforth) when $\mu = 1$ and Greenwood, Hercowitz & Huffman (1988) when $\mu = 0$ (GHH henceforth). The inclusion of $Z_t^{1-\mu}$, where $Z_t = \frac{X_t}{X_{t-1}}$, allows the model to account for the possibility of having a trend growing labor augmenting productivity X_t.[23]

[23] In Jaimovich & Rebelo (2009) they impose $\mu > 0$ in order to put some weight on the KPR preferences which are growth consistent. Given our focus on low values of μ the introduction of $(Z_t)^{1-\mu}$ allows us to avoid problems coming from highly persistent deviations from the steady state growth path.

Table 5: Prior and Posterior Distribution with JR preferences

			Prior			Posterior	
		Distr.	Mean	St. Dev	Mean	Lower	Upper
Estimated Parameters							
μ	wealth effect param	*Uniform*	0.500	0.3	0.0110	-0.0003	0.0216
v	elast labor supply	*Gamma*	1.400	1	5.6894	4.8901	6.3686
η	T Vs NT	*Gamma*	0.500	0.1	0.9343	0.8687	1.0073
ϵ	home VS foreign	*Norm*	1.500	0.5	2.0012	1.8333	2.1589
h	habit formation	*Beta*	0.500	0.1	0.9110	0.8973	0.9227
η_v	Utilization rate elast	*Beta*	0.500	0.1	0.1921	0.1682	0.2131
η_k	Capital adj cost elast	*Norm*	4.000	1.5	8.0591	7.2450	8.6886
AR Coefficients							
ρ_{A_h}	T Techn	*Beta*	0.7	0.1	0.9478	0.9183	0.9738
ρ_{A_N}	NT Techn	*Beta*	0.7	0.1	0.5957	0.5516	0.6433
ρ_ζ	Preference	*Beta*	0.5	0.1	0.6882	0.6520	0.7358
$\rho_{\epsilon_r b}$	Risk Prem	*Beta*	0.7	0.1	0.5034	0.4409	0.5727
ρ_{ϵ_I}	Invest	*Beta*	0.7	0.1	0.4985	0.3689	0.6138
ρ_{ϵ_L}	Labor	*Beta*	0.7	0.1	0.8154	0.7730	0.8472
Standard Deviation							
$\sigma_{u^A_{0,t}}$	Common Techn	*Gamma*	0.7	0.3	0.0434	0.0197	0.067
$\sigma_{u^{Ah}_{0,t}}$	T Techn	*Gamma*	0.7	0.3	0.2560	0.2115	0.3002
$\sigma_{u^{An}_{0,t}}$	NT Tech	*Gamma*	0.7	0.3	0.0776	0.0442	0.1109
$\sigma_{u^\zeta_{0,t}}$	Preference	*Gamma*	1	0.5	0.7317	0.5151	0.9326
$\sigma_{u^{Risk}_{0,t}}$	Risk Prem	*Gamma*	0.7	0.3	0.3190	0.2003	0.4191
$\sigma_{u^I_{0,t}}$	Invest	*Gamma*	0.7	0.3	0.5034	0.3650	0.6912
$\sigma_{u^L_{0,t}}$	Labor	*Gamma*	0.7	0.3	0.0466	0.0194	0.0728
$\sigma_{u^r_{0,t}}$	Int rate	*Gamma*	0.7	0.3	0.2470	0.2147	0.2805
$\sigma_{u^X_{0,t}}$	Trend shock	*Gamma*	0.7	0.3	0.0071	0.0052	0.0091
$\sigma_{u^A_{4,t}}$	Ant Common Techn	*Gamma*	0.7	0.3	0.0614	0.0293	0.0932
$\sigma_{u^{Ah}_{4,t}}$	Ant Ah	*Gamma*	0.7	0.3	0.0883	0.0463	0.1306
$\sigma_{u^{An}_{4,t}}$	Ant An	*Gamma*	0.7	0.3	0.1136	0.0433	0.1805
$\sigma_{u^\zeta_{4,t}}$	Ant ζ	*Gamma*	1	0.5	0.7438	0.3685	1.2024
$\sigma_{u^I_{4,t}}$	Ant I	*Gamma*	0.7	0.3	0.8078	0.6730	0.9529
$\sigma_{u^L_{4,t}}$	Ant L	*Gamma*	0.7	0.3	0.0337	0.0098	0.0584
$\sigma_{u^{Risk}_{4,t}}$	Ant Risk Prem	*Gamma*	0.7	0.3	0.2129	0.1177	0.3044
$\sigma_{u^X_{4,t}}$	Ant Trend shock	*Gamma*	0.7	0.3	0.0071	0.0052	0.0092
$\sigma_{u^A_{10,t}}$	Ant Common Techn	*Gamma*	0.7	0.3	0.0624	0.0311	0.0930
$\sigma_{u_{10,t}Ah}$	Ant Ah	*Gamma*	0.7	0.3	0.0922	0.0460	0.1342
$\sigma_{u_{10,t}An}$	Ant An	*Gamma*	0.7	0.3	0.1141	0.0577	0.1729
$\sigma_{u_{10,t}\zeta}$	Ant ζ	*Gamma*	1	0.5	0.5933	0.3921	0.8458
$\sigma_{u_{10,t}I}$	Ant I	*Gamma*	0.7	0.3	0.9563	0.8696	1.0563
$\sigma_{u_{10,t}L}$	Ant L	*Gamma*	0.7	0.3	0.0478	0.0199	0.0749
$\sigma_{u_{10,t}Risk}$	Ant Risk Prem	*Gamma*	0.7	0.3	0.1745	0.0921	0.2617
$\sigma_{u_{10,t}X}$	Ant Trend shock	*Gamma*	0.7	0.3	0.0072	0.0052	0.0094

As presented in section 3, before estimating the model with Bayesian techniques we calibrate some parameters. The majority of the parameters are the same as the ones used in the baseline model. For these parameters we confirm the previous calibration or prior distribution. Three are the new parameters of which only one is calibrated: σ, the intertemporal elasticity of substitution, is set equal to 1, following Schmitt-Grohe & Uribe (2012). The two estimated parameters are μ, the degree of the wealth elasticity of the labor supply, and v, the elasticity of labor supply when μ is equal to zero. We use standard and sufficiently wide priors in order to let the data speak as much as possible. Given that $\mu \in (0, 1]$ we set a uniform prior distribution defined over the interval (0,1]. For v we impose a wide uniform prior distribution over the interval (1.1,11), following again Schmitt-Grohe & Uribe (2012).

Table 5 summarizes the prior mean, posterior mean and the 90-percent lower and upper bound for all the estimated parameters. The statistics are computed using the last 40 percent of 1 million draws generated with a random walk Metropolis Hastings chain algorithm. The most relevant parameter of the new estimation is μ, the parameter governing the wealth elasticity of the labor supply. The value of the posterior mean is 0.01 which implies a really small wealth elasticity. The result is in line with the first estimation of the parameter done by Schmitt-Grohe & Uribe (2012) with aggregated data. v is estimated to be pretty high, close to 5.7 which implies, given the small value of μ, a low Frisch elasticity of labor supply. The elasticity of substitution between tradable and non tradable goods is estimated to be slightly lower than the previous section estimation while the estimate for the trade elasticity is not statistically different. Capital adjustment cost elasticity is higher in this second estimation and the degree of habit persistence in consumption is slightly lower.

The autoregressive component on tradable productivity and labor shocks are more persistent with respect to the baseline specification. For the standard deviation of the shocks the same analysis presented for the baseline model applies. The only major difference is the higher standard deviation of preference shocks. Focusing on the role of anticipated shocks in explaining variables fluctuation the results are robust: 10-quarters anticipated fluctuation of the risk premium plays even a bigger role in explaining the unconditional variance of output growth, current account and real exchange rate fluctuations.

Figure 9 plots the impulse response of output growth, current account and real exchange rate for a 10-quarters 1 standard deviation anticipated productivity increase (common to both sector) and risk premium anticipated drop. Both shocks generate a current account deficit but only the risk premium decrease is able to generate a contemporaneous appreciation of the real exchange rate. We can conclude that our main result in the baseline model is not driven by the misbehavior of the labor market and the conclusion are unchanged when we consider Jaimovich and Rebelo preferences.

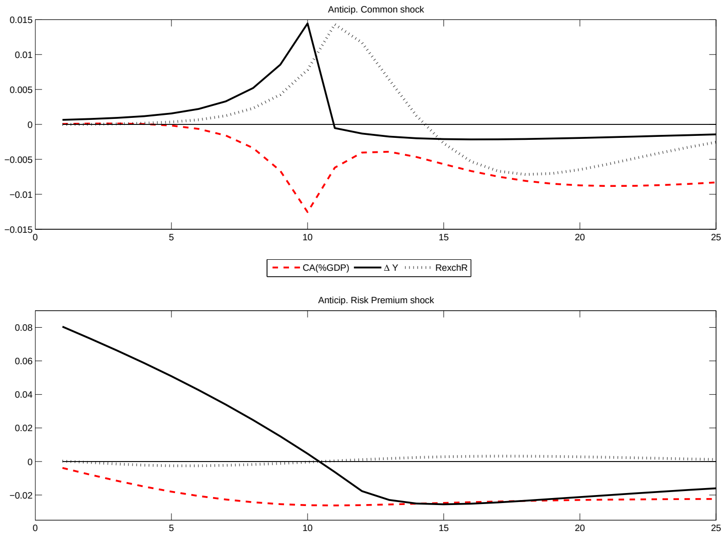


Figure 9: Impulse Response with JR preferences

5.2 Imperfect Information

Let us assume now that there is imperfect information. Agents can only observe the level of technology but they cannot perfectly distinguish if the change is coming from the trend or the cyclical component. Hoffmann et al. (2011) show that in such a framework the technology shock can explain the accumulation of current account deficit inside the US. We are interested in understanding if that is the case also for Ireland, Portugal and Spain. We follow Boz, Daude & Durdu (2011) and Hoffmann et al. (2011) assuming that agents form expectations about the shock through a filtering problem. Agents have available the entire history of TFP shocks at time t and they know the underlying distribution of both trend and cyclical shocks. At each point in time they use the new information available to form the best possible estimation of the current level of trend growth and behave accordingly. Given our focus on the linear solution the best estimate of the forecasting of agents is obtained by the Kalman Filter according to the recursion used by Hoffmann et al. (2011)

$$\widetilde{A}_{j,t|t} = (1-\kappa)\rho_{A_j}\widetilde{A}_{j,t-1|t-1} + \kappa z_t \qquad \text{where} \quad z_t = ln(Z_t) = ln(\frac{X_t}{X_{t-1}}) \tag{41}$$

κ represent the Kalman gain and it is given by the following equation

$$\kappa = \frac{\sigma_1 - (1-\rho_{A_j}) + \sigma_1\sqrt{((1-\rho_{A_j})/\sigma_1)^2 + 1 + 2(1+\rho_{A_j})/\sigma_1}}{1 + \sigma_1 - (1-\rho_{A_j}) + \sigma_1\sqrt{((1-\rho_{A_j})/\sigma_1)^2 + 1 + 2(1+\rho_{A_j})/\sigma}} \tag{42}$$

where $\sigma_1 \equiv \frac{\sigma^2_{A_j}}{\sigma_X}$ is the signal to noise ratio that measures the relative weights assigned to trend growth relative to one time permanent change in the level of technology. Figure 10 shows the difference between the true dynamics of the shock (in the figure we present a one time level shock) with respect to the perceived dynamics. As time goes by, the agents learn that the shock was not permanent and converges to the right path.

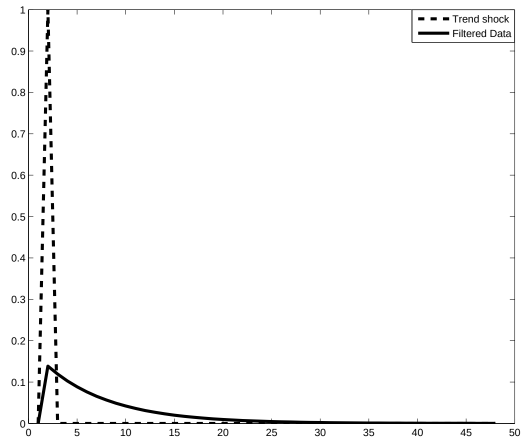


Figure 10: Beliefs attached to the technology process

The impulse responses with imperfect information are less pronounced and more persistent but the main result of the paper does not change. This confirms that the hard task is not to replicate the dynamics of the current account, as shown in Hoffmann et al. (2011), but the joint dynamics of the current account and the real exchange rate. Using just imperfectly learned change in trend growth rates is not sufficient, for the set of estimated and calibrated parameters presented above, to explain the current account deficit and the real exchange rate appreciation.

5.3 No Capital

As a final robustness exercise we check what happens when we consider a model with labor as the only input of production. The reason why we do that is that some previous studies used a simplified model without capital in production to draw conclusions on international variables. Our results still hold when we use a simplified version but the model performs worst when brought to the data. As for the dynamics of the impulse response the introduction of capital and investment play an important role in the dynamics of the current account. In fact, if we exclude capital, the initial movement of the current account is much less pronounced: in the baseline model when a positive technology shock hits the economy, the marginal product of capital increases the incentives to invest in capital. Investment goes up with money borrowed from abroad. All this mechanism is absent if labor is the only input of production. In our opinion, in order to be able to bring a model to the data with the goal of studying the international dynamics of the current account and relative prices, capital and investment sectors cannot be excluded.

6 Conclusions

Ireland, Portugal and Spain, small open economy members of the European Monetary Union, from the birth of the euro to the 2008 financial crisis, experienced large current account deficit, appreciated real exchange rate and output growth above trend. The goals of the paper are to theoretically test different reasonable determinants of those accumulated imbalances and to understand the role of anticipated shocks in explaining international variable fluctuations.

That capitals were flowing towards "catching-up" euro area countries with high current or expected productivity growth seems to have lost empirical support. This paper shows that also theoretically, it is hard to replicate the joint path of current account, real exchange rate and output growth with unanticipated as well as anticipated productivity shocks. On the other hand the anticipated shock in the uncovered interest rate parity is more likely to be an important source of those imbalances. Uncovered interest parity shock in a monetary union with fixed nominal exchange rate can be interpreted as an anticipated decrease in the premium cost of borrowing. It is plausible that agents, as soon as the monetary union became a credible agreement in 1996, anticipated a future drop in the borrowing cost. The results are robust to different specification of the model and do not seem to be much affected by the introduction of preferences which are able to better match the dynamic of the labor sector or by the incomplete information set available to agents.

Anticipated shocks are responsible for a large fraction of the variance of output growth, current account and real exchange rate: 54 percent for the growth rate of output, 40 percent for the real exchange rate and 86 percent for the current account. Among the possible sources of instability introduced in the model, long term anticipated risk premium shocks are the most relevant components.

Our final conclusion is that when we are interested in understanding if international imbalances are "structural" or not, we cannot abstract from the joint analysis of relative prices, such as the real exchange rate or the terms of trade. The ability of replicating a particular movement of the current account can be miss-leading because it does not allow us to differentiate between different sources.

A new distinction between types of current account imbalances is needed and this distinction is to be characterized by the sources of those imbalances. Future studies should go in the direction of researching what the implications of different sources are and under which conditions current account imbalance can be defined as "good" or "bad".

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Appendices

A Data Sources

We list here the time series used in the estimation:

1. Gross Value Added, Eurostat, Millions of euro, Current prices, Seasonally adjusted and adjusted data by working days, without public administration and community services.
2. Gross Value Added, Eurostat, Millions of euro, chain-linked volumes, reference year 2000, Seasonally adjusted and adjusted data by working days,without public administration and community services.
3. Final consumption expenditure, Eurostat, Millions of euro, Current prices, Seasonally adjusted and adjusted data by working days.
4. Gross capital formation, Eurostat, Millions of euro, Current prices, Seasonally adjusted and adjust¡ed data by working days.
5. Real Effective Exchange Rate, Eurostat, deflator: consumer price indices - 12 trading partners.
6. Real GVA in non tradable sector, Eurostat, Millions of euro, chain-linked volumes, reference year 2000, Seasonally adjusted and adjusted data by working days.
7. Harmonized Index Consumer Prices inflation [IPS, EURO AREA], Eurostat.
8. Harmonized Index Consumer Prices Services Inflation [IPS], Eurostat.
9. Average number of usual weekly hours of work in main job, by sex, professional status, full-time/part-time and occupation (hours), Eurostat.
10. Current Account per cent of GDP, Versus all countries of the world, Eurostat.
11. 3-month money market interest rates for euro area countries , Eurostat.
12. GDP Deflator = (1)/(2) [IPS, EURO AREA]
13. Real Consumption = (3)/(12) [IPS, EURO AREA]
14. Real Investment = (4)/(12) [IPS]
15. Harmonized Index Consumer Prices inflation EURO AREA, Eurostat
16. HICP - Country weights, Eurostat

B Equilibrium Conditions

We present here the full list of necessary and sufficient equilibrium condition.

B.1 Household

The representative household optimal demand within each sector and varieties of goods yields:

$$C_{N,t} = \gamma_{N,t} \left(m(J_t)\right)^{\eta} C_t \tag{B.1}$$

$$C_{h,t} = \gamma_{T,t}\gamma_{h,t} \left(\frac{m(J_t)}{J_t}\right)^{\eta} g(S_t)^{\epsilon} C_t, \tag{B.2}$$

$$C_{f,t} = \gamma_{T,t}\gamma_{f,t} \left(\frac{m(J_t)}{J_t}\right)^{\eta} \left(\frac{g(S_t)}{S_t}\right)^{\epsilon} C_t \tag{B.3}$$

where

$$P_t = [\gamma_{T,t} P_{T,t}^{1-\eta} + \gamma_{N,t} P_{N,t}^{1-\eta}]^{\frac{1}{1-\eta}} \qquad \text{and} \qquad P_{T,t} = [\gamma_{h,t} P_{h,t}^{1-\epsilon} + \gamma_{f,t} P_{f,t}^{1-\epsilon}]^{\frac{1}{1-\epsilon}}$$

are respectively the consumer price index and the tradable goods price index.
Similarly foreign demand for the home produced tradable can be written as:

$$C_{h,t}^{*} = \gamma_{T,t}^{*}\gamma_{h,t}^{*} Q^{\eta} \left(\frac{m(J_t)}{J_t}\right)^{\eta} g(S_t)^{\eta} S_t^{\epsilon-\eta} C_t^{*} \tag{B.4}$$

The first order necessary conditions of the maximization problem of the households are:

$$\zeta_t \frac{1}{C_t - hC_{t-1}} - h\beta_t\zeta_{t+1}\frac{1}{C_{t+1} - hC_t} = \lambda_t \tag{B.5}$$

$$\lambda_t = \beta_t E_t \left\{ \lambda_{t+1} \frac{R_t^B}{\Pi_{N,t+1}} \frac{m_t}{m_{t+1}} \right\} \text{ and } \lambda_t = \beta_t E_t \left\{ \lambda_{t+1} \frac{R_t}{\Pi_{N,t+1} \frac{m_t}{m_{t+1}}} \right\} \tag{B.6}$$

$$r_t^k = \Psi'(u_t) \tag{B.7}$$

$$1 = q_t \epsilon_t i \left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}} \right] + \beta_t E_t \left\{ q_{t+1}\epsilon_{t+1}^{i} \frac{\lambda_{t+1}}{\lambda_t} S'\left(\frac{I_{t+1}}{I_t}\right) \frac{I_{t+1}^2}{I_t^2} \right\} \tag{B.8}$$

$$q_t = \beta_t E_t \left[\frac{\lambda_{t+1}}{\lambda_t} [r_{t+1}^k u_{t+1} - \Psi(u_{t+1}) + q_{t+1}(1-\delta)] \right] \tag{B.9}$$

$$\zeta_t \epsilon_t^L L_t^{\nu} = \lambda_t W_t \tag{B.10}$$

where λ_t is the lagrangian multiplier associated with the budget constraint, Q_t the lagrangian multiplier associated with installed capital. We denote with $q_t = \frac{Q_t}{\lambda_t}$ the Tobin's Q, which is the value of installed capital in consumption units.
In equilibrium:

$$K_t = u_t k_{t-1}^p \tag{B.11}$$

$$k_t^p = (1-\delta)k_{t-1}^p + I_t \left[1 - S\left(\frac{I_t}{I_{t-1}}\right) \right] \epsilon_t^I \tag{B.12}$$

$$\beta_t = \frac{1}{1 + \psi^{\beta} log\overline{C}_t - \psi^{\beta}\chi} \tag{B.13}$$

B.2 Firms

Firms produce in the two sectors with the following production functions:

$$Y_{j,t} = A_{j,t} X_t^{1-\alpha} K_{j,t}^{\alpha} L_{j,t}^{1-\alpha} \tag{B.14}$$

The optimality conditions of the cost minimization problem are:

$$K_{j,t} = \frac{\alpha}{1-\alpha} \frac{W_t}{r_t^k} L_{j,t} \tag{B.15}$$

and

$$MC_{j,t} = \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^{\alpha} \frac{W_t^{1-\alpha} r_t^{k\,\alpha}}{A_{j,t} X_t^{1-\alpha}} \tag{B.16}$$

When setting the prices, assuming a symmetric equilibrium in which each domestic producer sets optimally equal prices and produces the same level of output as other producers, the resulting equation are:

$$\frac{\Pi_{N,t}}{\Pi^N}\left(\frac{\Pi_{N,t}}{\Pi^N}-1\right) = E_t\left\{\beta_t \frac{\lambda_{t+1}}{\lambda_t} \frac{m(J_t)}{m(J_{t+1})} \frac{Y_{N,t+1}}{Y_{N,t}} \left(\frac{\Pi_{N,t+1}}{\Pi^N}-1\right) \frac{\Pi_{N,t+1}}{\Pi^N}\right\} + \frac{\theta}{\psi} MC_{N,t} m(J_t) - \frac{\theta-1}{\psi} \tag{B.17}$$

$$\frac{\Pi_{h,t}}{\overline{\Pi}^h}\left(\frac{\Pi_{h,t}}{\overline{\Pi}^h}-1\right) = E_t\left\{\beta_t \frac{\lambda_{t+1} Y_{h,t+1}}{\lambda_t Y_{h,t}} \frac{m(J_t) g(S_t) J_{t+1}}{m(J_{t+1}) g(S_{t+1}) J_t} \left(\frac{\Pi_{h,t+1}}{\overline{\Pi}^h}-1\right) \frac{\Pi_{h,t+1}}{\overline{\Pi}^N}\right\} + \frac{\phi}{\psi} \frac{MC_{h,t} m(J_t) g_t}{J_t} - \frac{\phi-1}{\psi} \tag{B.18}$$

where we used $\pi_{(N,h),t} = \frac{P_{(N,h),t}}{P_{(N,h),t-1}}$ and $\frac{v_{0,t+1}}{v_{0,t}} = \beta_t \frac{\lambda_{t+1}}{\lambda t} \frac{P_t}{P_{t+1}}$.

B.3 Relative prices and International variables

The relevant relative prices are the terms of trade, the relative prices of TPI over the prices of home produced tradable goods, the relative price of tradable over non tradable goods and the CPI over the price of non tradable goods:

$$S_t \equiv \frac{P_{f,t}}{P_{h,t}} \tag{B.19}$$

$$g(S_t) = \frac{P_{T,t}}{P_{h,t}} = [\gamma_{h,t} + \gamma_{f,t} S_t^{1-\epsilon}]^{\frac{1}{1-\epsilon}} \qquad \text{with} \quad \frac{\delta g(S_t)}{\delta S_t} > 0 \tag{B.20}$$

$$J_t \equiv \frac{P_{T,t}}{P_{N,t}} \tag{B.21}$$

$$m(J_t) = \frac{P_t}{P_{N,t}} = [\gamma_{T,t} J_t^{1-\eta} + \gamma_{N,t}]^{\frac{1}{1-\eta}} \qquad \text{with} \quad \frac{\delta m(J_t)}{\delta J_t} > 0 \tag{B.22}$$

$$\tag{B.23}$$

We define the real exchange rate in the monetary union as

$$Q_t = \frac{P_t^*}{P_t} \tag{B.24}$$

The balance of payment condition, as share of steady state GDP, Y:

$$NX_t + \frac{R^B_{t-1}B_{t-1}}{YP_t} - \frac{R_{t-1}A_{t-1}}{YP_t} - \frac{B_t - A_t}{YP_t} = 0 \tag{B.25}$$

where nx_t denotes the real value of net exports as a ratio to Y and it is equal to

$$NX_t = \frac{J_t}{g(S_t)m(J_t)} \frac{(Y_{h,t} - C_{h,t} - S_t C_{f,t})}{Y} \tag{B.26}$$

The current account as the net change in real bond holding, as share of steady state GDP, Y:

$$CA_t = \frac{(B_t - A_t)}{P_t Y} - \frac{(B_{t-1} - A_{t-1})}{P_t Y} \tag{B.27}$$

B.4 Market Clearing and Monetary Policy Rule

Labor and capital can move freely across sectors and demand will equal labor when

$$K_t = K_{N,t} + K_{h,t} \tag{B.28}$$

$$L_t = L_{N,t} + L_{h,t} \tag{B.29}$$

In the non tradable and in the tradable sector market clears:

$$Y_{N,t} = C_{N,t} + \frac{\psi}{2}\left(\frac{\pi_{N,t}}{\overline{\pi}_N} - 1\right)^2 Y_{N,t} \tag{B.30}$$

$$Y_{h,t} = C_{h,t} + C^*_{h,t} + \frac{\psi}{2}\left(\frac{\pi_{h,t}}{\overline{\pi}_h} - 1\right)^2 Y_{h,t} \tag{B.31}$$

Real GDP aggregates tradable and nontradable production weighted by the relative prices:

$$Y_t = \frac{J_t}{m(J_t)g(S_t)} Y_{h,t} + \frac{1}{m(J_t)} Y_{N,t} + I_t \tag{B.32}$$

To complete the model we introduce a monetary policy rule, set by the European Central Bank:

$$R_t = R^{\rho_r}_{t-1}\left(\frac{\Pi^{EMU}_t}{\Pi^{EMU}}\right)^{(1-\rho_r)\rho_\pi} \tag{B.33}$$

C Detrended Equilibrium Conditions

In the model we allow for different grow rates in the two sectors and for a common trend in all aggregate variables induced by the technological process. To be able to solve the model with standard techniques we need first to make the model stationary by detrending each variable with its particular growth rate. We rewrite the equations using stationary transformation of each variable, indicated with a overwritten tilde.

C.1 Technologies and Prices

Before going into the details of each equation notice that given the technology process specified in equation (9) and (**??**), variables in the non tradable sector grow at rate $(1+g^N)^t X_t$ while in the tradable sector the growing rate is $(1+g^T)^t X_t$. The growth rate of aggregate variable $\frac{X_t}{X_{t-1}} = Z_t$ Assuming that CPI prices grow at Π^t then the two sectors specific prices grow at $\frac{\Pi^t}{(1-g^j)^t}$.

C.2 Household

The demand functions for each type of good become:

$$\widetilde{C}_{N,t} = \widetilde{\gamma}_{N,t}\left(\widetilde{m}(\widetilde{J}_t)\right)^{\eta}\widetilde{C}_t \tag{C.1}$$

$$\widetilde{C}_{h,t} = \widetilde{\gamma}_{T,t}\widetilde{\gamma}_{h,t}\left(\frac{\widetilde{m}(J_t)}{\widetilde{J}_t}\right)^{\eta}\widetilde{g}(S_t)^{\epsilon}\widetilde{C}_t, \tag{C.2}$$

$$\widetilde{C}_{f,t} = \widetilde{\gamma}_{T,t}\widetilde{\gamma}_{f,t}\left(\frac{\widetilde{m}(J_t)}{\widetilde{J}_t}\right)^{\eta}\left(\frac{\widetilde{g}(S_t)}{\widetilde{S}_t}\right)^{\epsilon}\widetilde{C}_t \tag{C.3}$$

$$\widetilde{C}^*_{h,t} = \widetilde{\gamma}^*_{T,t}\widetilde{\gamma}^*_{h,t}\widetilde{Q}^{\eta}\left(\frac{\widetilde{m}(J_t)}{\widetilde{J}_t}\right)^{\eta}\widetilde{g}(S_t)^{\eta}\widetilde{S}_t^{\epsilon-\eta}\widetilde{C}^*_t \tag{C.4}$$

where

$$\widetilde{C}_{N,t} = \frac{C_{N,t}}{(1+g^N)^t X_t} \qquad \widetilde{C}_{h,t} = \frac{C_{h,t}}{(1+g^T)^t X_t} \qquad \widetilde{C}_{f,t} = \frac{C_{f,t}}{(1+g^{T\,*})^t X_t}\frac{\Pi^*}{\Pi}$$

$$\widetilde{C}^*_{h,t} = \frac{C^*_{h,t}}{(1+g^{T\,*})^t X^*_t}\frac{\Pi}{\Pi^*} \qquad \widetilde{C}_{h,t} = \frac{C_t}{X_t} \qquad \widetilde{C}^*_t = \frac{C^*_t}{X^*_t}$$

$$\widetilde{\gamma}_{N,t} = \frac{\gamma_{N,t}}{(1+g^N)^{(1-\eta)t}} \qquad \widetilde{\gamma}_{T,t}\frac{\gamma_{N,t}}{(1+g^T)^{(1-\eta)t}} \qquad \widetilde{\gamma}_{h,t} = \gamma_{h,t}$$

$$\widetilde{\gamma}_{f,t} = \gamma_{f,t}\left(\frac{(1+g^T)}{(1+g^{T\,*})}\right)^{(1-\epsilon)t}\left(\frac{\Pi^*}{\Pi}\right)^{(1-\epsilon)t} \qquad \widetilde{\gamma}^*_{T,t} = \frac{\gamma^*_{T,t}}{(1+g^{T\,*})^{(1-\eta)t}}$$

$$\widetilde{\gamma}^*_{h,t} = \gamma_{h,t}\left(\frac{(1+g^{T\,*})}{(1+g^T)}\right)^{(1-\epsilon)t}\left(\frac{\Pi}{\Pi^*}\right)^{(1-\epsilon)t}$$

and

$$
\begin{aligned}
\widetilde{S}_t &= S_t \left(\frac{1+g^{T\,*}}{1+g^T}\right)^t \left(\frac{\Pi}{\Pi^*}\right)^t \qquad\qquad \widetilde{g}(S_t) = g(S_t)\\
\widetilde{J}_t &= \left(\frac{1+g^T}{1+g^N}\right)^t \qquad\qquad \widetilde{m}(J_t) = \frac{m_t}{(1+g^N)^t}\\
\widetilde{Q}_t &= Q_t \left(\frac{\Pi}{\Pi^*}\right)^t
\end{aligned}
$$

Notice that

$$
\begin{aligned}
&\widetilde{\Pi_t} = \frac{\Pi_t}{\Pi} \qquad \text{because} \quad \widetilde{P}_t = \frac{P_t}{(\Pi)^t}\\
&\widetilde{\Pi_{N,t}} = \Pi_{N,t}\frac{(1+g^N)}{\Pi} \qquad \text{because} \quad \widetilde{P}_{N,t} = \Pi_{N,t}\frac{(1+g^N)^{t\,t}}{\Pi}\\
&\widetilde{\Pi_{h,t}} = \Pi_{h,t}\frac{(1+g^T)}{\Pi} \qquad \text{because} \quad \widetilde{P}_{h,t} = \Pi_{h,t}\frac{(1+g^T)^{t\,t}}{\Pi}
\end{aligned}
$$

The first order conditions of the household:

$$\zeta_t \frac{1}{\widetilde{C}_t - \frac{h}{Z_t}\widetilde{\widetilde{C}}_{t-1}} - h\beta_t\zeta_{t+1}\frac{1}{\widetilde{C}_{t+1} - hZ_{t+1}\widetilde{C}_t} = \widetilde{\lambda}_t \tag{C.5}$$

$$\widetilde{\lambda}_t = \beta_t E_t \left\{ \widetilde{\lambda}_{t+1}\frac{\Pi}{Z_{t+1}}\frac{R_t^B}{\widetilde{\Pi_{N,t}}_{t+1}\frac{\widetilde{m}_t}{\widetilde{m}_{t+1}}} \right\} \tag{C.6}$$

$$R_t^B = R_t \tag{C.7}$$

$$r_t^k = \Psi'(u_t) \tag{C.8}$$

$$1 = q_t\epsilon_t i\left[1 - S\left(\frac{\widetilde{I}_t}{\widetilde{I_{t-1}}}Z_t\right) - S'\left(\frac{\widetilde{I}_t}{\widetilde{I_{t-1}}}Z_t\right)\frac{\widetilde{I}_t}{\widetilde{I_{t-1}}}Z_t\right] + \beta_t E_t\left\{ q_{t+1}\epsilon_{t+1}^i \frac{\widetilde{\lambda}_{t+1}}{\widetilde{\lambda}_t}\frac{1}{Z_{t+1}} S'\left(\frac{\widetilde{I_{t+1}}}{\widetilde{I}_t}Z_{t+1}\right)\frac{\widetilde{I}_{t+1}^2}{\widetilde{I}_t^2}Z_{t+1}^2 \right\} \tag{C.9}$$

$$q_t = \beta_t E_t\left[\frac{\widetilde{\lambda}_{t+1}}{\widetilde{\lambda}_t}\frac{1}{Z_{t+1}}[r_{t+1}^k u_{t+1} - \Psi(u_{t+1}) + q_{t+1}(1-\delta)]\right] \tag{C.10}$$

$$\zeta_t\epsilon_t^L L_t^\nu = \widetilde{\lambda}_t\widetilde{W}_t \tag{C.11}$$

where

$$\widetilde{\lambda} = \lambda X_t \quad \widetilde{I}_t = \frac{I_t}{X_t} \quad \text{and} \quad \widetilde{w_t} = \frac{w_t}{X_t}$$

The other equilibrium conditions will be:

$$\widetilde{K}_t = u_t \widetilde{k}^p_{t-1} \tag{C.12}$$

$$\widetilde{k}^p_t = (1-\delta)\widetilde{k}^p_{t-1} + \widetilde{I}_t \left[1 - S\left(\frac{\widetilde{I}_t}{\widetilde{I}_{t-1}}\right)\right] \epsilon^I_t \tag{C.13}$$

$$\beta_t = \frac{1}{1 + \psi^\beta log \widetilde{C}_t - \psi^\beta \chi} \tag{C.14}$$

where

$$\widetilde{K}_t = \frac{K_t}{X_{t-1}} \qquad \text{and} \qquad \widetilde{k}^p_{t-1} = \frac{k^p_{t-1}}{X_{t-1}}$$

C.3 Firms

Firms production function in the two sectors are:

$$\widetilde{Y}_{N,t} = \widetilde{A}_{N,t} Z_t^{-\alpha} \widetilde{K}^\alpha_{N,t} L^{1-\alpha}_{N,t} \tag{C.15}$$

$$\widetilde{Y}_{h,t} = \widetilde{A}_{h,t} Z_t^{-\alpha} \widetilde{K}^\alpha_{h,t} L^{1-\alpha}_{h,t} \tag{C.16}$$

where

$$\widetilde{Y}_{N,t} = \frac{Y_{N,t}}{(1+g^N)^t X_t} \quad \widetilde{A}_{N,t} = \frac{A_{N,t}}{(1+g^N)^t} \quad \widetilde{K}_{N,t} = \frac{K_{N,t}}{X_{t-1}}$$

$$\widetilde{Y}_{h,t} = \frac{Y_{h,t}}{(1+g^T)^t X_t} \quad \widetilde{A}_{h,t} = \frac{A_{h,t}}{(1+g^T)^t} \quad \widetilde{K}_{h,t} = \frac{K_{h,t}}{X_{t-1}}$$

Cost minimization and marginal cost:

$$\widetilde{K}_{N,t} = \frac{\alpha}{1-\alpha} \frac{\widetilde{W}_t}{r^k_t} L_{N,t} \tag{C.17}$$

$$\widetilde{K}_{h,t} = \frac{\alpha}{1-\alpha} \frac{\widetilde{W}_t}{r^k_t} L_{h,t} \tag{C.18}$$

$$\widetilde{MC}_{N,t} = \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^\alpha \frac{\widetilde{W}_t^{1-\alpha} r_t^{k\,\alpha}}{\widetilde{A}_{N,t}} \tag{C.19}$$

$$\widetilde{MC}_{h,t} = \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^\alpha \frac{\widetilde{W}_t^{1-\alpha} r_t^{k\,\alpha}}{\widetilde{A}_{h,t}} \tag{C.20}$$

where

$$\widetilde{MC}_{N,t} = MC_{N,t}(1+g^N)^t \qquad \text{and} \qquad \widetilde{MC}_{h,t} = MC_{h,t}(1+g^T)^t$$

Pricing equations become:

$$\frac{\widetilde{\Pi}_{N,t}}{\widetilde{\Pi}^N}\left(\frac{\widetilde{\Pi}_{N,t}}{\widetilde{\Pi}^N}-1\right) = E_t\left\{\beta_t\frac{\lambda_{t+1}}{\lambda_t}\frac{m(J_t)}{m(J_{t+1})}\frac{Y_{N,t+1}}{Y_{N,t}}\left(\frac{\Pi_{N,t+1}}{\overline{\pi}^N}-1\right)\frac{\Pi_{N,t+1}}{\overline{\pi}^N}\right\} + \frac{\theta}{\psi}MC_{N,t}m(J_t) - \frac{\theta-1}{\psi} \tag{C.21}$$

$$\frac{\Pi_{h,t}}{\overline{\Pi}^h}\left(\frac{\Pi_{h,t}}{\overline{\Pi}^h}-1\right) = E_t\left\{\beta_t\frac{\lambda_{t+1}Y_{h,t+1}}{\lambda_t Y_{h,t}}\frac{m(J_t)g(S_t)J_{t+1}}{m(J_{t+1})g(S_{t+1})J_t}\left(\frac{\Pi_{h,t+1}}{\overline{\Pi}^h}-1\right)\frac{\Pi_{h,t+1}}{\overline{\Pi}^N}\right\} + \frac{\phi}{\psi}\frac{MC_{h,t}m(J_t)g_t}{J_t} - \frac{\phi-1}{\psi} \tag{C.22}$$

C.4 Relative prices and International variables

The balance of payment condition, as share of steady state GDP, Y:

$$\widetilde{NX}_t + \frac{R^B_{t-1}\widetilde{B}_{t-1}}{Z_t\widetilde{Y}\widetilde{P}_t} - \frac{R_{t-1}\widetilde{A}_{t-1}}{Z_t\widetilde{Y}\widetilde{P}_t} - \frac{\widetilde{B}_t-\widetilde{A}_t}{\widetilde{Y}\widetilde{P}_t} = 0 \tag{C.23}$$

The real value of net exports as a ratio to Y becomes

$$\widetilde{NX}_t = \frac{\widetilde{J}_t}{\widetilde{g}(\widetilde{S}_t)\widetilde{m}(J_t)}\frac{\left(\widetilde{Y}_{h,t}-\widetilde{C}_{h,t}-\widetilde{S}_t\widetilde{C}_{f,t}\right)}{\widetilde{Y}} \tag{C.24}$$

The current account, as share of steady state GDP, Y is:

$$\widetilde{CA}_t = \frac{(\widetilde{B}_t-\widetilde{A}_t)}{\widetilde{Y}\widetilde{P}_t} - \frac{(\widetilde{B}_{t-1}-\widetilde{A}_{t-1})}{Z_t\widetilde{P}_t\widetilde{Y}} \tag{C.25}$$

where

$$\widetilde{NX}_t = \frac{NX_t}{X_t} \qquad \widetilde{B}_t = \frac{B}{X_t} \qquad \widetilde{A}_t = \frac{A}{X_t} \qquad \widetilde{CA}_t = \frac{CA}{X_t}$$

C.5 Market Clearing and Monetary Policy Rule

Labor supply and capital supply equalize labor demand and supply:

$$\widetilde{K}_t = \widetilde{K}_{N,t} + \widetilde{K}_{h,t} \tag{C.26}$$

$$L_t = L_{N,t} + L_{h,t} \tag{C.27}$$

Same for demand and supply of non tradable and home tradable:

$$\widetilde{Y}_{N,t} = \widetilde{C}_{N,t} + \frac{\psi}{2}\left(\frac{\pi_{N,t}}{\overline{\pi}_N} - 1\right)^2 \widetilde{Y}_{N,t} \tag{C.28}$$

$$\widetilde{Y}_{h,t} = \widetilde{C}_{h,t} + \widetilde{C}^*_{h,t} + \frac{\psi}{2}\left(\frac{\pi_{h,t}}{\overline{\pi}_h} - 1\right)^2 \widetilde{Y}_{h,t} \tag{C.29}$$

Real GDP:

$$\widetilde{Y}_t = \frac{\widetilde{J}_t}{\widetilde{m}(J_t)\widetilde{g}(\widetilde{S}_t)}\widetilde{Y}_{h,t} + \frac{1}{\widetilde{m}(\widetilde{J}_t)}\widetilde{Y}_{N,t} + \widetilde{I}_t \tag{C.30}$$

where

$$\widetilde{Y}_t = \frac{Y_t}{X_t}$$

To complete the model we introduce a monetary policy rule, set by the European Central Bank:

$$R_t = R_{t-1}^{\rho_r}\left(\frac{\widetilde{\Pi}_t^{EMU}}{\widetilde{\Pi}^{EMU}}\right)^{(1-\rho_r)\rho_\pi} \tag{C.31}$$

D Log Linearizated model

Here we present the entire set of equation log linearized around the steady state. Lower case letters denote log version of the capital letter and the upper hat indicates log deviation from steady state. The demand functions for each type of good become:

$$\widehat{c}_{N,t} = \eta\widehat{m}(J_t) + \widehat{c}_t \tag{D.1}$$

$$\widehat{c}_{h,t} = \eta\widehat{m}(j_t) - \eta\widehat{j}_t + \epsilon\widehat{g}(s_t) + \widehat{c}_t \tag{D.2}$$

$$\widehat{c}_{f,t} = \eta\widehat{m}(j_t) - \eta\widehat{j}_t + \epsilon\widehat{g}(s_t) - \epsilon\widehat{s}_t + \widehat{c}_t \tag{D.3}$$

$$\widehat{c}^*_{h,t} = \eta\widehat{q} + \eta\widehat{m}(j_t) - \eta\widehat{j}_t + \eta\widehat{g}(s_t) + (\epsilon - \eta)\widehat{s}_t + \widehat{c}^*_t \tag{D.4}$$

The first order conditions of the household are:

$$(1-h\beta z)\widehat{\lambda}_t = \widehat{\zeta}_t - h\beta z E_t[\widehat{\beta} + \widehat{\zeta}_{t+1}] + \frac{h}{z-h}\widehat{c}_{t-1} + \left[\frac{1+h^2\beta}{1-\frac{h}{z}}\right]\widehat{c}_t + \left[\frac{h\beta z}{1-\frac{h}{z}}\right]E_t\widehat{c}_{t+1} - \frac{h}{z-h}\widehat{z}_t \tag{D.5}$$

$$\widehat{\lambda}_t = \widehat{\beta}_t + E_t\left\{\widehat{\lambda}_{t+1} + \widehat{r}_t^B - \widehat{\Pi}_{N,t+1} + \widehat{m}_t - \widehat{m}_{t+1}\right\} \tag{D.6}$$

$$\widehat{r}_t^k = \frac{\Psi''(1)u}{\Psi'(1)}\widehat{u}_t \tag{D.7}$$

$$\widehat{q}_t = (1-\delta)\frac{\beta}{z}E_t\widehat{q}_{t+1} + \left[1 - \frac{\beta(1-\delta}{z}\right]E_t\widehat{r}_{t+1}^k + \widehat{\beta}_t + E_t\widehat{\lambda}_{t+1} - \widehat{\lambda}_t \tag{D.8}$$

$$\widehat{q} = \eta_K z^2\widehat{z}_t - \widehat{\epsilon}_t^I - \eta_K z^2\widehat{i}_{t-1} + (1-\beta)\eta_K z^2\widehat{i}_t - \beta z^2\eta_K E_t\widehat{i}_{t+1} \tag{D.9}$$

$$\widehat{\zeta}_t + \widehat{\epsilon}_t + \nu\widehat{l}_t = \widehat{\lambda}_t + \widehat{w}_t \tag{D.10}$$

The other equilibrium conditions are:

$$\widehat{k}_t = \widehat{u}_t + \widehat{k}_{t-1}^p \tag{D.11}$$

$$\widehat{k}_t^p = \frac{(1-\delta)}{z}\left[\widehat{k}_{t-1}^p - \widehat{z}_t\right] + \frac{z-(1-\delta)}{z}\left[\widehat{i}_t + \widehat{\epsilon}_t^I\right] \tag{D.12}$$

$$\widehat{\beta}_t = -\beta\psi^\beta\widehat{c}_t \tag{D.13}$$

D.1 Firms

Firms production function in the two sectors are:

$$\widehat{y}_{N,t} = \widehat{a}_{N,t} - \alpha\widehat{z}_t + \alpha\widehat{k}_{N,t} + (1-\alpha)\widehat{l}_{N,t} \tag{D.14}$$

$$\widehat{y}_{h,t} = \widehat{a}_{h,t} - \alpha\widehat{z}_t + \alpha\widehat{k}_{h,t} + (1-\alpha)\widehat{l}_{h,t} \tag{D.15}$$

Cost minimization and marginal cost:

$$\widehat{k}_{N,t} - \widehat{l}_t = \widehat{w}_t - \widehat{r}_t^k \tag{D.16}$$

$$\widehat{k}_{h,t} - \widehat{l}_t = \widehat{w}_t - \widehat{r}_t^k \tag{D.17}$$

$$\widehat{mc}_{N,t} = (1-\alpha)\widehat{w}_t + \alpha\widehat{r}_t^K - \widehat{a}_{N,t} \tag{D.18}$$

$$\widehat{mc}_{h,t} = (1-\alpha)\widehat{w}_t + \alpha\widehat{r}_t^K - \widehat{a}_{h,t} \tag{D.19}$$

Pricing equation:

$$\widehat{\pi}_{h,t} = E_t\left\{\beta\widehat{\pi}_{h,t+1}\right\} + \frac{\phi-1}{\psi}\left[\widehat{mc}_{h,t} + \widehat{m}_t + \widehat{g}(s_t) - \widehat{j}_t\right] \tag{D.20}$$

$$\widehat{\pi}_{N,t} = E_t\left\{\beta\widehat{\pi}_{N,t+1}\right\} + \frac{\theta-1}{\psi}\left[\widehat{mc}_{N,t} + \widehat{m}_t\right] \tag{D.21}$$

D.2 Relative prices and International variables

Relative prices:

$$\widehat{s}_t = \widehat{s}_{t-1} + \widehat{\pi}_{f,t} - \widehat{\pi}_{h,t} \tag{D.22}$$

$$\widehat{g}_t = \widehat{g}_{t-1} + \widehat{\pi}_{T,t} - \widehat{\pi}_{h,t} \tag{D.23}$$

$$\widehat{j}_t = \widehat{j}_{t-1} + \widehat{g}_t - \widehat{g}_{t-1} + \widehat{\pi}_{h,t} - \widehat{\pi}_{N,t} \tag{D.24}$$

$$\widehat{q}_t = \widehat{q}_{t-1} + \widehat{s}_t - \widehat{s}_{t-1} + \widehat{j}_t - \widehat{j}_{t-1} + \widehat{g}_t - \widehat{g}_{t-1} - \widehat{m}(j_t) + \widehat{m}(j_{t-1}) + \widehat{\pi}^*_t - \widehat{\pi}_{f,t} \tag{D.25}$$

$$\widehat{m}(j_t) = \gamma_T\widehat{j}_t \tag{D.26}$$

$$\widehat{\pi}_{T,t} = \gamma_h\widehat{\pi}_{h,t} + \gamma_f\widehat{\pi}_{f,t} \tag{D.27}$$

where γ_T, γ_h and γ_f are respectively the steady state share of tradable in CPI and share of home and foreign produced tradable goods in TPI.
International variables become:

$$\widehat{b}_t = \frac{1}{\beta z}\widehat{b_{t-1}} + \widehat{nx}_t \tag{D.28}$$

$$\widehat{nx}_t = share_n x[\widehat{y}_{h,t} - \widehat{c}_{h,t} - \widehat{s}_t - \widehat{c}_{f,t}] \tag{D.29}$$

$$\widehat{ca}_t = \widehat{b}_t - \widehat{b}_{t-1}\frac{1}{z} \tag{D.30}$$

D.3 Market Clearing and Monetary Policy Rule

Market clearing conditions

$$\widehat{K}_t = \gamma_N\widehat{K}_{N,t} + \gamma_T\widehat{K}_{h,t} \tag{D.31}$$

$$\widehat{L}_t = \gamma_N\widehat{L}_{N,t} + \gamma_T\widehat{L}_{h,t} \tag{D.32}$$

$$\widehat{Y}_{N,t} = \widehat{C}_{N,t} \tag{D.33}$$

$$\widehat{Y}_{h,t} = \frac{c_h}{y_h}\widehat{C}_{h,t} + \frac{c^*_h}{y_h}\widehat{C}^*_{h,t} \tag{D.34}$$

Real GDP:

$$\widehat{y}_t = \frac{P_h}{P}\frac{y_h}{y}[j_t - g_t - m(j_t) + y_{h,t}] + \frac{P_N}{P}\frac{y_N}{y}[m(j_t) + y_{N,t}] + \frac{I}{y}\widehat{I}_t \tag{D.35}$$

Monetary policy rule (ECB):

$$\widehat{r_t} = \rho_r \widehat{r_{t-1}} + (1-\rho_r)\rho_\pi \frac{\pi_{IPS}}{\pi_{EMU}}[\widehat{m}(j_t) - \widehat{m}(j_{t-1}) + \widehat{\Pi}_{N,t}] \tag{D.36}$$

E Jaimovich and Rebelo Preferences Model

Here we list the first order conditions, the detrended version and the log linearization of the equilibrium equations for the household when we use utility function 39. We just specifiy those equations that are different with respect to the baseline model.

$$\zeta_t \left[c_t - hC_{t-1} - \epsilon_t^L \psi^L L_t^{1+v} \Omega_t\right]^{-\sigma} + \lambda_t^{JR} \mu \left[c_t - h\bar{c}_{t-1}\right]^{\mu-1} \Omega_{t-1}^{1-\mu} Z_t^{1-\mu} = \lambda_t \tag{E.1}$$

$$-\zeta_t \left[c_t - hC_{t-1} - \epsilon_t^L \psi^L L_t^{1+v} \Omega_t\right]^{-\sigma} \epsilon_t^L \psi^L (1+v) L_t^v \Omega_t = \lambda_t W_t \tag{E.2}$$

$$\zeta_t \left[c_t - hC_{t-1} - \epsilon_t^L \psi^L L_t^{1+v} \Omega_t\right]^{-\sigma} \epsilon_t^L \psi^L L_t^{1+v} - \lambda_t^{JR} + \beta_t E_t \left\{\lambda_{t+1}^{JR}(1-\mu)\left[c_{t+1} - h\bar{c}_t\right]^{\mu} \Omega_t^{-\mu} Z_{t+1}^{1-\mu}\right\} = 0 \tag{E.3}$$

and finally the law of motion of Ω_t

$$\Omega_t = (C_t - h\overline{C}_{t-1})^{\mu} \Omega_{t-1}^{1-\mu} (Z_t)^{1-\mu} \tag{E.4}$$

where λ_t is the lagrangian multiplier associated with the budget constraint, and λ_t^{JR} is the multiplier attached to low of motion of Ω_t. The model allows for growth rate so we need to detrend it. Following the procedure explained in the previous appendix and changing variables in order to express the equations as functions of stationary variables we can rewrite the previous equation as follows:

$$\zeta_t \left[\widetilde{C}_t - \frac{h}{Z_t}\widetilde{C}_{t-1} - \epsilon_t^L \psi^L L_t^{1+v} \widetilde{\Omega}_t\right]^{-\sigma} + \widetilde{\lambda}_t^{JR} \mu \left[\widetilde{C}_t - \frac{h}{Z_t}\widetilde{C}_{t-1}\right]^{\mu-1} \widetilde{\Omega}_{t-1}^{1-\mu} = \widetilde{\lambda}_t \tag{E.5}$$

$$-\zeta_t \left[\widetilde{C}_t - \frac{h}{Z_t}\widetilde{C}_{t-1} - \epsilon_t^L \psi^L L_t^{1+v} \widetilde{\Omega}_t\right]^{-\sigma} \epsilon_t^L \psi^L (1+v) L_t^v \widetilde{\Omega}_t = \widetilde{\lambda}_t \widetilde{W}_t \tag{E.6}$$

$$\zeta_t \left[\widetilde{C}_t - \frac{h}{Z_t}\widetilde{C}_{t-1} - \epsilon_t^L \psi^L L_t^{1+v} \widetilde{\Omega}_t\right]^{-\sigma} \epsilon_t^L \psi^L L_t^{1+v} - \widetilde{\lambda}_t^{JR} + \beta_t E_t \left\{\widetilde{\lambda}_{t+1}^{JR}(1-\mu)\left[\widetilde{C}_{t+1} - h\widetilde{C}_t\right]^{\mu} \widetilde{\Omega}_t^{-\mu}\right\} = 0 \tag{E.7}$$

$$\widetilde{\Omega}_t = (\widetilde{C}_t - h\widetilde{C}_{t-1})^{\mu} \widetilde{\Omega}_{t-1}^{1-\mu} \tag{E.8}$$

where

$$\widetilde{\lambda}_t^{JR} = \lambda_t^{JR} X^{\sigma} \qquad \widetilde{\lambda}_t = \lambda_t X^{\sigma} \qquad \widetilde{C}_t = \frac{C_t}{X_t} \qquad \text{and} \quad \widetilde{\Omega}_t = \frac{\Omega_t}{X_t} \tag{E.9}$$

The log linearized version of the first order conditions using JR preferences are the following:

$$\tag{E.10}$$

$$\zeta M1^{-\sigma}[\widehat{\zeta}_t - \sigma\widehat{M1}_t] + \lambda^{JR}\mu[\widehat{\lambda}_t^{JR} + (\mu-1)\widehat{M2}_t + (1-\gamma)\widehat{\omega}_{t-1}] = \lambda\widehat{\lambda}_t \tag{E.11}$$

$$M1\widehat{M1}_t = c\widehat{c}_t - \frac{hc}{z}[\widehat{c}_{t-1} - \widehat{z}_t] - \epsilon^L\psi^L L^{1+v}\omega[\widehat{\epsilon}_t + (1+v)\widehat{L}_t + \widehat{\omega}_t] \tag{E.12}$$

$$M2\widehat{M2}_t = c\widehat{c}_t - \frac{hc}{z}[\widehat{c}_{t-1} - \widehat{z}_t] \tag{E.13}$$

$$\widehat{\zeta}_t - \sigma\widehat{M1}_t + \widehat{\epsilon}_t^L + v\widehat{L}_t + \widehat{\omega}_t = \widehat{\lambda}_t + \widehat{w}_t \tag{E.14}$$

$$\zeta M1^{-\sigma}psi^L L^{1+v}[\widehat{\zeta}_t - \sigma\widehat{M1}_t + \widehat{\epsilon}_t^L + (1+v)\widehat{L}_t] + \lambda^{JR}\widehat{\lambda}_t^{JR} = \tag{E.15}$$

$$= E_t\left\{\beta\lambda^{JR}z^{1-\sigma}(1-\mu)[\widehat{\beta}_t + \widehat{\lambda}_{t+1}^{JR} + \mu\widehat{M2}_t - \mu\widehat{\omega}_t]\right\} \tag{E.16}$$